May 2000

Applied MICROWAVE & WIRELESS

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Cover Story

New LDMOS Transistors Power 2100 MHz Applications

Circuit Design

An Efficient Procedure for Narrowband Bandpass Filter Design

Design Techniques

Techniques for Small-Signal Modeling

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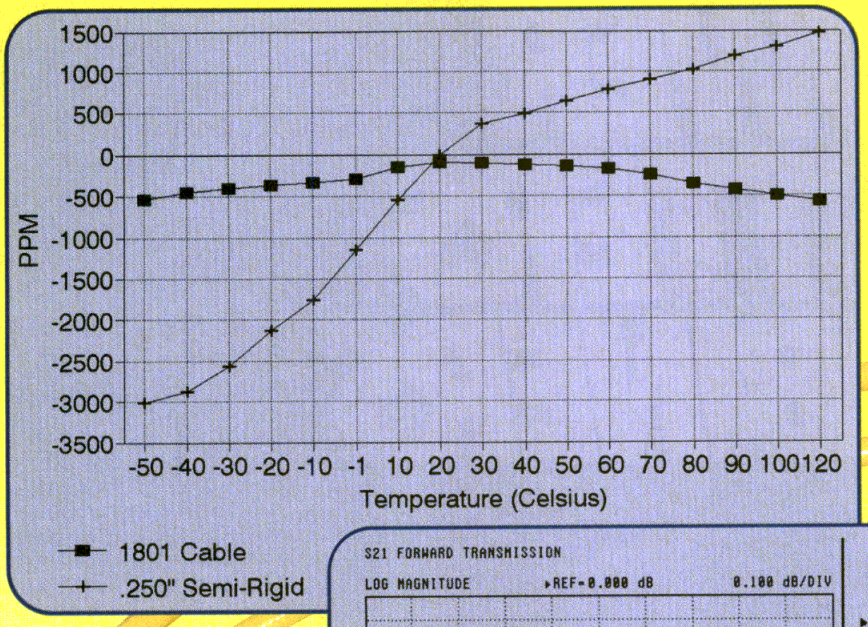
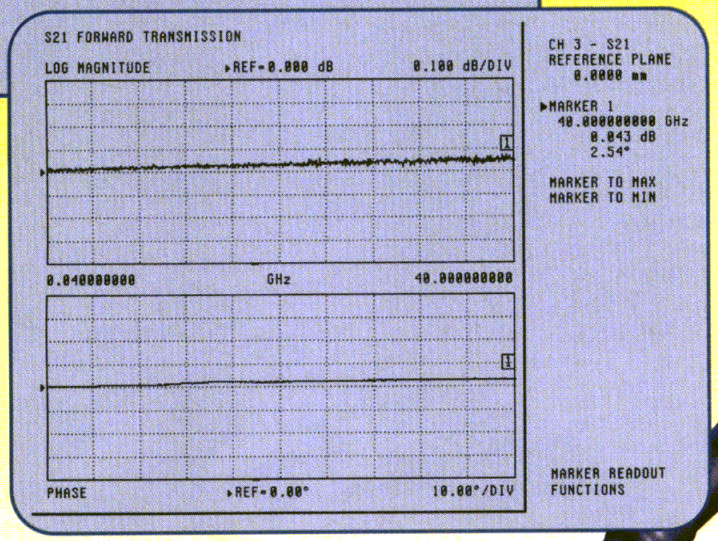
Circle 10

New Phase Stable Coaxial Cable Assemblies



With Temperature and Flexing



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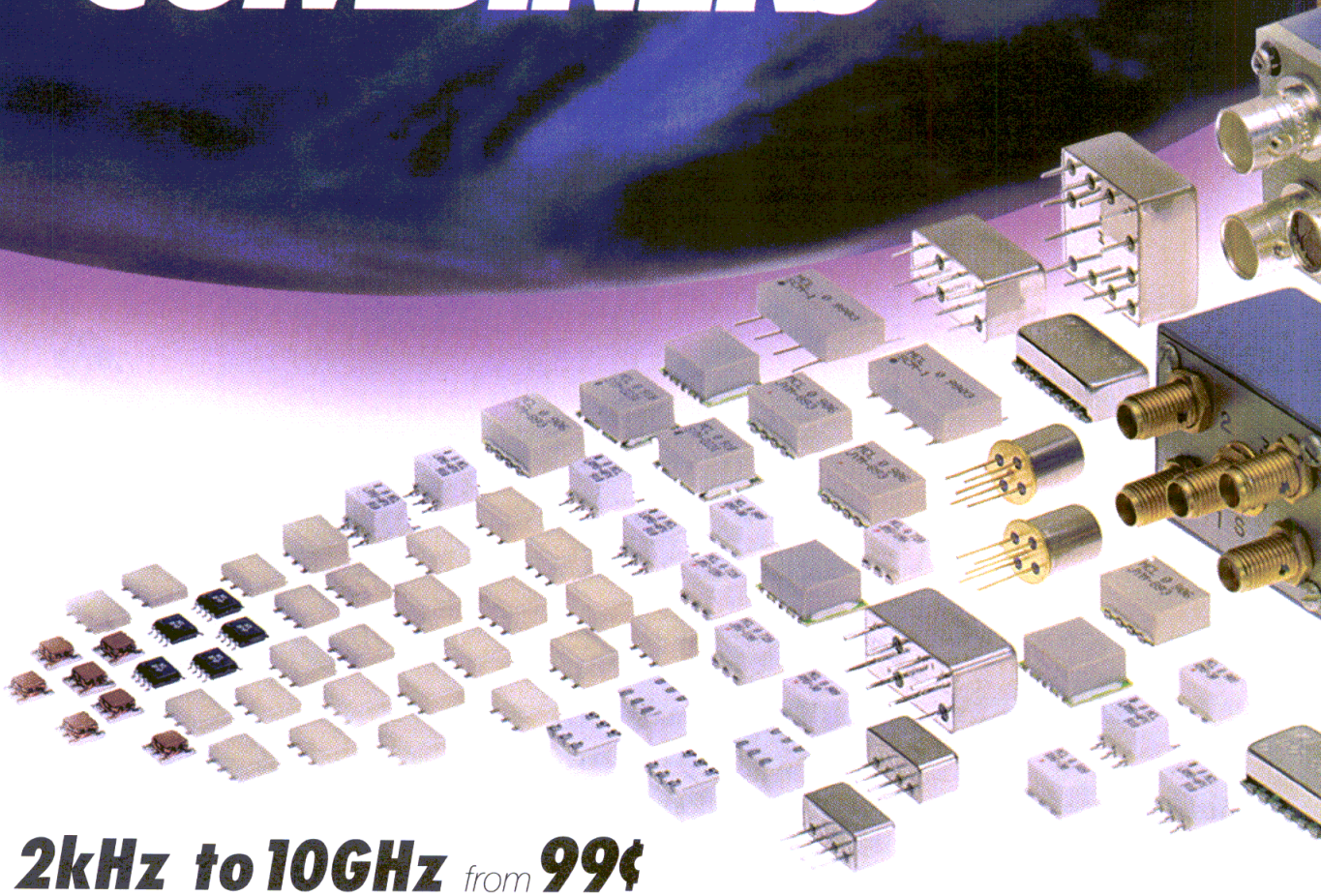

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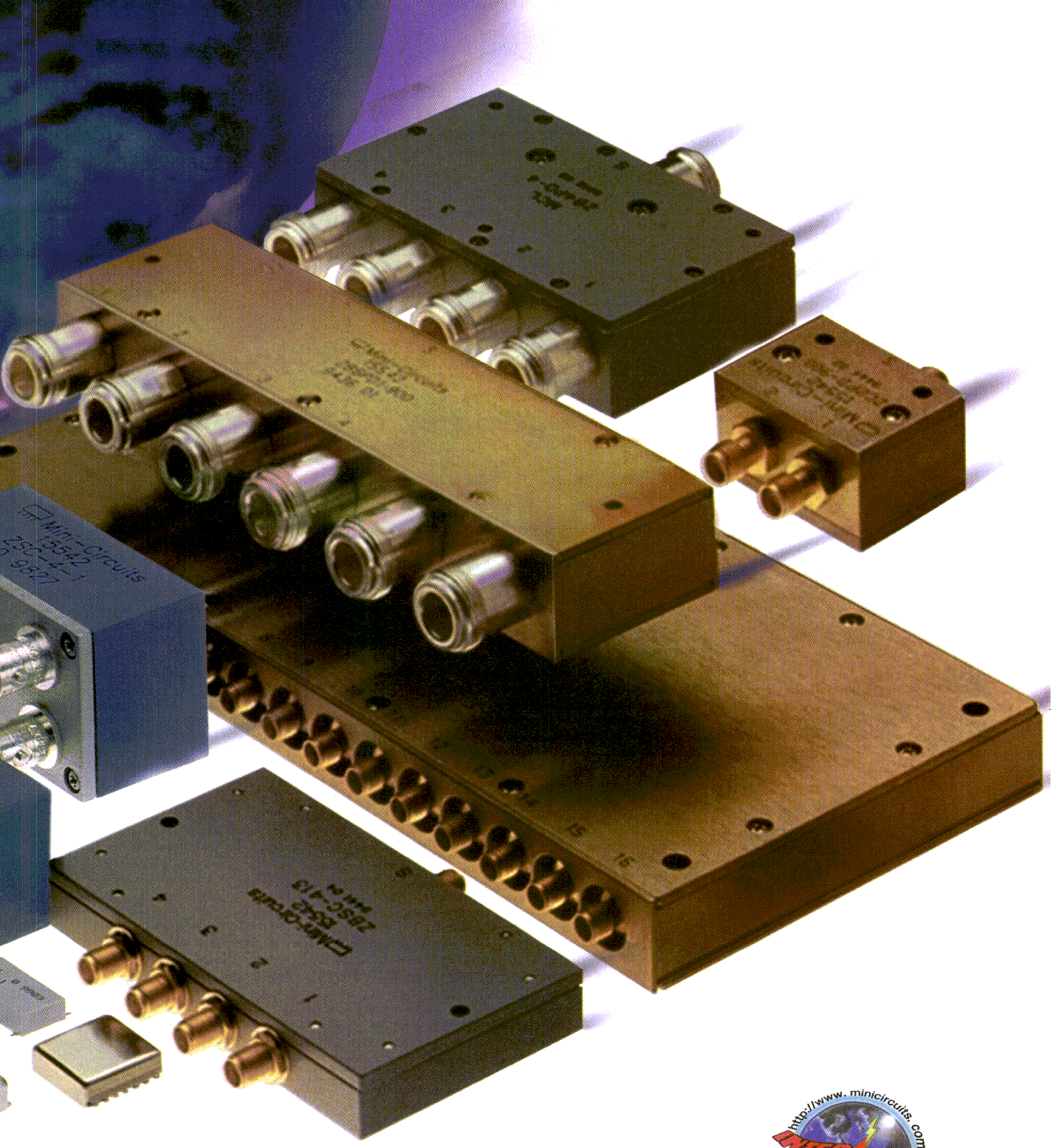

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Model	Freq Range (GHz)	Vd (V)	Id (mA)	Gain (dB)	PldB (dBm)	IP_3 (dBm)	Thermal Resistance (°C/W)
NGA-186	0.1-6.0	4.1	50.0	12.5	14.6	32.9	120
NGA-286	0.1-6.0	4.0	50.0	15.5	15.2	32.0	120
NGA-386	0.1-5.0	4.0	35.0	20.8	14.5	25.8	144
NGA-486	0.1-6.0	5.0	80.0	14.8	18.3	39.5	118
NGA-586	0.1-6.0	5.0	80.0	19.9	18.9	39.6	121
NGA-686	0.1-6.0	5.9	80.0	11.8	19.5	37.5	121

Data at 1 GHz and is typical of device performance.

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Circle 36

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Introducing the SXT-289. A new wideband GaAsHBT power amplifier.

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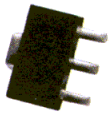

With power to spare, giving you freedom from design constraints, this amplifier was designed and manufactured using state-of-the-art Gallium Arsenide heterojunction bipolar transistor (GaAs HBT) process technology. These devices are ideal for use as a driver stage for power amplifiers installed in cellular PCS infrastructure equipment and conform to TDMA, CDMA and PCS 1900 modulation standards. The SXT-289 operates from a single 5VDC supply and offers exceptional linearity performance in a small form-factor plastic SOT-89 with backside ground.

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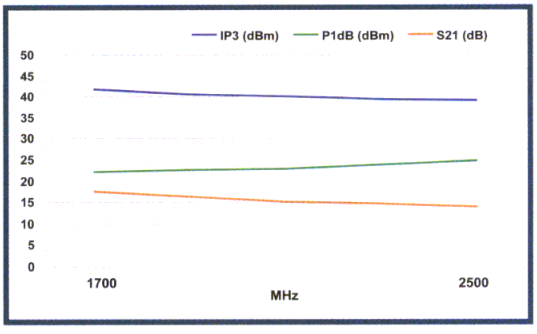

Typical device performance. Bias =5V @ 110mA typ.

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Circle 25

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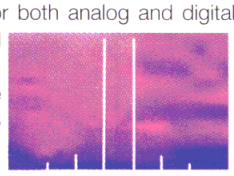

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Model	Freq. (MHz)	IP3 Midband (dBm)	Isolation (dB) L-R	Isolation (dB) L-I	Conv. Loss Midband (dB)	Price $ea. Qty. 1-24
SYM-18H	5 -1800	30	45	40	5.75	16.85
SYM-15VH	10 -1500	31	45	35	6.5	27.95
SYM-14H	100-1370	30	36	30	6.5	14.95
SYM-10DH	800 -1000	31	45	29	7.6	17.80
SYM-22H	1500 -2200	30	33	38	5.6	18.75
SYM-20DH	1700-2000	32	35	34	6.7	14.95

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DEPARTMENTS

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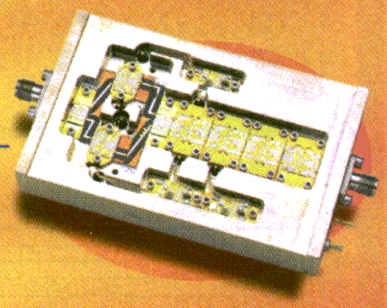
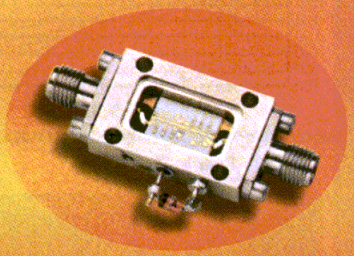
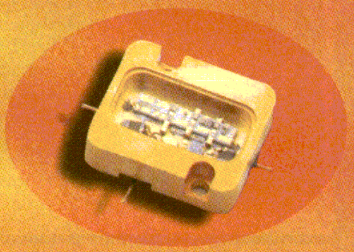
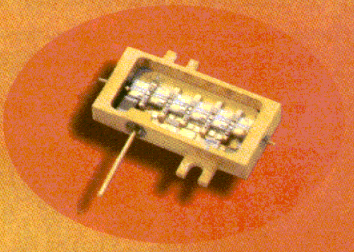
Model#	Freq Range (GHz)	Gain (dB min)	N/F (dB max)	Gain Flat (+/-dB)	1 dB comp. pt. (dBm min)	3rd Order ICP min	VSWR In/Out max	DC Current (mA)
MEDIUM POWER AMPLIFIERS (UP TO 2 WATTS)								
JCA01-P01	0.5-1.0	25	3.5	1	30	40	2.0:1	250
JCA12-P01	1.0-2.0	32	3	1	30	40	2.0:1	800
JCA34-P01	3.7-4.2	30	3	1	30	40	2.0:1	750
JCA56-P01	5.9-6.4	30	3	1	30	40	2.0:1	850
JCA78-P01	7.9-8.4	30	4	1	30	40	2.0:1	900
JCA812-P02	8.3-11.7	40	5	1.5	33	40	2.0:1	1700
JCA910-P01	9.5-10.0	30	4	1	33	40	2.0:1	1300
JCA1011-P01	10.7-11.7	30	4	1	30	40	2.0:1	950
JCA1819-P01	18.1-18.6	30	5	1	27	37	2.0:1	800
RADAR & COMMUNICATION BAND LOW NOISE AMPLIFIERS								
JCA23-302	2.2-2.3	30	0.8	0.5	10	20	2.0:1	80
JCA34-301	3.7-4.2	30	1	0.5	10	20	2.0:1	80
JCA56-502	5.4-5.9	50	1	0.5	10	20	2.0:1	160
JCA78-305	7.25-7.75	27	1.2	0.5	13	23	2.0:1	100
JCA910-305	9.0-9.5	27	1.4	0.5	13	23	1.5:1	150
JCA1112-305	11.7-12.2	27	1.5	0.5	13	23	1.5:1	150
JCA1415-305	14.0-14.5	26	1.6	0.5	13	23	1.5:1	160
JCA1819-305	18.1-18.6	22	2.0	0.5	10	20	1.5:1	160
JCA2021-600	20.2-21.2	30	2.2	1	13	23	1.5:1	240
TRI-BAND AMPLIFIERS (5.85 TO 14.5)								
JCA514-201	5.85-14.5	8	7	1.5	10	20	2.0:1	100
JCA514-300	5.85-14.5	14	6	1.5	10	20	2.0:1	150
JCA514-302	5.85-14.5	22	6	1.5	20	30	2.0:1	350
JCA514-400	5.85-14.5	25	6	1.5	10	20	2.0:1	250
JCA514-403	5.85-14.5	32	6	1.5	23	33	2.0:1	500
JCA514-501	5.85-14.5	35	6	1.5	16	26	2.0:1	375
JCA514-503	5.85-14.5	41	6	1.5	23	33	2.0:1	500
ULTRA-BROAD BAND AMPLIFIERS (2.0 TO 18 GHZ)								
JCA218-200	2.0-18.0	15	5	2.5	10	20	2.0:1	90
JCA218-300	2.0-18.0	23	5	2.5	10	20	2.0:1	110
JCA218-400	2.0-18.0	29	5	2.5	10	20	2.0:1	150
JCA218-500	2.0-18.0	39	5	2.5	10	20	2.0:1	180









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Circle 49

Editorial

A Few Words of Appreciation for Materials Science

By Gary A. Breed
Publisher

Once in a while, each of has a moment when we grasp the importance of something quite common, usually something we have taken for granted. My most recent realization of this kind was about electronic materials — from materials with ancient roots (ceramics) to miracles of modern chemistry and physics.

When I was a pre-teen experimenting with electronics, many natural materials were still in use — insulation was typically glass, mica, or even varnished or waxed wood and paper. Processed materials were quite primitive by today's standards — germanium for transistors, selenium for diodes, bakelite plastics and a few phenolic resins to replace the varnish and wax.

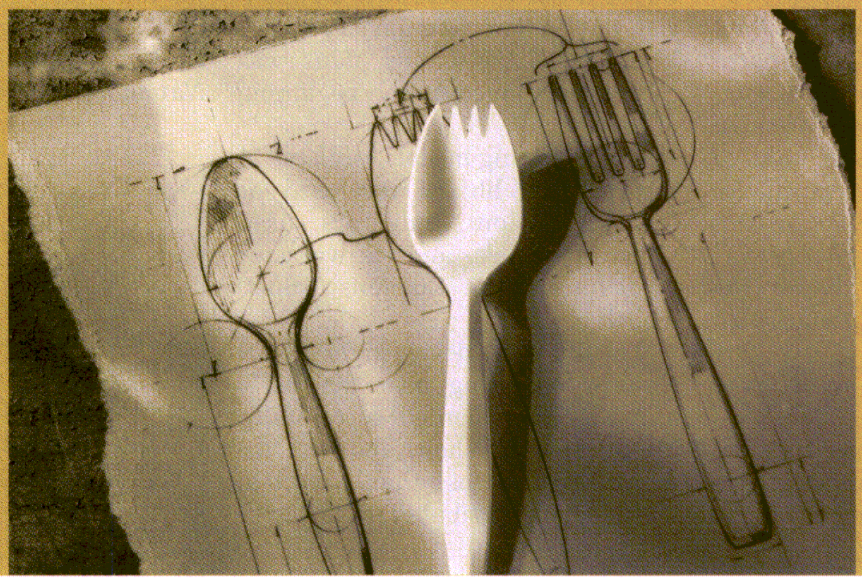
Now we have an astonishing number of "miracles of modern chemistry" to make circuits and components. A few of my favorites are epoxy resins, air-curing silicone rubber, PTFE variants like Teflon® and a wide range of polyester, polycarbonate and other plastics. While copper, silver and gold remain the best conductors, modern electronics also use metals and alloys like aluminum, nickel, tungsten, palladium, invar and tantalum to meet performance or fabrication requirements.

Semiconductor materials have seen a remarkable transformation in the past fifteen years. Silicon replaced germanium and was nearly alone in solid-state technology for twenty years. Now we have an alphabet soup of chemical symbols like GaAs, InGaP, InP, SiC and AlGaAs to go with silicon, silicon-on-sapphire, silicon-on-glass and silicon with doping of any number of common and rare elements, including germanium (SiGe).

Even that old standby, quartz, has undergone changes. We grow ultrapure crystals, cut it into new high-stability forms like SC-cut, process it in new ways like inverted-mesa high frequency fundamental resonators or print conductors on it to make SAW resonators and filters.

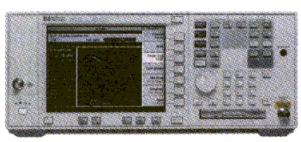
The materials that triggered these comments are ceramics. High dielectric constant materials have shrunk the size of coaxial resonators, enabling smaller filters and VCOs with excellent performance. Low firing temperature ceramics are encouraging engineering creativity in the development of three-dimensional super-components with integral lumped and discrete elements. When you add established materials like alumina to the picture, the importance of ceramics in RF and microwave electronics is undeniable.

When you undertake the next circuit design project, take a moment to appreciate the materials science that helped create the components, substrates and housings you are using! ■



Every once in a while someone comes along with the perfect combination. When you're testing 2G and 3G products, you can't afford to choose between accuracy and speed. But most of the time, that's exactly what you're forced to do.

We've got the perfect solution. The Agilent Technologies E4406A Vector Signal Analyzer. We designed the E4406A specifically for the manufacturing test needs of 2G and 3G base stations and components. It has unmatched test speed—up to 5 times faster than the competition. Amplitude accuracy of .5dB for critical measurements. And pre-configured measurements for faster setup than traditional spectrum analyzers. So you get all the speed you want. Along with all the accuracy you need. And that's a combination you don't see very often.



Agilent Technologies' E4406A Vector Signal Analyzer

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Circle 20

Letters

Measured data is always best

We received a strongly-worded comment expressing concern that the design presented in K. Jeganathan's article, "Design of a Simple Tunable/Switchable Bandpass Filter" (March 2000 issue), was not realizeable due to the effects of parasitic capacitance. The original complaint was withdrawn after a reminder that this was not a microwave design where parasitics would play a critical role in construction. To confirm the performance of the filter, the author has graciously provided additional measured performance data.

Editor:

Of course, at microwave frequencies, parasitic and 2nd order effects and component tolerances play a major role and no one will disagree with these well known facts at microwave frequencies. But these concerns can be neglected for the current filter design, as the design is targeted not to microwave frequencies but to low frequencies in the VHF and UHF bands. This was clearly mentioned at the beginning of the article.

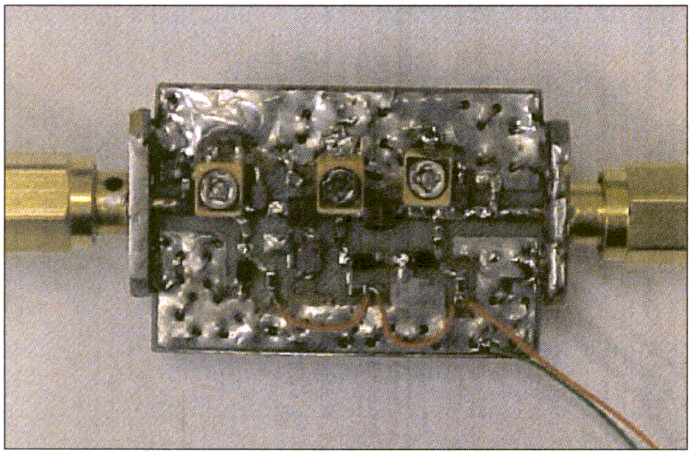
The following models available in the H-P ADS library were used for the simulation: inductors used Coilcraft models, and the varactor diodes used the Siemens BB640 model.

The filter was designed for a DAB receiver operating near 200 MHz and was implemented successfully. Measurements show about 2 dB more insertion loss than expected, which can be attributed to the low Q value components used in the prototype circuit and the PCB loss arising from the use of FR4 board.

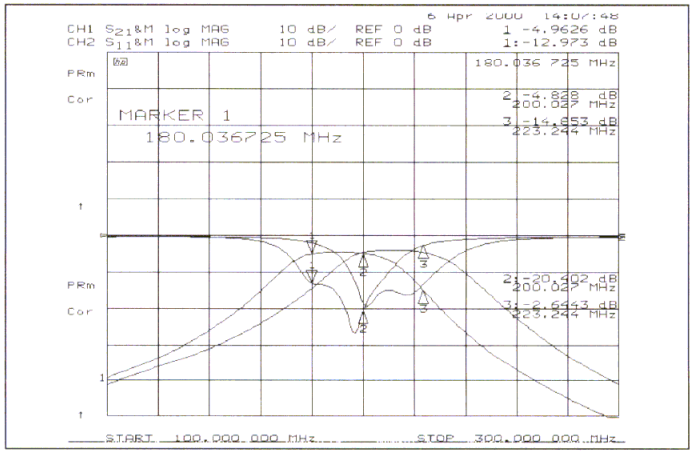
A photo of the circuit and the measurement results are presented for your reference (shown below).

K. Jeganathan
National University of Singapore

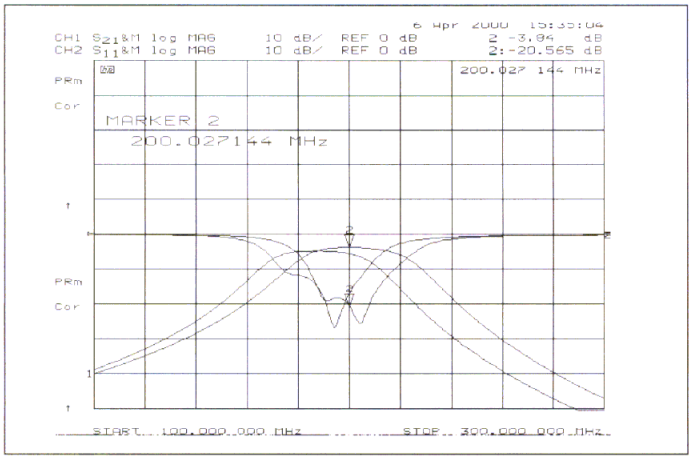
Your comments and feedback are appreciated. Send your letters to the Editor at: *Applied Microwave & Wireless*, 4772 Stone Drive, Tucker, GA 30084; fax: 770-939-0157; e-mail: amw@amwireless.com. When published, letters may be edited for length or clarity.



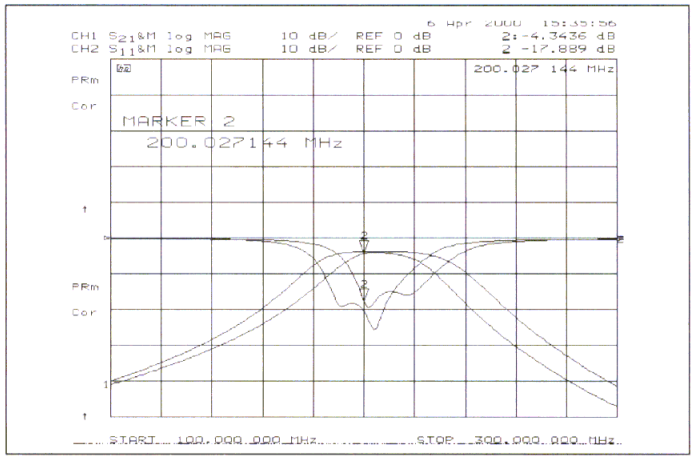
▲ **Photo of the completed prototype filter based on the design described in the article.**



▲ **Two traces corresponding to filter insertion loss and return loss with control voltages of 0 V and 3 V.**



▲ **Plot of filter performance with 0 V and 1.5 V control.**



▲ **Plot of filter performance with 1.5 V and 3.0 V control.**

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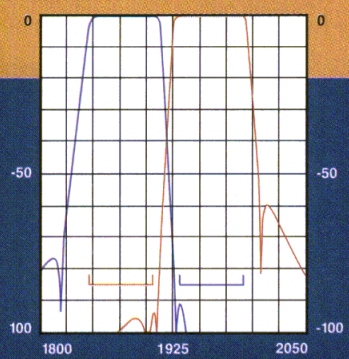

Example Performance:

WD-00007 FULL BAND PCS DIPLEXER

RX Passband Frequency: 1850-1910 MHz
TX Passband Frequency: 1930-1990 MHz

Circle 17

Calendar

CONFERENCES

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2000 IEEE/EIA International Frequency Control Symposium and Exhibition
Kansas City, MO
Information: IEEE Ultrasonics, Ferroelectrics and Frequency Control Society
E-mail: pwalsh@eia.org
Internet: http://www.ieee.org/uffc/fc

June 8-9, 2000
5th International Workshop on Finite Elements for Microwave Engineering
Boston, MA
Information: Ms. Yurong Sun
Tel: 508-831-5757
Fax: 508-831-5491
E-mail: ysun@ece.wpi.edu

June 11-13, 2000
2000 IEEE Radio Frequency Integrated Circuits Symposium
Boston, MA
Information: Jyoti Mondal
Tel: 847-259-9600, ext. 4130
E-mail: mondajy@mail.northgrum.com
Internet: http://www.ims2000.org/rfic.htm

June 11-16, 2000
MTT-S International Microwave Symposium
Boston, MA
Information: LRW Associates
Tel: 704-841-1915
Fax: 704-845-3078
E-mail: lrwassoc@sprintmail.com
Internet: http://www.ims2000.org

June 14-16, 2000
2000 MPRG/Virginia Tech Symposium on Wireless Personal Communications
Blacksburg, VA
Information: Jenny Frank
Tel: 757-686-3765
E-mail: mprg@vt.edu
Internet: http://www.mprg.ee.vt.edu

June 15-16, 2000
Automatic RF Techniques Group 55th Conference
Boston, MA
Information: D. Michael Fennelly
Tel: 978-258-4101
Fax: 978-258-4102
E-mail: m.fennelly@ieee.org
Internet: http://www.arftg.org

June 18-22, 2000
ICC 2000 — IEEE International Conference on Communications
New Orleans, LA
Information: Richard W. Miller
Tel: 504-248-7719
E-mail: r.w.miller@ieee.org
Internet: http://www.icc00.org

SEPTEMBER

September 10-13, 2000
RAWCON2000 — 2000 IEEE Radio and Wireless Conference
Denver, CO
Information: Michael S. Heutmaker
Tel: 609-639-3116
Fax: 609-639-3197
E-mail: heutmaker@lucent.com
Internet: http://rawcon.org

The challenge of classifying activity as friendly or hostile has increased with the prevalence of multi-national operations. The result? An increased burden on threat-warning receivers to protect deployed personnel with accurate signal identification and processing.

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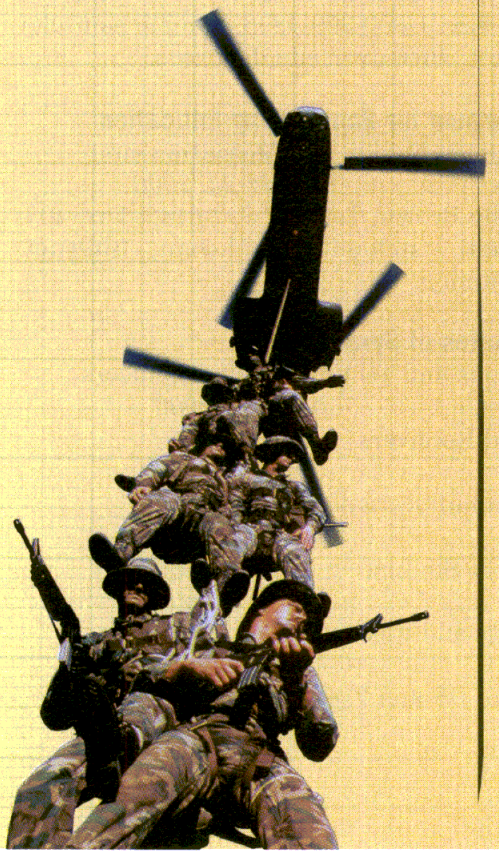

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Calendar

SHORT COURSES

The George Washington University Center for Professional Development

Satellite Communications with Emphasis on Mobile Applications
Washington, DC . . . . . .May 16-18, 2000
Safety Issues and Requirements for PCS and Wireless Communications Devices
Washington, DC . . . . . .May 17-19, 2000
Digital Television
Washington, DC . . . . . .June 5-7, 2000
Advanced Development in Radar
Washington, DC . . . . . .June 7-10, 2000
Radio Frequency Spectrum Management
Washington, DC . . . . . .June 12-16, 2000
Modern Receiver Design
Washington, DC . . . . . .June 12-16, 2000
Multiple Access Techniques for Wireless Communications Systems
Washington, DC . . . . . .June 21-23, 2000
Information: P.J. Mondin, Program Director, Tel: 1-800-424-9773; Fax: 202-872-0645; E-mail: pj@admin.dup.gwu.edu; Internet: www.cpd.gwu.edu.

Besser Associates

Applied RF Techniques I
New York, NY . . . . . .May 15-19, 2000
High Efficiency Power Amplifiers
New York, NY . . . . . .May 15-27, 2000
Mobile Computing and Wireless Data Networks
New York, NY . . . . . .May 15-17, 2000
Frequency Synthesis and Phase-Locked Loop Design
New York, NY . . . . . .May 18-19, 2000
Wideband CDMA Communications
New York, NY . . . . . .May 18-19, 2000
RF and Wireless Made Simple
New York, NY . . . . . .May 22-23, 2000
Mountain View, CA . . . . . .June 5-6, 2000
RF Wireless System Design Fundamentals
New York, NY . . . . . .May 22-24, 2000
Behavioral Modeling
Mountain View, CA . . . . . .May 31-June 2, 2000
All About 3G (Third Generation Wireless)
New York, NY May 24, 2000
Mountain View, CA . . . . . .June 7, 2000
RF Component Modeling
Mountain View, CA . . . . . .June 5-9, 2000
CDMA: The Physical Interface (IMT2000 3G WCDMA)
Mountain View, CA . . . . . .June 12-15, 2000
RF Test Equipment Operation (laboratory course)
Mountain View, CA . . . . . .June 19, 2000
RF Testing for the Wireless Age (laboratory course)
Mountain View, CA . . . . . .June 20-22, 2000
Short Range Wireless and Bluetooth
Mountain View, CA . . . . . .June 21-23, 2000
Electromagnetic Shielding for Wired and Wireless Technology
Mountain View, CA . . . . . .June 26-29, 2000
Information: Annie Wong, Tel: 415-949-3300; Fax: 415-949-4400; E-mail: info@bessercourse.com; Internet: www.bessercourse.com.

RTT Programmes Limited

SMR/PMR Design
London, England . . . . . .May 15-17, 2000
Information: Lorraine Gannon, Tel: +44 181 844 1811; Fax: +44 181 751 2616; E-mail: seminars@rttsys.com; Internet: www.rttsys.com.

Georgia Institute of Technology

CMOS Analog Integrated Circuits
Milpitas, CA . . . . . .May 15-19, 2000
Principles of Enhanced Radar Resolution
Smyrna, GA . . . . . .May 23-26, 2000
Information: Georgia Tech Distance Learning, Tel: 404-894-2547; Fax: 404-894-7398; E-mail: conted@gatech.edu; Internet: www.conted.gatech.edu.

University of Wisconsin at Milwaukee

Advances in Printed Circuit Technology
Milwaukee, WI . . . . . .May 18-19, 2000
Milpitas, CA . . . . . .June 12-13, 2000
SMT Implementation: New and Emerging Technologies
Milwaukee, WI . . . . . .May 31-June 2, 2000
High-Frequency Digital Design & Printed Circuit Board Layout
Milwaukee, WI . . . . . .June 5-7, 2000
Information: Loraine Samsel, Program Assistant, Tel: 1-800-222-3623; Fax: 1-800-399-4896; E-mail: samsel@uwm.edu; Internet: www.uwm.edu/dept/ccee.

Northeast Consortium for Engineering Education

Antennas: Principles, Design and Measurements
Orlando, FL . . . . . .May 22-25, 2000
Information: Kelly Brown, Tel: 407-892-6146; Fax: 407-892-0406; E-mail: stcloudof1@aol.com; Internet: www.usit.com/antenna.

Research Associates of Syracuse, Inc.

Aircraft Operations and Tactics for EW Engineers
Syracuse, NY . . . . . .June 6-8, 2000
Digital Wideband Receivers
Syracuse, NY . . . . . .June 6-8, 2000
Principles of Communications Ssytems
Syracuse, NY . . . . . .June 6-9, 2000
Electronic Combat Simulation and Modeling
Syracuse, NY . . . . . .June 6-9, 2000
Ship Survivability and Electronic Warfare
Syracuse, NY . . . . . .June 13-15, 2000
Emitter Location, DF and Frequency Estimation
Syracuse, NY . . . . . .June 13-15, 2000

USB Transceiver for Less

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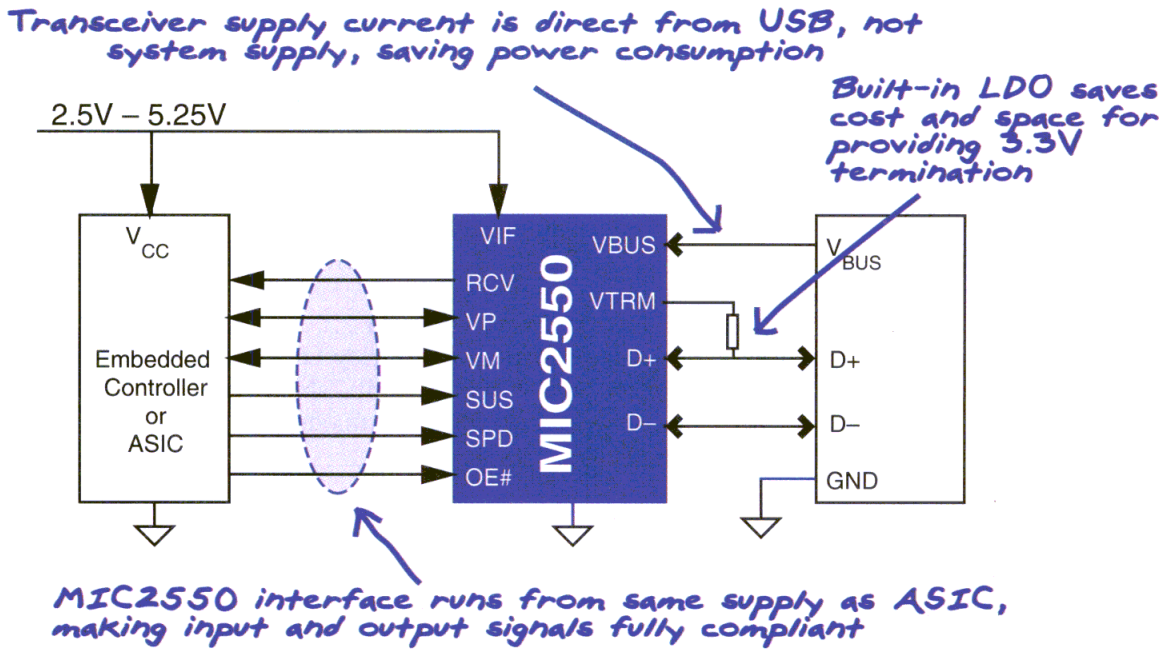

The Good Stuff

- Compliant to USB specifications
- Interfaces to standard SIE interface
- Unique dual supply voltage operation
- Low and full speed support
- Operates down to 2.5V
- Integrated LDO for speed termination voltage
- Low power suspend mode
- Low height TSSOP package

Micrel's new USB transceiver will save your next USB peripheral design time, cost, and reduce design complexity.

The MIC2550 employs a unique dual supply voltage design which allows operation down to 2.5V on the system side, and connects directly to the USB voltage bus. An integrated LDO provides the speed termination voltage without requiring additional space or cost.

With the MIC2550, you can operate your embedded controller or ASIC from 2.5V to 5.5V without additional voltage translation circuitry or special I/O cells to support USB's 3.3V signalling.

In addition, the MIC2550 takes its operating power direct from the USB voltage bus, decreasing power consumption from the system battery.

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Calendar

Radar and Electronic Warfare: The View from Both Sides
Syracuse, NY . . . . . June 13-16, 2000
Modern Radar Decoys
Syracuse, NY . . . . . June 20-22, 2000
Phased Array Radar
Syracuse, NY . . . . . June 20-22, 2000
Stockholm, Sweden . . . . November 14-16, 2000
ELINT Interception and Analysis
Syracuse, NY . . . . . June 20-23, 2000
Introduction to Microwave and RF
Syracuse, NY . . . . . June 22-23, 2000
Information: Mary Chamberlain or Richard Wiley, Tel: 315-463-2266; E-mail: seminars@ras.com; Internet: www.ras.com.

University of California at Berkeley Extension

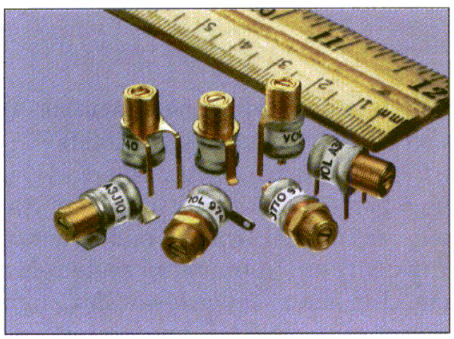
Methodologies and Fundamentals of High-Level ASIC Design
San Francisco, CA . . . . . June 5-6, 2000
MEMS: Design, Fabrication, and Packaging
Berkeley, CA . . . . . June 12-13, 2000
High-Performance Communication Networks
Berkeley, CA . . . . . June 12-14, 2000
BSIM — Standard MOSFET Model for Circuit Simulation
Berkeley, CA . . . . . June 29-30, 2000
Design of Analog Integrated Circuits for Mixed-Signal Integrated Systems
Berkeley, CA . . . . . June 12-13, 2000
Information: Continuing Education in Engineering, Tel: 510-642-4111; Fax: 510-642-0374; E-mail: course@unex.berkeley.edu; Internet: www.unex.berkeley.edu/enroll.

University of Wisconsin at Madison

Using the IS-136 TDMA Wireless Air Interface
Madison, WI . . . . . June 13-16, 2000
Information: Katie Peterson, Tel: 1-800-462-0876; Fax: 608-263-3160; E-mail: custserv@epd.engr.wisc.edu; Internet: http://epd.engr.wis.edu.

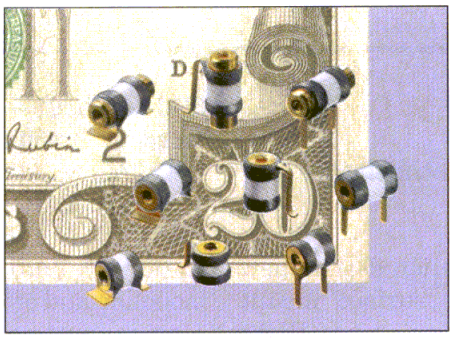
California State University, Northridge

Far-Field, Near-Field, Compact Ranges and Anechoic Chambers
Northridge, CA . . . . . June 20-23, 2000
Information: Shirley Lang, Tel: 818-677-2146; Fax: 818-677-5982; E-mail: shirley.lang@csun.edu; Internet: http://www.ecs.csun.edu/~crs/mam/.



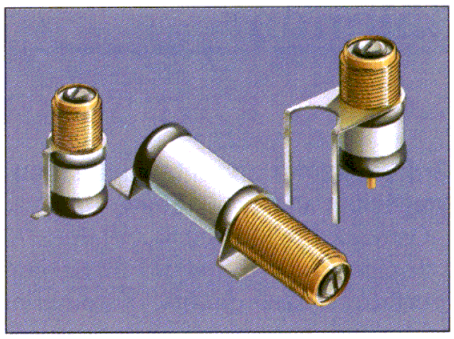
A_3 Series

- Capacitance range: 1 to 10 pF
- Self-resonance 2.3 GHz at 10 pF
- Working voltage up to 1000 VDC
- 10 turns of linear tuning
- Drop-in replacement for expensive air piston trimmers
- High reliability solid dielectric



A_4 Series

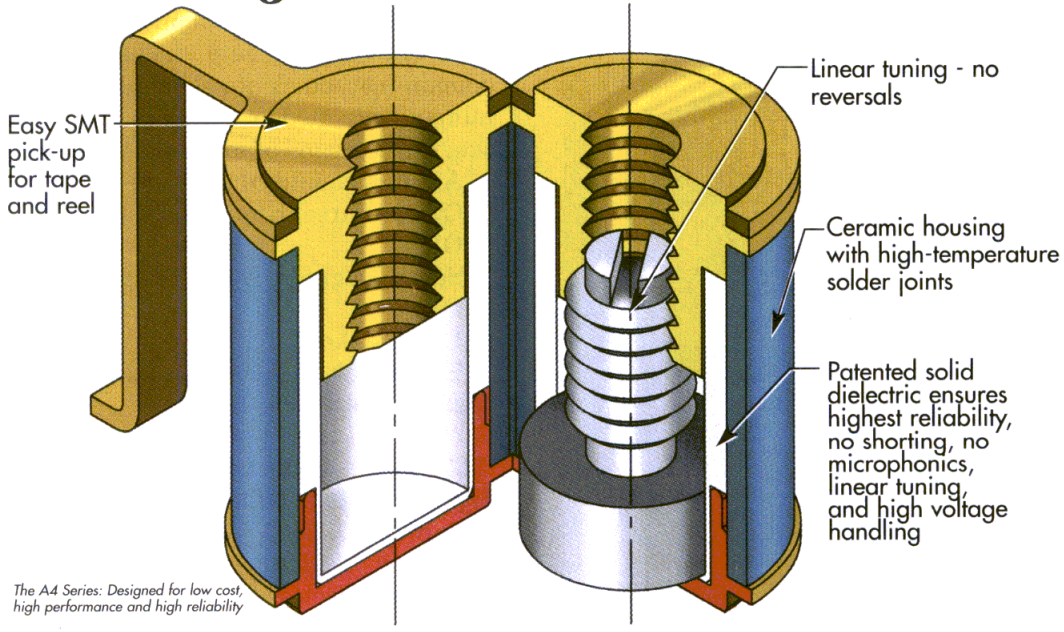
- 3 capacitance ranges from 0.45 to 5 pF
- Shortest length of any piston trimmer
- Size from 0.150" long x 0.155" diameter
- Up to 5 turns of linear tuning
- High reliability solid dielectric
- Replaces expensive sapphire trimmers



HV Series

- 7 capacitance ranges with max capacitance from 4 pF to 55 pF
- Working voltage up to 1000 VDC
- Frequency up to 1.5 GHz
- Up to 29 turns of linear tuning
- Sealed construction, 40 psi
- Various mounting styles
- Non-magnetic versions

What makes Voltronics trimmer capacitors the world's best? Just look inside...



The A4 Series: Designed for low cost, high performance and high reliability

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- **Lowest profile in the industry**
- **Available on tape-and-reel**
- **High-voltage options**
- **Capacitance ranges from 0.2-1.0pF to 1.5-55pF**

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Calendar

CALLS FOR PAPERS

33rd Connector and Interconnection Technology Symposium and Trade Show

October 23-25, 2000 — Orlando, FL

Topics: Radio frequency interconnection design, new interface styles, quality, automation, surface mount technology, automotive interconnections, space flight connector technology, medical applications, materials, finishes, plating and test methods.

Authors should submit a 200-word abstract, including proposed title, objectives, approach, results, and complete contact information. Submit to:

IICIT Annual Symposium
P.O. Box 399
Waretown, NJ 08758
Fax: 609-693-1614
E-mail: sromeo@iicit.org
AND
Steve Ulett, RF Interconnect Chairman
6321 San Ignacio Ave.
San Jose, CA 95119
Fax: 408-281-8722
E-mail: steve.ulett@avnet.com

Deadline: May 26, 2000

EMC Zurich '01 — 14th International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility

February 20-22, 2001 — Zurich, Switzerland

Topics: EMC management, specifications and standards, measurement techniques (theory and practice), stationary and transient environments, system-level modeling and effects, chip and package level EMC, lightning, innovation, power systems EMC and protection.

Detailed submission information is available at the symposium web site (URL below). Submit to:

Technical Program Committee
EMC Zurich '01
ETH Zentrum
IKT – ETF
Zurich CH-8092
Switzerland
E-mail: emc@nari.ee.ethz.ch
Internet:
http://www.nari.ee.ethz.ch/emc/emc01/emc01.html

Deadline: July 1, 2000

The Applied Computational Electromagnetics Society

Special issue of the ACES Journal on Computational Bioelectromagnetics

Topics: Cellular telephone analysis and design, medical imaging, EM safety analysis, finite-difference time-domain method, finite element method, high resolution human body models, electrical properties of human tissue, comparisons of methods, models, or techniques.

Authors should contact one of the guest editors:

Cythia Furse, E-mail: furse@ece.usu.edu
OR
Susan Hagness, E-mail: hagness@engr.wisc.edu
OR
Ulrich Jakobus
E-mail: jakobus@ihf.uni-stuttgart.de

Deadline: August 25, 2000

ISSSE 2001 — 2001 International Symposium on Signals, Systems and Electronics

July 24-27, 2001 — Tokyo, Japan

Topics: Software-oriented radio transmitters/receivers, wireless channel equalization, signal detection, advanced wireless radio networks, hardware/software cooperation, anti-fading techniques, radio-frequency synthesizers, digital signal processing, integrated modules and elements, hardware-oriented signal processing and compression, advanced technologies, devices for microwaves and photonics, numerical and CAD techniques, millimeter-wave applications, and full-scale systems on a single chip.

Send submissions to:

ISSSE 2001
E-mail: issse01@ee.kagu.sut.ac.jp
Internet: http://issse01.ee.kagu.sut.ac.jp

Deadline: January 15, 2001

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Type	Case	Ratings			f_T	I_T	Characteristics, typical					
		V_{CEO} (V)	I_C (mA)	P_{TOT} (mW)	(GHz)	(mA)	F (dB)	G_{um} (dB)	@ (MHz)	F (dB)	G_{um} (dB)	@ (MHz)
PMBTH10	SOT23	25	40	400	0.6	1-20						
PMBTH81	SOT23	20	40	400	0.6	1-20						
BFS17W	SOT323	15	50	300	1.6	2-20	4.5		500			
BFR92AT	SC-75*	15	25	300	5	3-30	2	14	1000	3	8	2000
BFT92W	SOT323	15	35	300	4	3-30	2.5	17	500	3	11	1000
BFR93AT	SC-75*	12	35	300	5	5-40	1.5	13	1000	2.1	8	2000
BFQ67T	SC-75*	10	50	300	8	3-30	1.3	13	1000	2.2	8	2000
PBR941	SOT23	10	50	360	8	3-30	1.4	15	1000	2	9.5	2000
PRF947	SOT323	10	50	250	8	3-30	1.5	16	1000	2.1	10	2000
PRF949	SC-75*	10	50	150	8	3-30	1.5	16	1000	2.1	10	2000
PRF957	SOT323	10	100	270	8	5-50	1.3	15	1000	1.8	9.2	2000
BFR505T	SC-75*	15	18	150	9	1-10	1.2	17	900	1.9	10	2000
BFR620T	SC-75*	15	70	300	9	3-30	1.1	15	900	1.9	9	2000
BFC520	SOT353	8	70	1000	9	3-30	1.3	31	900	1.5	19	2000
BFE520	SOT353	8	70	100	9	3-30	1.2	17	900	1.9	10	2000
BFM520	SOT363	8	70	100	9	3-30	1.1	15	900	1.9	9	2000
BFG520W/X	SOT343	15	70	500	9	3-30	1.6	17	900	1.8	11	2000
BFG540W/X	SOT343	15	120	500	9	10-60	1.9	16	900	2.1	10	2000
BFG11W/X	SOT343	8	500	760	9	50-150					7	1900
BFG403W	SOT343R	4.5	3.6	16	17	5-5	1	20	900	1.6	22	2000
BFG410W	SOT343R	4.5	12	54	22	2-15	.9		900	1.2	22	2000
BFG425W	SOT343R	4.5	30	135	22	3-30	.8		900	1.2	20	2000
BFG480W	SOT343R	4.5	250	360	18	30-150	1.2		900	1.8	16	2000
BFG21W	SOT343R	4.5	200	600	18	50-250					12	1900

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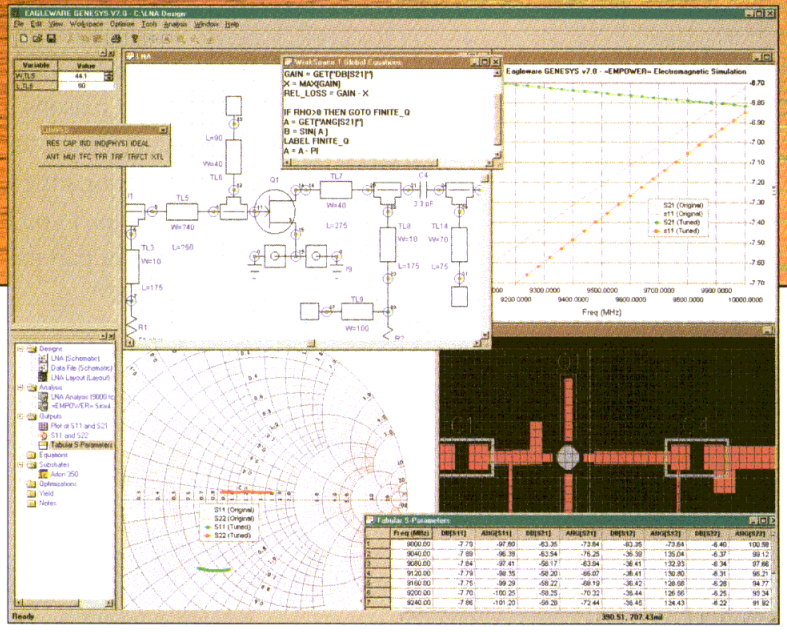
PREPARE FOR THE NEXT GENESYS



BRIEFS

• M/A-COM Inc. has introduced wireless web access for its web site through wireless web-enabled phones at http://209.67.226.186. The site offers datasheets and other product information, as well as e-mail and fax capabilities.

• Andrew Corporation has launched a On-Line Document Center through its web site, www.andrew.com, offering searchable information on the company's products and services. Documents may be viewed online, sent via e-mail, or sent to a fax machine.

• Zeta's new web site, www.zeta-idt.com, offers information, brochures and datasheets on the company's RF, microwave and signal intercept and location systems.

• AD Products Co. has launched a new web site, www.adproductsco.com, offering product information and ordering options for industrial and OEM electrical enclosures.

• LEMO USA, a supplier of electronic and optical connectors, has opened a new headquarters office in Rohnert Park, CA.

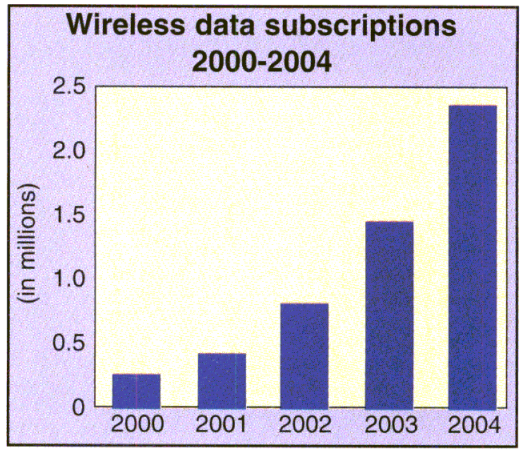
• EMI/RFI shielding company Boldt Metronics International Inc. (BMI) has announced the opening of an international headquarters office and manufacturing facility in Berlin, Germany.

• Schaffner EMC Inc., a provider of EMI components, instrumentation and test systems, has moved into a new US corporate headquarters in Edison, NJ.

• Xemod Inc., a manufacturer of integrated RF power products, has relocated its headquarters to Santa Clara, CA, and completed expansion of its Tempe, AZ, location.

Companies, organizations and institutions may submit information for our News section to: Shannon O'Connor, Managing Editor, Applied Microwave & Wireless, 4772 Stone Drive, Tucker, GA; 770-939-0157 (fax); amw@amwireless.com (e-mail).

Study: Wireless data to grow with 3G services



A new study from Allied Business Intelligence (ABI) predicts that the growth of new third generation (3G) wireless services will kick-start the market for wireless data services over the next five years.

According to the report, "3G Wireless: Global Data and Voice Networking STrategies — WAP, GPRS, 1XRTT, EDGE and Internet Access," actual direct internet access via wireless handsets will become available to more than 100 million wireless users worldwide during 2000, with about 26 million subscribers taking advantage of the services. The number of data users will grow to more than 240 million by 2005, the study said.

Larry Swasey, ABI's vice president of communications and the author of the report, cited the expansion of GPRS in western Europe and worldwide growth of truncated access services such as WAP as two main reasons for building wireless data demand.

"As 3G radio channel element upgrades take place and data strategies are placed into mobile wireless networks, the handset will become a much more valuable tool to both the operator and the user," Swasey said.

ABI, based in Oyster Bay, NY, is a technology research think tank targeting the broadband, wireless, electronics, automation, energy and transportation industries.

Wyle forms RF Vision subsidiary for component distribution

Wyle Electronics, part of the VEBA Electronics Group, has created a new subsidiary business unit, RF Vision™, to target the RF/microwave and fiber optics component distribution markets.

The new company, headquartered at Wyle's facility in Santa Clara, CA, is focusing on five primary product categories — small-signal components, RF power devices, RF/IF passives, RF interconnect and fiber-optic products. The company also offers value-added services including parametric testing, tape and reeling, solder dipping, production qualification, screening and special cabling.

RF Vision customers will also be able to use Wyle's e-commerce system to place orders online. Available at www.wyle.com, the site offers parts searches, new product and sample information, total solution packages and a newsletter.

The new company is operating initially through 22 sales offices and expects to expand globally in the near future, according to company officials.

Paradigm Wireless created for power amplifier design

Paradigm Wireless Communications is a new company formed to design and manufacture RF power amplifiers for wireless base stations.

Based in Irvine, CA, with offices in Korea, the company has made available its first multi-carrier power amplifiers, using its patent-pending Pre-forward Wide-band Cross-cancellation (PWC) linearization technology. This technology allows for simpler packaging designs, providing scalability and flexibility for products using wireless communications bands worldwide, including cellular, PCS and IMT-2000.

THE NEW STANDARD REFERENCE FOR MODERN SMALL SIGNAL AMPLIFIER DESIGN

Small Signal Microwave Amplifier Design

by Theodore Grosch

280 pages
ISBN 1-884932-06-1

This book explains classical and modern techniques for designing small signal high frequency amplifiers with practical design examples. Linear network theory and transmission line principles provide the foundation for an in-depth discussion that includes broadband amplifier design and low-noise techniques.

- Overview of design issues for RF and microwave circuits
- Introduction to networks: *Z*-, *Y*- and chain parameters
- Transmission line principles and the Smith chart
- Wave vectors and *S*-parameters
- *S*-parameter circuit analysis
- Narrowband circuit synthesis and matching
- Amplifier design: device data, stability, gain, biasing
- Broadband matching
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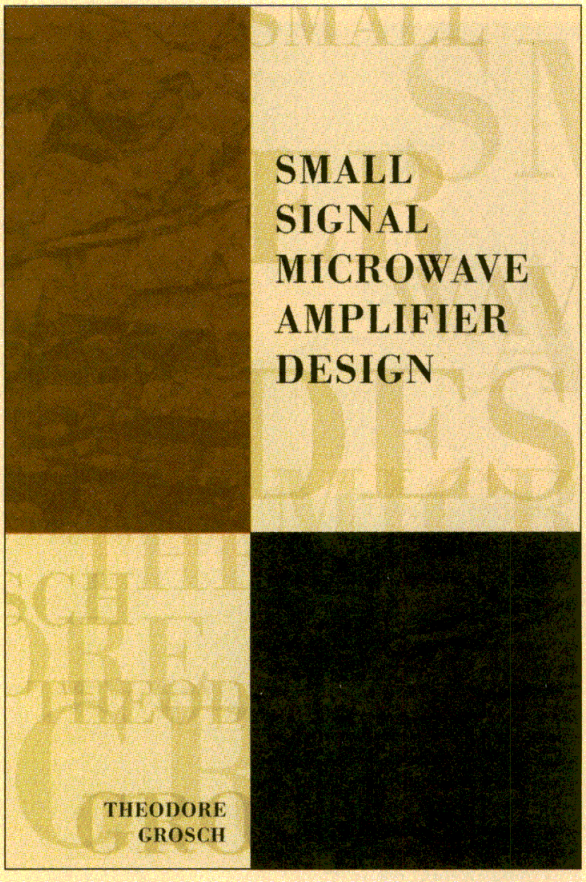

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Peregrine, Symbol team up for Bluetooth development

Peregrine Semiconductor and Symbol Technologies have signed an agreement to jointly develop solutions for the emerging Bluetooth wireless high-speed personal area networking (PAN) market.

Under the agreement, Peregrine's UTSi® (Ultra-Thin Silicon) CMOS technology and background in radio frequency integrated circuit development will be combined with Symbol's baseband processing, software and systems expertise to create complete Bluetooth subsystems.

Peregrine will then introduce Bluetooth integrated circuits, reference designs and software support based on the products developed. Symbol will integrate the new components into its application-specific information appliances, data and voice wireless networks and bar code and data capture scanner products, as well as providing OEM Bluetooth radio solutions.

Peregrine, headquartered in San Diego, CA, designs integrated circuits based on its UTSi CMOS technology. Symbol Technologies, based in Holtsville, NY, provides wireless and internet-based mobile data management systems and services.

Videotape set covers FCC rules workshop

The ACIL Institute is offering a videotape set covering the five-day workshop on Federal Communications Commission rules that was presented in December 1999. The set is aimed at those working in telecommunications whose products or services will require review by the FCC or one of the new Telecommunications Certification Bodies.

The 20-tape set is 31 hours long and gives in-depth information on FCC rules regarding such topics as telephone equipment and both licensed and unlicensed transmitters. The set is accompanied by a CD-ROM containing an index of the entire set, broken down by part number, subject and chronological order, as well as copies of the handouts provided during the workshop.

A related Computer-Based Training (CBT) program is also being offered, with 15 modules covering detailed information on technical requirements for such areas as spread spectrum devices and mobile and microwave radio services.

The packages may be ordered through ACIL, Tel: 202-887-5872; Fax: 202-887-0021; E-mail: jdahl@acil.org; Internet: www. acil.org.

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PhaseCom Inc., based in Cupertino, CA, has changed its name to Vyyo Inc. The new company web site is www.vyyo.com.

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BUSINESS AND FINANCE

Sync Research to merge with Osicom subsidiary

WAN provider Sync Research Inc. has announced plans to merge with the Network Access subsidiary of Osicom Technologies Inc. The new company will be called Entrada Networks.

Osicom's Network Access subsidiary, based in Annapolis Junction, MD, manufactures high-speed local area network (LAN) and wide area network (WAN) products. Sync Research, based in Irvine, CA, manufactures frame relay solutions and digital transmission products.

Conexant to acquire Philsar

Conexant Systems Inc. has agreed to acquire Philsar Semiconductor. Philsar will become part of Conexant's Wireless Communications Division.

Philsar, based in Ottawa, Ontario, Canada, develops RF semiconductor solutions for wireless. Conexant, based in Newport Beach, CA, provides semiconductor solutions for communications.

Giga-Tronics receives synthesizer order

Giga-Tronics Inc.'s Instrument Division has received an order valued at more than $2.3 million to provide its three-slot VXI Microwave Synthesizer for Advantest Corporation.

The Instrument Division of Giga-Tronics, based in San Ramon, CA, produces test instruments for power measurement and frequency generation.

Motorola NSS awarded new contract in China

Motorola Inc.'s Network Solutions Sector (NSS) has received a new $14.5 million GSM 1800 network contract from China's Shandong Mobile Communications Corporation. The network will be deployed in four major cities in the province.

Motorola, based in Schaumburg, IL, provides semiconductors, integrated communications solutions, embedded electronic systems and components.

Signal Technology receives order from Raytheon

Signal Technology Corporation has been awarded a $3.6 million contract to provide audio/video switches for Raytheon Systems, Greenville Division.

Signal, based in Danvers, MA, produces electronic components and systems for communications, defense and space applications.

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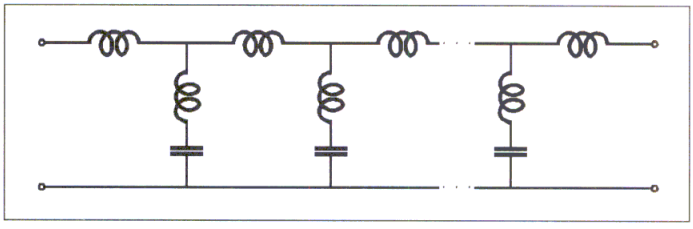
An Efficient Procedure for Narrowband Bandpass Filter Design

Here is a review of lowpass-to-bandpass transformations with an example filter operating at 5 GHz

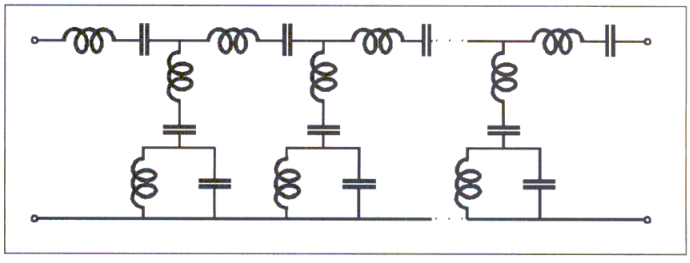
By Zlatoljub D. Milosavljevic and Miodrag V. Gmitrovic
Faculty of Electronic Engineering, University of Nis, Yugoslavia

Bandpass filters (BPF) may be constructed by cascading lowpass (LP) and highpass (HP) filters. This type of realization is suitable for devices with wide bandwidths but is not convenient for the realization of narrowband BPFs, that is, for bandwidths of less than about 10 percent [1]. This is related to the high degree (number of poles and zeros) needed for the filters to achieve good selectivity. The cascaded type of realization causes large insertion losses and poor amplitude flatness.

Cauer and generalized Chebyshev [2, 3] LP prototype filters are very good starting points for the design of selective BPFs. This article discusses the BPF network transformations suitable for physical realization [4, 5]. These transformations are based on the insertion of redundancy ideal transformers in BPFs and the use of Norton's equivalent networks [6].



▲ **Figure 1. LP prototype filter with real transmission zeros.**



▲ **Figure 2. BPF structure.**

A proper choice of transformer transformation ratio produces a network with a minimum spread of element values. A new and efficient numerically-based procedure for getting an exact solution of optimal parameter t in closed form is presented in [5]. The lumped element network ultimately obtained has no transformers and is very convenient for the design of microwave filters, diplexers and multiplexers using printed circuit technology.

This article also discusses the efficient transformation for the design of a narrowband bandpass filter with transmission lines. The use of suspended substrate techniques [1, 7] allows us to use highly selective prototypes, which can achieve excellent performances. The suspended substrate stripline (SSS) narrowband BPF design procedure is introduced by an example filter with excellent characteristics.

Lumped element network development

A typical LP prototype filter with real transmission zeros is shown in Figure 1. The BPF in Figure 2 is obtained from the use of a well-known frequency transformation on element immitances of the LP prototype filter.

The transformed network in Figure 2 has a large spread of element values and shunt structures unsuitable for practical construction. Since these are very difficult to realize directly, a more convenient equivalent circuit must be found. Such an equivalent structure has been derived [1] and is shown in Figure 3b.

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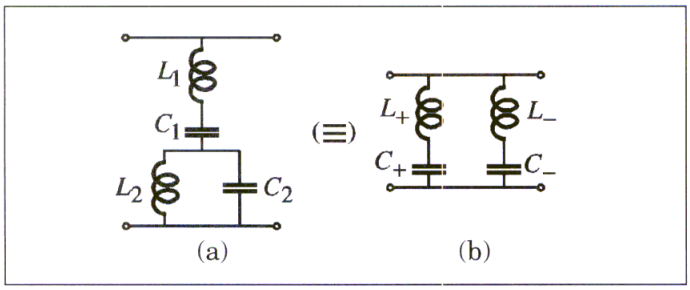
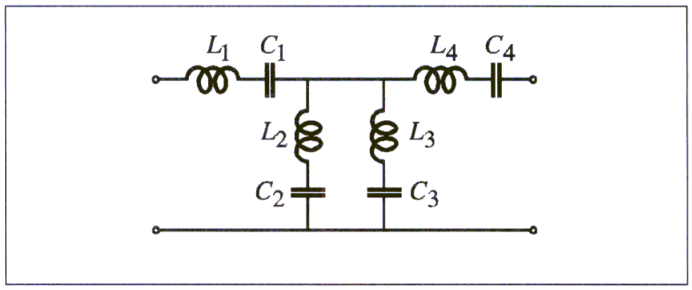


▲ **Figure 3. Alternative shunt element configurations.**



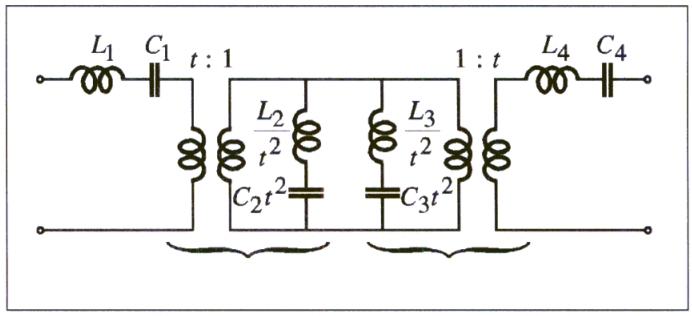
▲ **Figure 4. Transformed BPF.**

The element values L_+, C_+, L_-, C_- of the network in Figure 3b, are defined by relations [1]

$$
\begin{aligned}
a &= L_1C_1 + L_2C_2 + L_2C_1 \\
b &= L_1L_2C_1C_2 \\
\alpha_+ &= \sqrt{\frac{a}{2} + \left(\frac{a}{2}\right)^2 - b} \\
\alpha_- &= \frac{a}{2} + \sqrt{\left(\frac{a}{2}\right)^2 - b} \\
\beta_+ &= \frac{C_1L_2C_2 - C_1\alpha_+}{\alpha_- - \alpha_+} \\
\beta_- &= \frac{C_1L_2C_2 - C_1\alpha_-}{\alpha_+ - \alpha_-} \\
C_+ &= \beta_+, C_- = \beta_-, \\
L_+ &= \frac{\alpha_+}{\beta_+} \text{ and } L_- = \frac{\alpha_-}{\beta_-}
\end{aligned}
\tag{1}
$$

By transforming the network in Figure 2 into that of Figure 3, a more realizable network can be obtained. The spread of element values is smaller than in the original BPF, but it is still quite large. The simplest third degree network obtained in this manner is shown in Figure 4. This structure has the additional disadvantage that branches connected in parallel cause unwanted parasitic capacitance and inductance [6].

The parasitic effects can be removed and the spread of element values decreased by insertion of redundant ideal transformers with the transformation ratio t. For the network in Figure 4, two ideal transformers can be inserted as in Figure 5. As we can see, both networks have the same transfer function. Ideal transformers can be eliminated by Norton's equivalent networks [6] given in Figure 6. Equivalencies should be used twice on the parts of the network in Figure 5 designated with large brackets. It should be noted that one of the serial impedances in Norton's equivalent network always has a negative value. In many instances it is possible, using the other part of the network, for the ultimately transformed network to have all positive element values. The network in Figure 7 is obtained by transforming the network in Figure 5 with equivalencies in Figure 6. The last BPF element values are



▲ **Figure 5. BPF with ideal transformers.**

$$
\begin{aligned}
L_1' &= L_1 + L_2\frac{t-1}{t}, \frac{1}{C_1'} = \frac{1}{C_1} + \frac{t-1}{C_2t} \\
L_2' &= \frac{L_2}{t}, C_2' = C_2t \\
L_3' &= (L_2 + L_3)\frac{1-t}{t^2}, \frac{1}{C_3'} = \left(\frac{1}{C_2} + \frac{1}{C_3}\right)\frac{1-t}{t^2} \\
L_4' &= \frac{L_3}{t}, C_4' = C_3t \\
L_5' &= L_4 + L_3\frac{t-1}{t}, \frac{1}{C_5'} = \frac{1}{C_4} + \frac{t-1}{C_3t}
\end{aligned}
\tag{2}
$$

A sufficient condition for all the network element values in Figure 7 to be positive is

$$
\max\left\{\frac{L_2}{L_1+L_2}, \frac{C_1}{C_1+C_2}, \frac{L_3}{L_3+L_4}, \frac{C_4}{C_3+C_4}\right\} < t < 1 \tag{3}
$$

By inserting the two ideal transformers in the network shown in Figure 5, the resulting network has two additional elements. Element values depend on the value of the redundancy factor t, and the last network is without transformers. By inserting two transformers with different transformation ratios t_1 and t_2, it may be possible for the transformed network to have only one additional element. In this case the transformed net-

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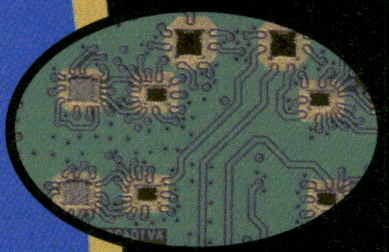

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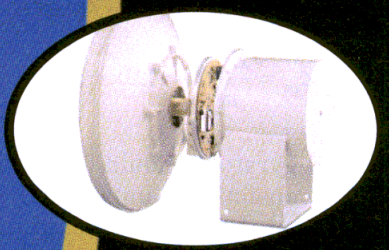

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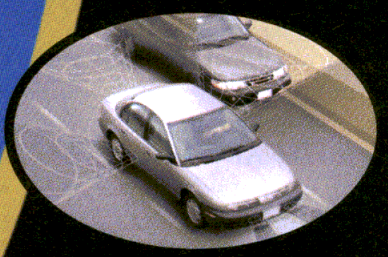

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work is also without transformers, but has different loads, $R_S \neq R_L$.

The optimum value of parameter t can be found in closed form [5]. The first step in getting optimal t is calculating maximum and minimum values of inductances and capacitances for the discrete values of the parameter t from the range defined by Equation (3). If the aim of the BPF design is to minimize the ratio between the maximum and minimum values of reactive elements, it can be noted that for the chosen step Δt, there is a value t for which this condition is fullfilled. The next step is equating minimum or maximum values of inductances or capacitances that change values in the vicinity of the chosen value t. This gives an equation which yields the optimum value of t.

Distributed element network development

The next step in designing a narrowband BPF is to transform the lumped element BPF into one with distributed elements. Inductors are replaced with short-circuited capacitors and capacitors with open-circuited transmission lines. In the case of the third degree BPF given in Figure 7, a transformed BPF with ideal transmission lines is given in Figure 8. The electrical length of all transmission lines is $\theta_c = 45°$ at the band center frequency f_c .

The BPF obtained this way usually has transmission lines with characteristic impedance values that are too high to be practical for realizaton in printed circuit technology. Therefore, a transformation should be applied on the last BPF. The impedance values of the filter could be scaled to the lower values:

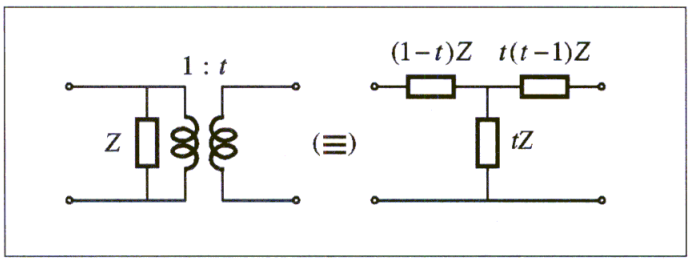
$$Z'_{ci} = \frac{Z_{ci}}{n},\ i = 1,2,\ldots,10 \tag{4}$$

and gyrators should be introduced at input and output to transform all impedances to the characteristic impedance at the input and output port, Z_c. The gyrators' constant is:

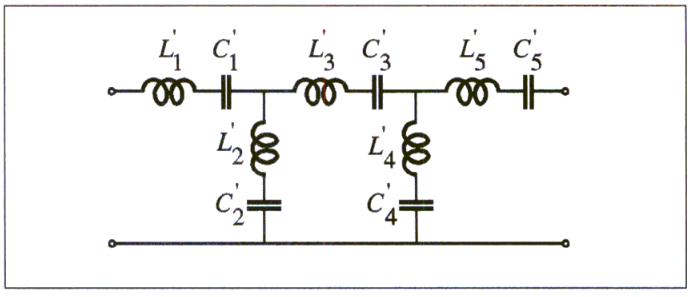
$$r = \frac{Z_c}{\sqrt{n}} \tag{5}$$

Parameter n from the equations (4) and (5) is a positive number.

A ladder BPF network can be efficiently characterized by ABCD parameters, as seen in Figure 9. For reciprocal networks $AD - BC = 1$, and for symmetrical networks $A = D$. The use of ABCD parameters at microwave frequencies is not very convenient from the measurement point of view. Scattering matrix formulation is a more general method of representing microwave networks. Therefore, conversion from the ABCD-matrix to the S-matrix for reciprocal and symmetrical network from Figure 9, gives [8]:



▲ **Figure 6. Norton's equivalent networks.**

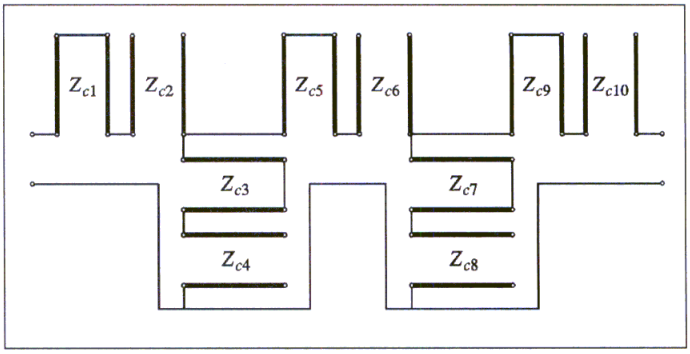


▲ **Figure 7. BPF structure ultimately obtained.**

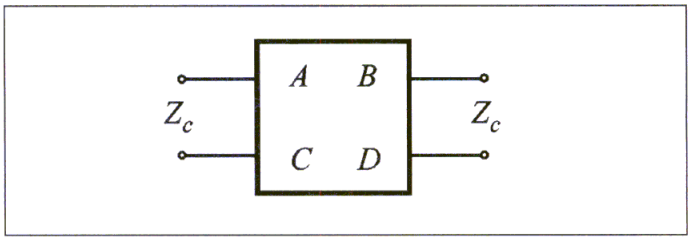
$$S_{11} = S_{22} = \frac{B - CZ_c^2}{2AZ_c + B + CZ_c^2} \tag{6}$$

$$S_{12} = S_{21} = \frac{2Z_c}{2AZ_c + B + CZ_c^2} \tag{7}$$

A transformed network from Figure 9 with scaled impedance values as in (4). This network with two gyrators defined by (5) is shown in Figure 10. It can be shown that this network has the next S-matrix



▲ **Figure 8. The BPF with ideal transmission lines.**



▲ **Figure 9. A generalized two-port network.**

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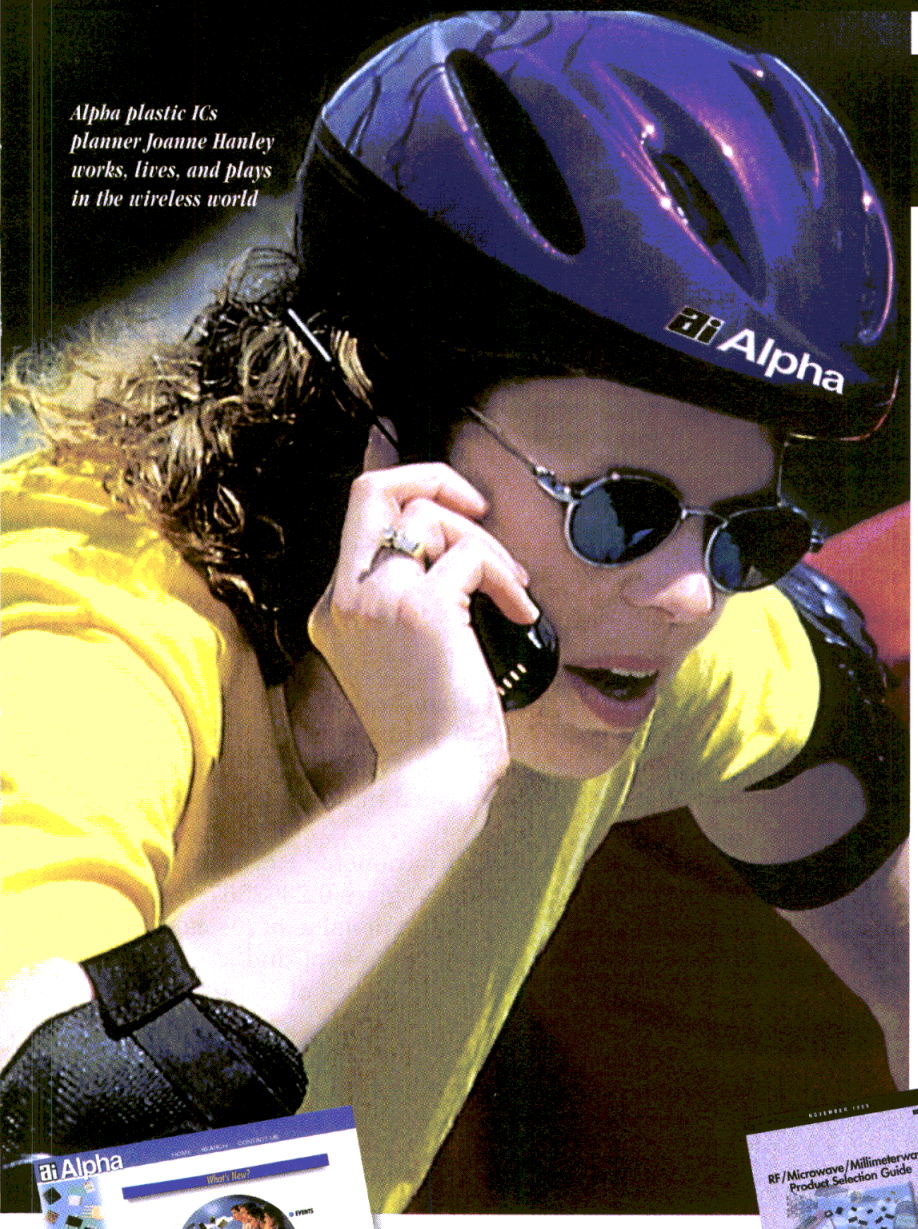

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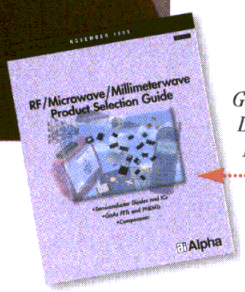

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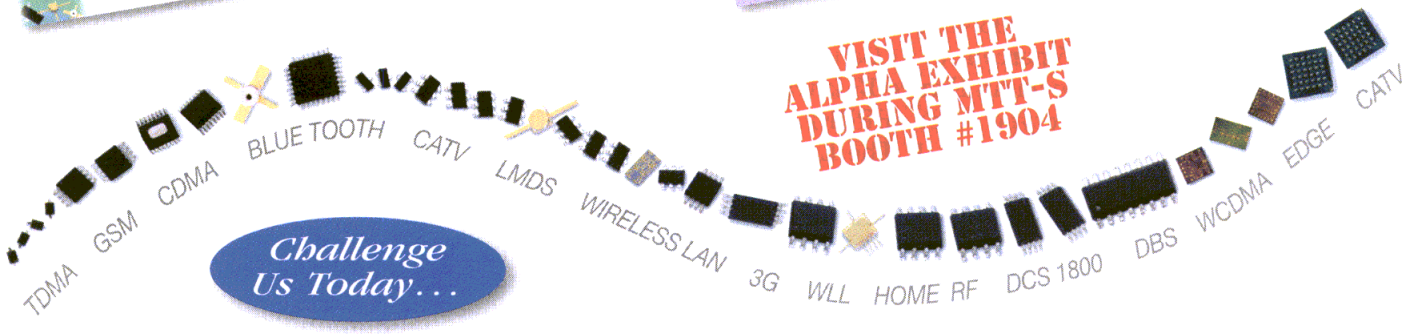

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$$S_{11}^g = S_{22}^g = -S_{11} = -S_{22} \tag{8}$$

$$S_{12}^g = S_{21}^g = S_{12} = S_{21} \tag{9}$$

Equations (8) and (9) show that the transformed network has the same S-parameters as the original network. The only difference is a phase shift of 180° for the reflection coefficients S_{11}^g and S_{22}^g. This fact enables the use of this network for the BPF realization. In the case of a narrowband BPF it is possible to realize gyrators as low impedance transmission lines one-quarter wavelength long at band center, with characteristic impedance $Z_c' = r$ and electrical length $\theta = 90°$ at the center frequency f_c.

In the next step, series connected, short-circuited and open-circuited transmission lines in parallel branches should be replaced with cascade-connected transmission lines to obtain shunt stubs suitable for practical realization. This is illustrated in Figure 11 and characteristic impedance values are defined by

$$Z_{c3} = Z_{c1} + Z_{c2}, Z_{c4} = \frac{Z_{c1}}{Z_{c2}} Z_{c3} \tag{10}$$

Another problem for printed circuit realization of the BPF is existance of short-circuited transmission lines in series branches. In the case of the third degree filter, those are scaled values Z_{c1}', Z_{c5}' and Z_{c9}'. This disadvantage can be removed by realizing these lines using short transmission lines with high characteristic impedance values Z_{ch} and electrical lengths:

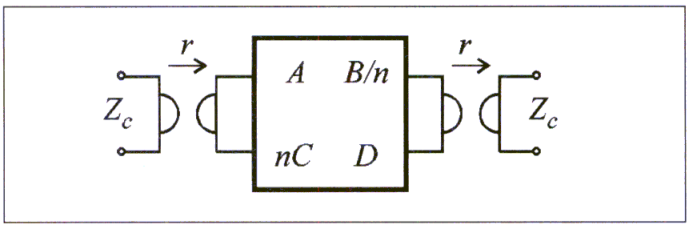
$$\theta_i = \frac{Z_{ci}'}{Z_{ch}} \frac{180}{\pi} [°], i = 1,5,9 \tag{11}$$

The final BPF structure with ideal transmission lines is given in Figure 12.

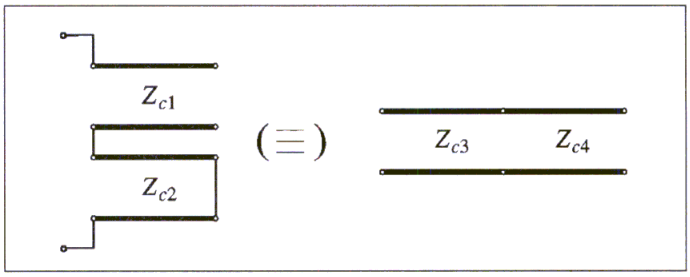
BPF design example

A design procedure for BPF in SSS technology can be given by example. A narrowband BPF, with passband frequencies of f_1 = 4875 MHz and f_2 = 5125 MHz, is a particularly good design example. In this case, the center frequency is $f_c = (f_1 f_2)^{1/2}$ = 4998.4373 MHz and the bandwidth is approximately 5 percent of f_c. Cauer's LP prototype third degree filter given in Figure 13 is transformed into a bandpass prototype filter (BPPF) with the normalized center frequency Ω_{cn} = 1. The LP prototype filter C0325-28 [9] has maximum attenuation in the pass-band α_p = –0.2803 dB, minimum attenuation in the stop-band α_s = –30.4 dB, and element values are L_{1p} = 1.221240, C_{2p} = 0.985344 and L_{2p} = 0.172857. From the Richards frequency transformation

$$\Omega_{cn} = \tan\theta_c = \tan\omega_c T \tag{12}$$



▲ **Figure 10. A transformed two-port network.**



▲ **Figure 11. Equivalent circuits.**

the time delay $T = 1/(8 f_c) = 2.5008 \times 10^{-11}$ s can be calculated. The normalized bandwidth of the BPPF is $B_n = \tan\omega_2 T - \tan\omega_1 T = 0.0786449$. Applying the previously presented procedure, the LP prototype filter given in Figure 13 can be transformed into a BPPF as shown in Figure 7.

The optimum value of parameter t can be found in closed form [5]. Equation (3) gives $0.2382307 < t < 1$. The first step in getting an optimum value of t is calculating maximum and minimum values of inductances and capacitances for the discrete values of the parameter t. It is shown in Table 1.

If the aim of the BPF design is to minimize the ratio between the maximum and minimum values of reactive elements, it can be seen from Table 1 that for $0.3 \le t \le 0.9$ and step $\Delta t = 0.1$, $t = 0.6$. Maximum and minimum values of reactive elements change the values in the vicinity of $t = 0.6$. Therefore, it is necessary to calculate extreme values for $t = 0.55$ and $t = 0.65$.

For $t = 0.55$, the values are

$$L_{max} = L_3' = 13.1974,\ L_{min} = L_2' = 7.3001,$$
$$C_{max} = C_4' = 0.136984,\ C_{min} = C_3' = 0.0757725,$$
$$L_{max}/L_{min} = C_{max}/C_{min} = 1.808$$

For $t = 0.65$, the values are

$$L_{max} = L_1' = 13.3666,\ L_{min} = L_2' = 6.17701,$$
$$C_{max} = C_4' = 0.161891,\ C_{min} = C_5' = 0.0748134,$$
$$L_{max}/L_{min} = C_{max}/C_{min} = 2.164$$

To obtain a closed form for the exact values of optimal parameter t, it is necessary to notice that for $t < 0.55$ the maximum inductance value is $L_{max} = L_3'$, and for $t > 0.55$ it is $L_{max} = L_1'$. Equating $L_3' = L_1'$, the optimal

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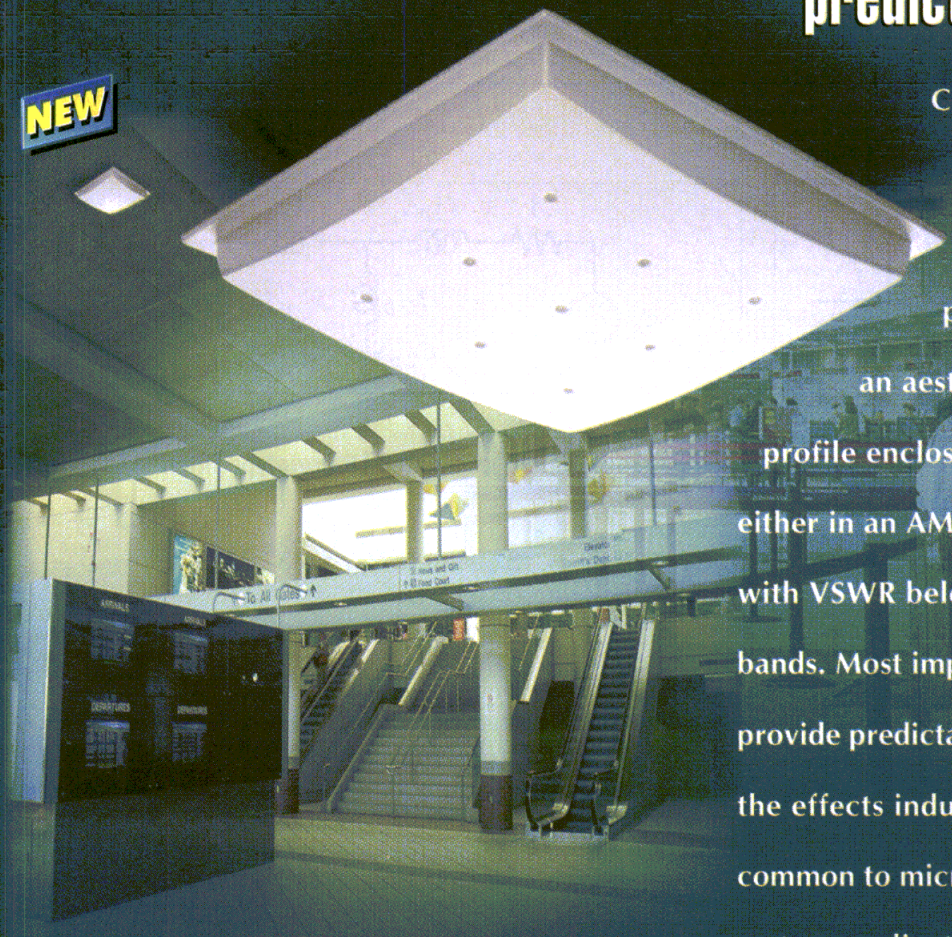

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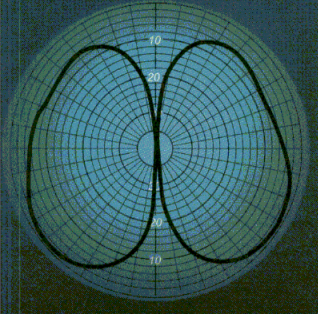

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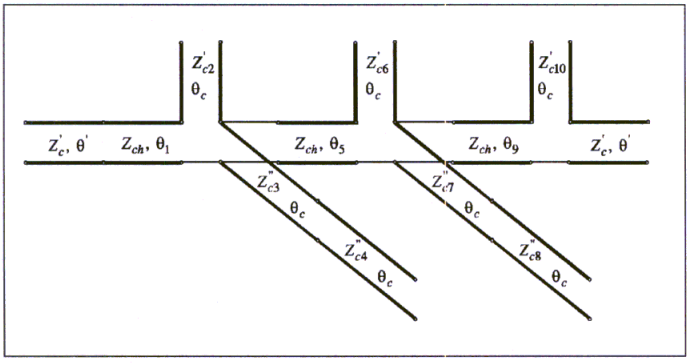
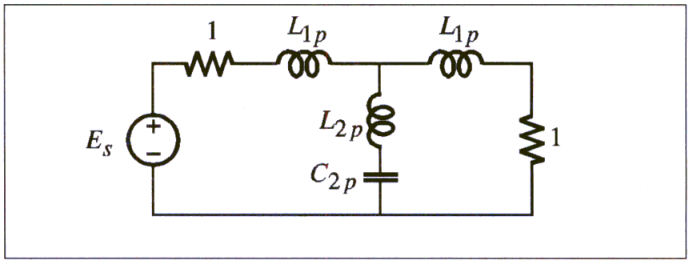
t	L_{max}	L_{min}	L_{max}/L_{min}	C_{max}	C_{min}	C_{max}/C_{min}
0.3	$L'_3 = 69.0012$	$L'_5 = 4.19663$	16.442	$C'_1 = 0.238287$	$C'_3 = 0.0144925$	16.442
0.4	$L'_3 = 33.2684$	$L'_5 = 8.24374$	4.035	$C'_1 = 0.121304$	$C'_3 = 0.0300585$	4.035
0.5	$L'_3 = 17.7432$	$L'_2 = 8.03011$	2.209	$C'_4 = 0.124531$	$C'_3 = 0.0563597$	2.209
0.6	$L'_1 = 12.8518$	$L'_2 = 6.69176$	1.920	$C'_4 = 0.149438$	$C'_5 = 0.0778099$	1.920
0.7	$L'_1 = 13.8078$	$L'_3 = 5.43158$	2.542	$C'_3 = 0.184108$	$C'_5 = 0.0724229$	2.542
0.8	$L'_1 = 14.5248$	$L'_3 = 2.77237$	5.239	$C_3 = 0.360702$	$C'_5 = 0.0688479$	5.239
0.9	$L'_1 = 15.0824$	$L'_3 = 1.09526$	13.771	$C'_3 = 0.913027$	$C'_5 = 0.0663024$	13.771

▲ **Table 1. The extreme element values for $0.3 \le t \le 0.9$.**



▲ **Figure 12. The approximated BPF structure with ideal transmission lines.**



▲ **Figure 13. Double terminated LP prototype filter.**

redundancy parameter

$$t = -\frac{L_3}{2(L_1+L_2)} + \sqrt{\left[\frac{L_3}{2(L_1+L_2)}\right]^2 + \frac{L_2+L_3}{L_1+L_2}} \qquad (13)$$

is obtained and the calculated value is $t = 0.560862$. The same value could be calculated from the requirement $C'_5 = C'_3$, because we started from the symmetrical LP prototype filter. The element values for the BPPF are $L'_1 = 12.3849$, $C'_1 = 0.0852805$, $L'_2 = 7.15873$, $C'_2 = 0.115486$, $L'_3 = 12.3849$, $C'_3 = 0.0807437$, $L'_4 = 8.65905$, and $C'_5 = 0.0807437$. The ratio between the maximum and minimum values is $L_{max}/L_{min} = C_{max}/C_{min} = 1.73$. The obtained structure of the BPPF is very convenient for realization in the printed circuit technology, because it has a minimum spread of element values.

The next step in SSS BPF designing is transforming the BPPF into the BPF with ideal transmission lines. The characteristic impedance at the input and output port is $Z_c = 50\ \Omega$. This BPF is shown in Figure 8. All transmission lines have the same electrical lengths of $\theta_c = 45°$ at the center frequency f_c. The characteristic impedance values are

$Z_{c1} = L'_1 Z_c = 619.245\ \Omega$, $Z_{c2} = Z_c/C'_1 = 586.3005\ \Omega$,
$Z_{c3} = L'_2 Z_c = 357.9365\ \Omega$, $Z_{c4} = Z_c/C'_2 = 432.9525\ \Omega$,
$Z_{c5} = L'_3 Z_c = 619.245\ \Omega$, $Z_{c6} = Z_c/C'_3 = 619.24336\ \Omega$,
$Z_{c7} = L'_4 Z_c = 432.9525\ \Omega$, $Z_{c8} = 357.9543\ \Omega$,
$Z_{c9} = L'_5 Z_c = 586.3\ \Omega$, and
$Z_{c10} = Z_c/C'_5 = 619.24336\ \Omega$

It can be seen that transmission lines have too high characteristic impedance values to be practical in SSS technology. Therefore, a transformation should be applied on the last BPF by scaling impedance values and introducing gyrators as described earlier. For this example, $n = 16$ in equations (4) and (5), and the electrical length of the gyrators is $\theta = 90°$ at the center frequency f_c.

Shunt stubs suitable for practical realization are obtained by using the transformation given in Figure 11 and equation (10).

Short-circuited transmission lines in series branches may be realized using short transmission lines with high characteristic impedance, $Z_{ch} = 150\ \Omega$, and electrical lengths given in Equation (11).

The final BPF structure with ideal transmission lines is shown in Figure 12. The element values are

$Z'_c = 12.5\ \Omega$, $Z_{ch} = 150\ \Omega$, $Z'_{c2} = 36.643781\ \Omega$,
$Z''_{c3} = 49.430588\ \Omega$, $Z''_{c4} = 59.790262\ \Omega$,
$Z'_{c6} = 38.70271\ \Omega$, $Z''_{c7} = 49.430495\ \Omega$,
$Z''_{c8} = 40.865742\ \Omega$, $Z'_{c10} = 38.70271\ \Omega$,
$\theta' = 90°$, $\theta_1 = 14.783386°$, $\theta_c = 45°$,
$\theta_5 = 14.783386°$, $\theta_9 = 13.996881°$

All electrical lengths are calculated at $f = f_c$.

The next step in the BPF design is the calculation of real printed circuit parameters with SSS and broadside coupled SSS (BCSSS) transmission lines. The chosen

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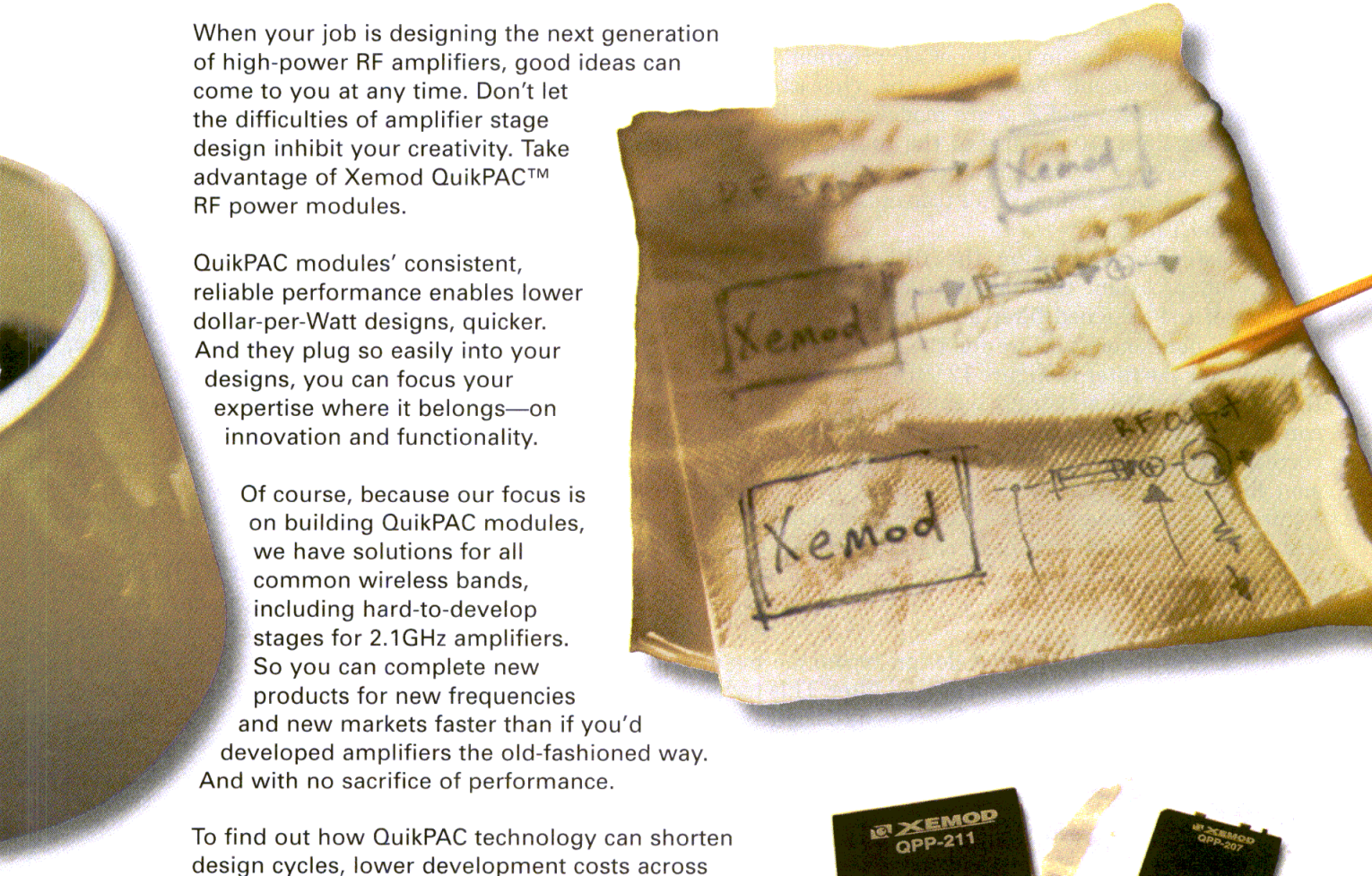

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	Z'_c θ	Z_{ch} θ_1	Z'_{c2} θ_c	Z''_{c3} θ_c	Z''_{c4} θ_c	Z_{ch} θ_5	Z'_{c6} θ_c	Z''_{c7} θ_c	Z''_{c8} θ_c	Z_{ch} θ_9	Z'_{c10} θ_c
w (mm)	27.11	0.58	3.087	5.39	4.09	0.58	5.706	5.39	6.99	0.58	8.889
l (mm)	14.51	2.15	4.542	6.97	6.91	2.15	3.355	6.97	7.01	2.03	2.361

▲ **Table 2. Physical dimensions of SSS and BCSSS transmission lines for BPF.**

substrate is Cu-Flon with relative dielectric constant ε_r = 2.1, substrate thickness h = 0.7874 mm, conductor thickness t = 0.0127 and upper and lower ground plane to substrate spacing $h_u = h_l$ = 1.7 mm. All transmission lines except Z'_{c2}, Z'_{c6}, and Z'_{c10} are synthesized by using SSS transmission lines in the LineCalc program. Open-circuited transmission lines with the characteristic impedances Z'_{c2}, Z'_{c6}, and Z'_{c10} are modeled with BCSSS transmission lines [10] by use of the tuning and optimization procedure in the Libra program. The calculated width and length values of all transmission lines are given in the Table 2.

The last step is drawing the BPF layout in the GasStation program. Calculated transmission characteristics of the designed filter are shown in Figure 14. The given characteristics are for the filter in Figure 8 (BPFIT), for the filter in Figure 12 (BPFITA) and for the filter in suspended substrate technology (BPFSSS). It can be seen that the designed filter in SSS technology corresponds very well to the filters with ideal transmission lines. The layout for designed filter is shown in Figure 15. The designed filter should be realized and tested very soon and measured characteristics will be given in a future article.

Conclusion

This article has presented A design technique for a physically realizable selective band-pass filter. This technique enables narrow-band SSS filters to be designed. In this article, transformations of BPFs have been given based on the insertion of ideal transformers and the use of Norton's equivalencies. The closed form of the optimal redundancy parameter t has been obtained. A few very efficient transformations and approximations convenient for the design of BPF with transmission lines have been given. The design procedure has introduced by one example of BPF designed in SSS and BCSSS technology. It is shown that a BPF can be designed very efficiently by using the presented technique. ■

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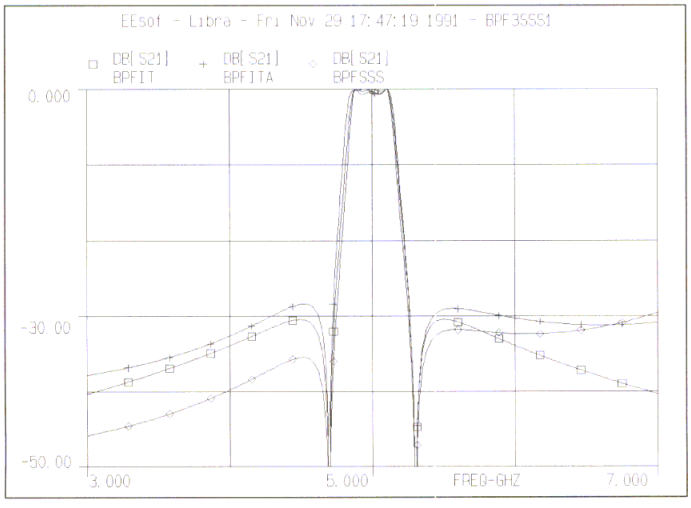
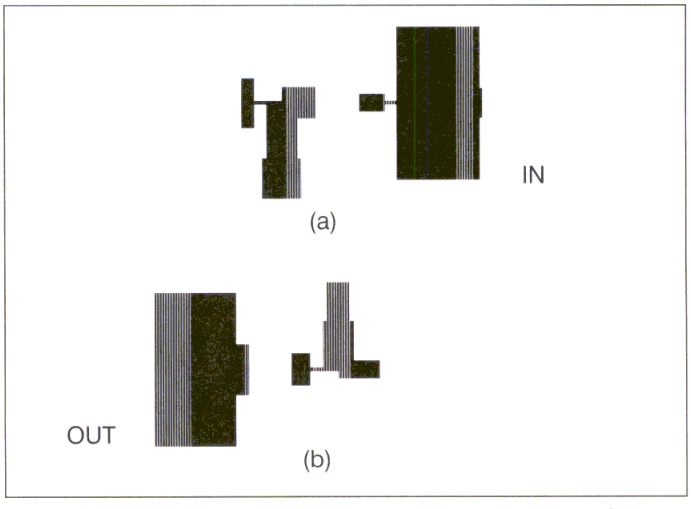


▲ **Figure 14. Transmission characteristics of the designed filters.**



▲ **Figure 15. BPF layout a) upper side and b) lower side.**

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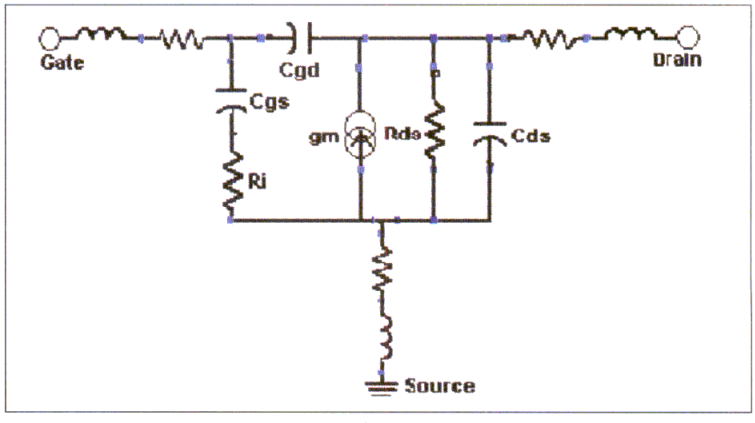
Techniques for Small-Signal Modeling

Designers should remember to include stability and maximum available gain in their models

By Christopher Giusto and Dr. Carl White
COMSARE, Morgan State University

In small signal modeling, the perennial wisdom is that if you can match the *S*-parameters, then you will have an excellent model. However, this is not always the case. The input and output reflection coefficients, along with the stability factor *K* and the maximum available gain, are also very important optimization goals for a model. These goals are rarely met for a typical small signal model.



▲ **Figure 1. Small-signal transistor equivalent circuit model.**

Matching the *S*-parameters from data can be accomplished through optimization of intrinsic and extrinsic elements. This created model may not be accurate; the maximum available gain and *K* may not meet with the data's characteristics. Therefore, watching these parameters allows for a more accurate model. Adding reflection coefficients, max gain and *K* as goals allows the model to be as precise as possible. In the past, a model would be generated without any knowledge of the reflection coefficients, maximum gain or *K* and sent on to a designer. Any credible designer would automatically label it as unreliable and not use it for designing.

Modeling procedure

From a modeler's standpoint, there is a fine line between a good model and an accurate one. Small-signal modeling starts by looking at the equivalent circuit (Figure 1). Starting with measured *S*-parameter data, the first step is to use parasitic values calculated by commercially available software, such as Agilent's ICCAP, for a test device. For this example, a PHEMT device was used at a drain voltage of 2.5 V and a gate voltage of –0.7 V.

Next, an in-house extraction program was used to generate starting values for the intrinsic elements:

g_m = 157.72 mS
Tau = 1.71 oms
R_i = 0.81 ohms
R_{ds} = 155.01 ohms
C_{ds} = 148.15 fF
C_{gd} = 49.59 fF
C_{gs} = 664.18 fF

Commercially available simulation software such as Agilent's Advanced Design System 1.1 is then used to optimize the model using *s*-parameters only, as the goals. The new intrinsic values are:

g_m = 155.2 mS
Tau = 0.8 ms

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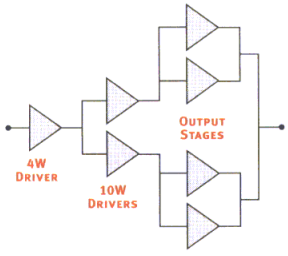

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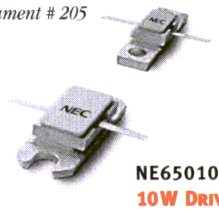

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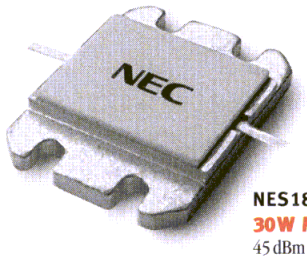

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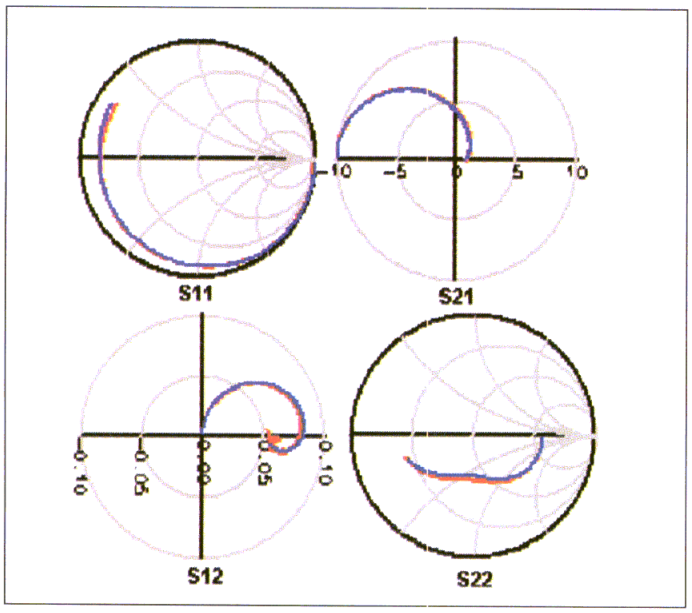


▲ **Figure 2. *S*-parameters, red = data, blue = model.**

R_i = 1.85 ohms
R_{ds} = 180.3 ohms
C_{ds} = 150.5 fF
C_{gd} = 62.0 fF
C_{gs} = 662.7 fF

Figure 2 shows that the *S*-parameters were matched very well, but Figure 3 shows that the reflection coefficients, max gain and *K* for this model are not as accurate. So by logical deduction the next process is to model these indicators as well as the *S*-parameters.

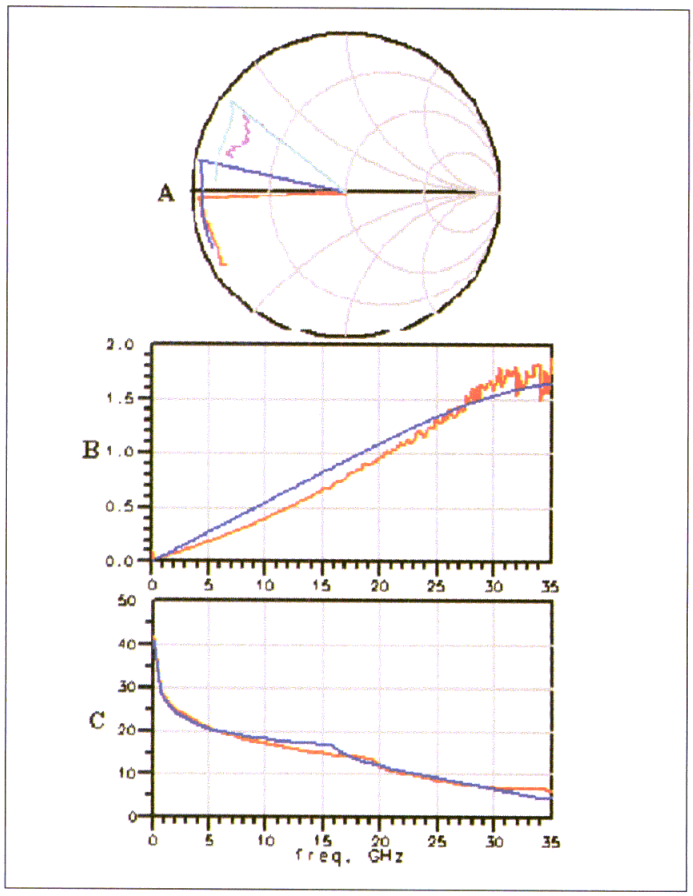
The new procedure is to add optimization goals for reflection coefficients, maximum available gain and stability factor *K*. The equation goals for ADS are:

Stability Factor, K
K_ratio = our_k/our_k2
(our_k = data's *K*, our_k2 = model's *K*)
with this ratio goal set to a magnitude of 1.

Maximum Available Gain
maxg_ratio = our_maxg/our_maxg2
(our_maxg = data, our_maxg2 = model)
with this ratio goal set to a magnitude of 1.

Input Reflection Coefficient
smg1_ratio = our_smg1/our_smg1_2
(smg1 = data's, smg1_2 = model's)
with two ratio goals, one for magnitude set to 1 and another for phase set to 0.

Output Reflection Coefficient
smg2_ratio = our_smg2/our_smg2_2
(smg2 = data's, smg2_2 = model's)



▲ **Figure 3. (A) Reflection coefficients, red = input for data, blue = input for model, pink = output for data, light blue = output for model. (B) Stability factor, *K*, red = data, blue = model. (C) Max available gain, red = data, blue = model.**

with two ratio goals, one for magnitude set to 1 and another for phase set to 0.

Now the small-signal modeling procedure is started all over again. Extracting the original data gives the same starting points for the intrinsic values, but now optimizing the *S*-parameters with the reflection coefficients, max gain and *K* as added goals. This gives the following value for the intrinsic elements:

g_m = 145.1 mS
Tau = 0.4 ms
R_i = 0.15 ohms
R_{ds} = 160.3 ohms
C_{ds} = 110.0 fF
C_{gd} = 54.0 fF
C_{gs} = 652.0 fF

Figure 4 show the new *S*-parameters and Figure 5 shows the matched coefficients, gain and *K*. As displayed, it takes only slight adjustments of the elements to match our goals.

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ERA-2SM	DC-6000	15.2	12.4	4.6	26.0	40	2.00
ERA-3	DC-3000	20.8	12.1	3.8	23.0	35	2.10
ERA-3SM	DC-3000	20.2	11.5	3.8	23.0	35	2.15
ERA-4	DC-4000	13.5	▲17.0	5.5	▲32.5	65	4.15
ERA-4SM	DC-4000	13.5	▲16.8	5.2	▲33.0	65	4.20
ERA-5	DC-4000	18.8	▲18.4	4.5	▲33.0	65	4.15
ERA-5SM	DC-4000	18.5	▲18.4	4.3	▲32.5	65	4.20
ERA-6	DC-4000	11.3	▲18.5	8.4	▲36.5	70	4.15
ERA-6SM	DC-4000	11.3	▲17.9	8.4	▲36.0	70	4.20

Note: Specs typical at 2GHz, 25°C. Exception: ▲ indicates typ. numbers tested at 1GHz.
* Low frequency cutoff determined by external coupling capacitors.
① Price (ea.) Qty.1000: ERA-1 $1.19, -2 $1.33, -3 $1.48, -4, -5 or -6 $2.95. SM option same price.

DESIGNER'S AMPLIFIER KITS:
K1-ERA: 10 of each ERA-1,-2,-3 (30 pieces) only $49.95
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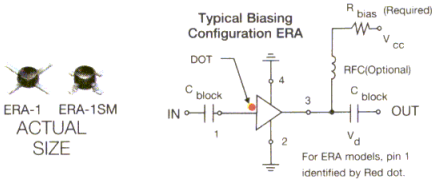
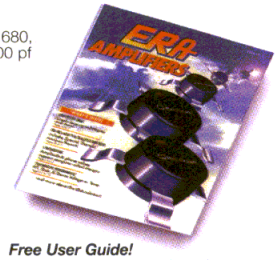
K2-ERASM: 10 each ERA-4SM,-5SM (20 pieces) only $69.95
K3-ERASM: 10 each ERA-4SM,-5SM,-6SM (30 pieces) only $99.95

Chip Coupling Capacitors at 12¢ each (50 min.)

Size (mils)	Value
80x50	10, 22, 47, 68, 100, 220, 470, 680, 1000, 2200, 4700, 6800, 10,000 pf
120x60	.002, .047, .068, .1 µf



ERA-1 ERA-1SM
ACTUAL SIZE



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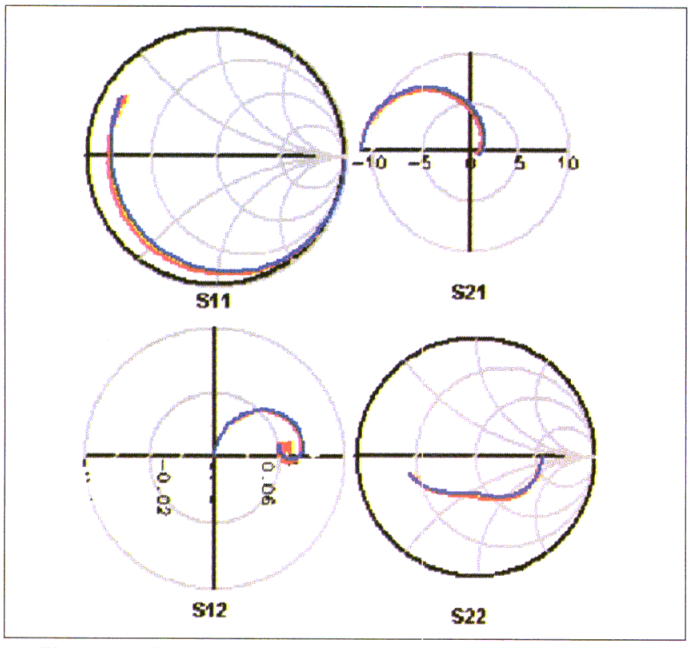
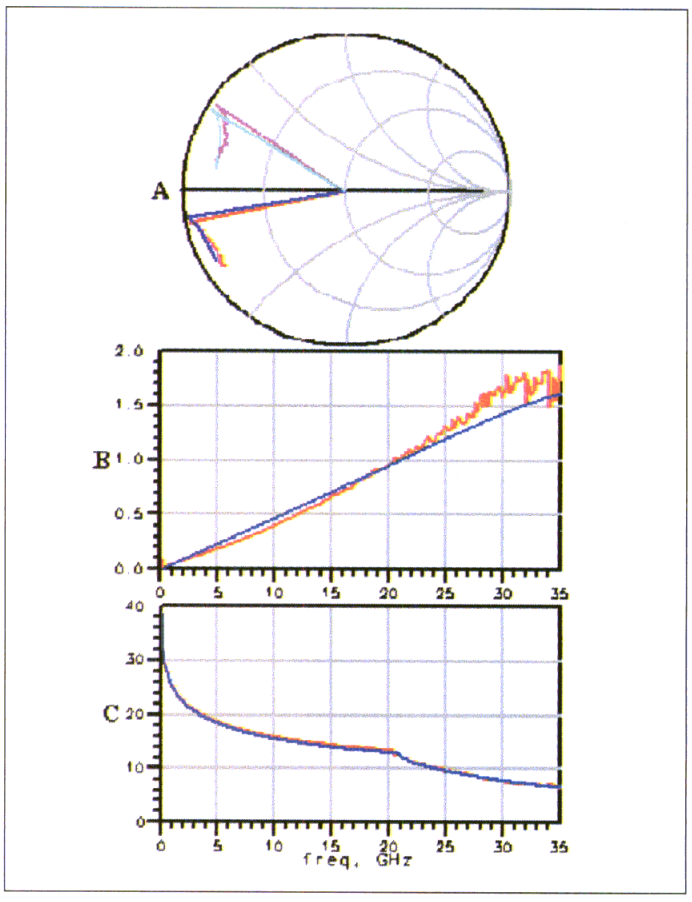


▲ **Figure 4. *S*-parameters, red = data, blue = model.**



▲ **Figure 5. (A) Reflection coefficients, red = input for data, blue = input for model, pink = output for data, light blue = output for model. (B) Stability factor, *K*, red = data, blue = model. (C) Max available gain, red = data, blue = model.**

Application example

A good example to illustrate the importance of reflection coefficients is the design of a simultaneously conjugent match amplifier. The process in designing this type of amplifier starts by taking the device data or model and matching the input and output reflection coefficients. If the designer uses a model that has not properly matched the reflection coefficients, then their amplifier when simulated, will not attain the maximum gain and in production will be an inferior device.

In the case of a matched amplifier the model's reflection coefficients are the most important characteristics. Without this parameter, a designer will have no need for a small signal model; all the elements will have a higher degree of inaccuracy.

Conclusion

In short, small signal modeling has been a somewhat inaccurate field of study from the point of view of a designer. However, this paper hopes to show new techniques that will add the proper indicators and optimization goals to the modeling procedures to give the most accurate and credible model possible. ■

Note

All graphs and optimizations were computed and produced by Agilent's Advanced Design System 1.1 with support from Agilent's ICCAP 5.0.

References

1. G. Gonzalez, *Microwave Transistor Amplifiers*, 2nd edition, Prentice Hall, 1997.

2. G. Dambrine, A. Cappy, F. Heliodore, E. Playez, "A New Method for Determining the FET Small-Signal Equivalent Circuit," *IEEE Trans. Microwave Theory Tech.*, Vol. 36, July 1988.

Author information

This research was completed by COMSARE, the Center of Microwave/Satellite and RF Engineering, at Morgan State University in Baltimore, MD. Participating in the research were John Brice, Christopher Giusto, Clifton Martin, Jerhome Petway and Ammyanna Williams. This undergraduate unit is under the leadership of Dr. Carl White and Willie Thompson, along with the rest of the COMSARE team. More information on COMSARE is available on its Web site, http://www.eng.morgan.edu/~comsare.

Christopher Giusto is a senior EE student at Morgan State University, with an interest in FET and HEMT modeling and characterizing. He may be reached at cgiusto@eng.morgan.edu

Dr. Carl White is an Associate Professor at Morgan State University and the founder of COMSARE. Dr. White may be reached at white@eng.morgan.edu.

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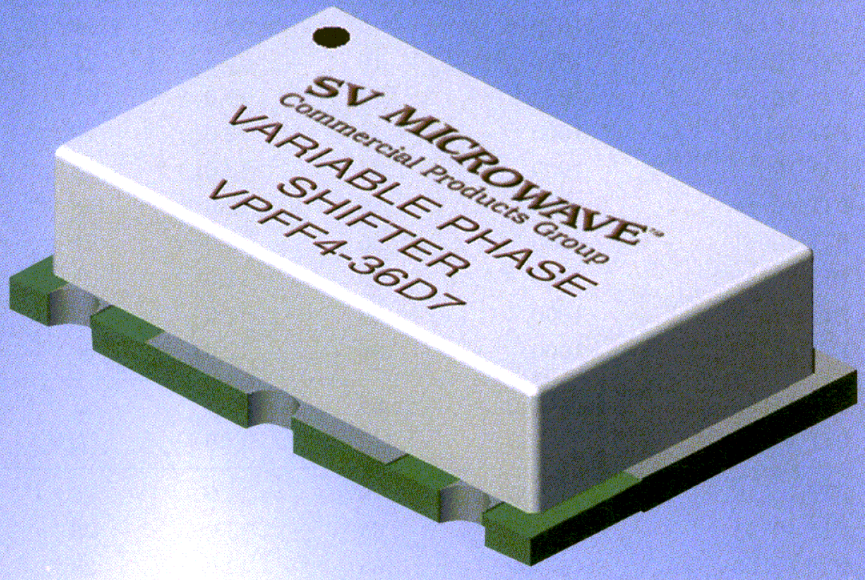
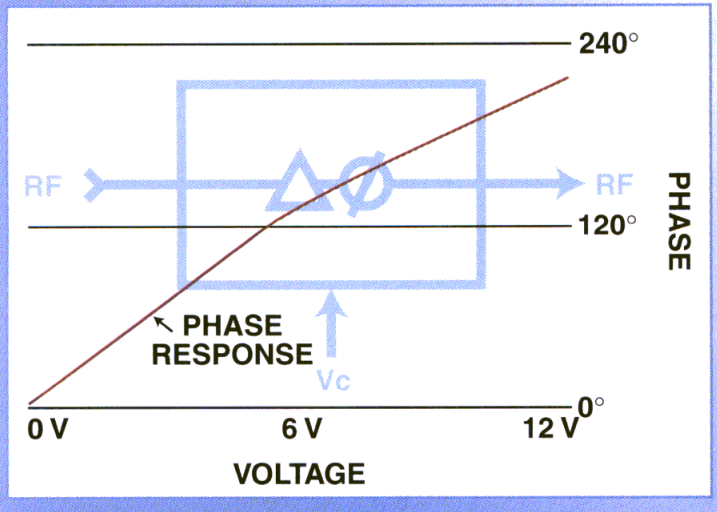


Designs for PCS/GSM/DCS/W-CDMA/WLL



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Circle 27

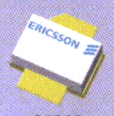
Ericsson Delivers GOLDMOS™ FETs

Product Number	Frequency Mhz	P_{OUT} Watts	Gain dB	Supply Voltage	Package Number	Internal Matching
To 1.0 GHz — GOLDMOS FET						
PTF 10136	1000	6	18.0	28	20244	N
PTF 10147	1000	10	15.0	26	20244	N
PTF 10137	1000	12	13.0	28	20244	N
PTF 10007	1000	35	12.0	28	20222	N
PTF 10052	1000	35	12.0	28	20235	N
PTF 10015	1000	50	12.0	28	20235	N
PTF 10031	1000	50	12.0	28	20222	N
PTF 10139*	1000	60	12.0	28	20235	N
PTF 10138*	1000	60	12.0	28	20222	N
PTF 10009	1000	85	12.0	28	20230	N
PTF 10049	470–860	85	12.0	32	20240	I
PTF 10159	470–860	120	12.0	32/28	20240	I
PTF 10019	860–900	70	13.0	28	20237	I
PTF 10133	860–900	85	13.0	28	20237	I
PTF 10100	860–900	165	12.0	28	20250	I
PTF 10162	860–960	18	14.0	26	20222	N
PTF 10036	860–960	85	11.0	28	20240	I
PTF 10160*	860–960	85	15.0	26	20248	I/O
PTF 10020	860–960	125	11.0	28	20240	I
PTF 10149	921–960	70	15.0	26	20252	I
1.0–2.2 GHz — GOLDMOS FET						
PTF 10111	1500	6	15.0	28	20222	N
PTF 10107	2000	5	11.0	26	20244	N
PTF 10135	2000	5	11.0	26	20249	N
PTF 10041*	2000	12	10.0	26	20249	N
PTF 10053	2000	12	10.0	26	20244	N
PTF 10021	1400–1600	30	11.0	28	20237	I/O
PTF 10125	1400–1600	135	11.5	28	20250	I/O
PTF 10045	1600–1650	30	10.0	28	20222	N
PTF 10112	1800–2000	60	11.0	28	20248	I/O
PTF 10153*	1800–2000	60	12.5	28	20248	I/O
PTF 10120	1800–2000	120	10.0	28	20250	I/O
PTF 10043	1900–2000	12	11.0	26	20222	I
PTF 10035	1900–2000	30	11.0	28	20237	I/O
PTF 10123*	2100–2200	5	11.0	28	20244	N
PTF 10119	2100–2200	12	10.0	28	20222	I
PTF 10048	2100–2200	30	10.0	28	20237	I/O
PTF 10122	2100–2200	50	10.0	28	20248	I/O
PTF 10134*	2100–2200	100	10.0	28	20250	I/O

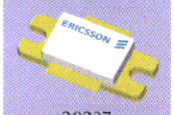
Packages are not to scale.

20222

20230



20235



20237

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20248

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20250

20252

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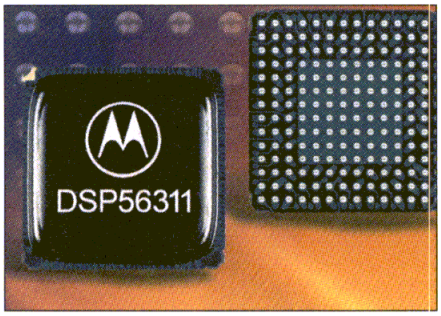
Circle 47

ERICSSON

DSP PRODUCTS

150 MHz DSP includes 3 Mb of on-chip RAM

Motorola has announced volume production of its DSP56311, with 3 Mb of on-chip static RAM and a 150 MHz on-chip Enhanced Filter Co-



processor (EFCOP). EFCOP can perform echo cancellation while the core processor performs compression or other signal processing functions, increasing the effective MIPS from 150 to 270 in some applications. The DSP56311 uses the company's HIP4 0.18 micron process for high performance and modest power consumption. Code and footprint of the device are compatible with previous generation DSP products in the 56300 family. In quantities of 50,000, the DSP56311 is priced at $36 each. Evaluation boards and development tools are also available.

Motorola
Circle #157

DSP-based paging infrastructure transmitter

Sonik Technologies Corporation has introduced the PTX-150, using DSP technology in a VHF transmit-

ter for high speed FLEX and simulcast operation. The transmitter is designed to generate all modern paging formats, including POCSAG, FLEX and ERMES. Standard power output is 100 watts continuous. Optional amplifiers can provide 250 or 500 watts output. Up to 16 channels can be preset for multichannel operation over the 138 to 174 MHz frequency range. For simulcast operation, the internal ±1 ppm TCXO can be locked to an external reference. Precision control over carrier offset and delay equalization is provided. A separate data port provides access to diagnostics and controllers.

Sonik Technologies Corporation
Circle #158

DSP development tools get C++ support

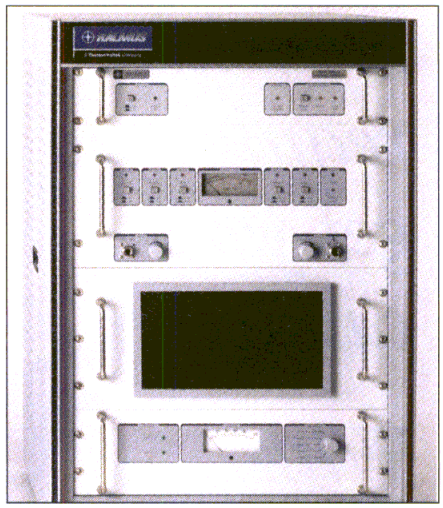
Analog Devices has added C++ language support to its VisualDSP® integrated development environment for programming DSP systems. Support of this widely-used programming language enables more programmers to take advantage of real-time processing using DSPs. VisualDSP provides support for ADI's product families, including SHARC®, TigerSHARC™, ADSP-182x and ADSP-219x DSPs. The first version, available now, is used with the ADSP-2106x/2106x SHARC DSP family.

Analog Devices, Inc.
Circle #159

AMPLIFIERS

Wideband amplifiers power immunity testing

Kalmus, a Division of Thermo Voltek, has added two new models to its 7000 series. The 7200LC (200 watts linear) and 7400LC (400 watts linear) each cover the frequency range of 20 to 1000 MHz in a single band. This power level and coverage is well suited for a variety of broadband applications, including radiated RF immunity testing. The amplifiers are class A linear, designed to be driven from 0 dBm sources. They feature low harmonics and spurious outputs, infinite VSWR tolerance and remote con-

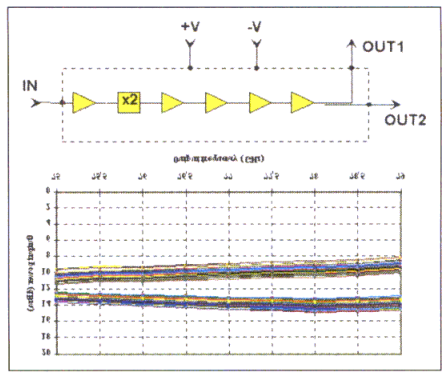


trol via an optional RS-232 interface. Indicators and controls can be set or monitored manually or remotely. The 7000 series amplifiers are all specified by linear power (1 dB compression point), avoiding confusion caused by less precise specifications.

Kalmus, Division of Thermo Voltek
Circle #160

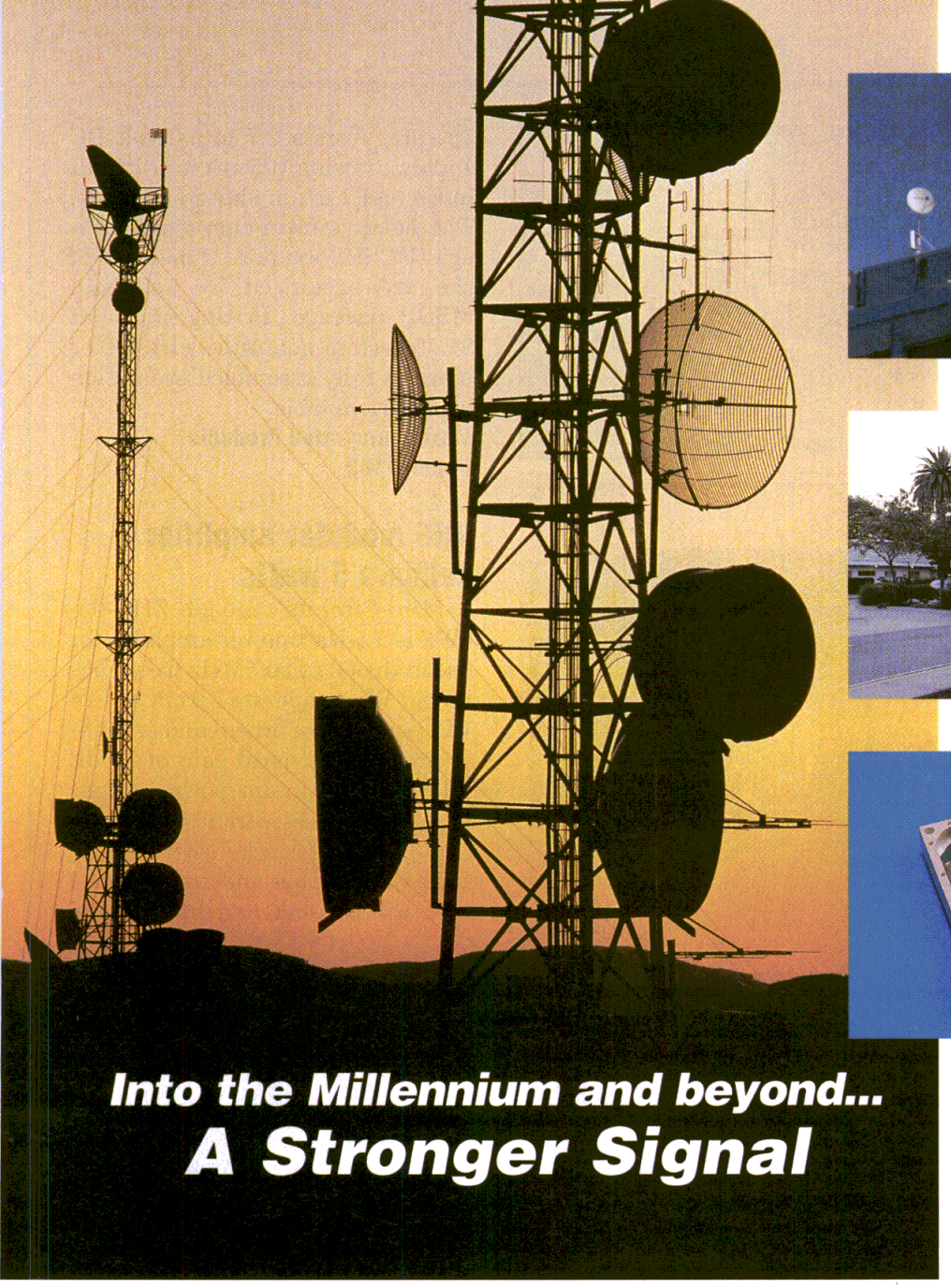
Multiplier and amplifier provide W-band output

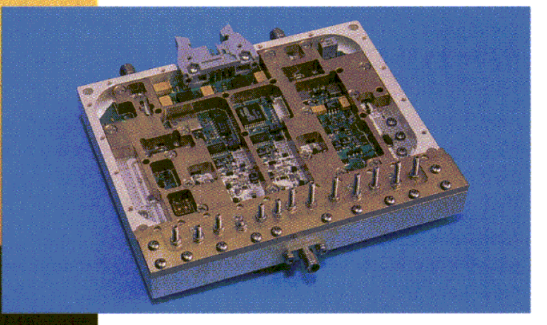
United Monolithic Semiconductors (UMS) introduces the CHU2277, a P-HEMT MMIC that



includes a frequency doubler and medium power amplifier. The CHU2277 is designed for an input of 37.5 to 40 GHz, providing two outputs at twice that frequency (e.g. 77 GHz), one at 13 dBm for the transmit chain and another at 9 dBm for the receive mixer.

United Monolithic Semiconductors
Circle #161





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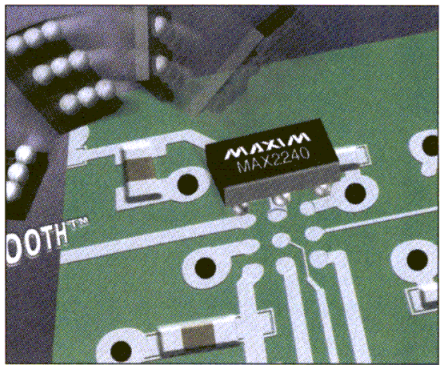
Circle 28

PA provides +20 dBm for Bluetooth radios

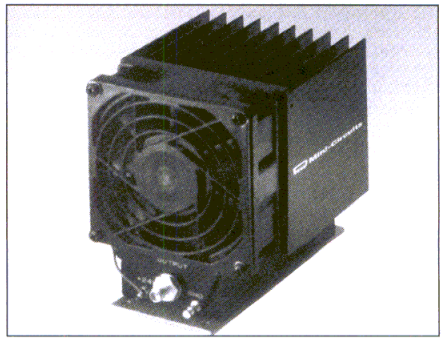
Maxim Integrated Products offers the MAX2240, which provides power amplification controllable from less than +4 dBm to +20 dBm for Bluetooth, IEEE 802.11, HomeRF and other 2.4 GHz radio applications. Integrated 50 ohm output matching reduces external parts requirements. The MAX2240 operates from a 2.7 to 5.0 volt DC supply, drawing 105 mA in transmit mode and 1 μA in shutdown mode. The device's ultra-chip-scale package (UCSP) occupies 16 percent of the area required by an 8-pin MSOP package. Pricing starts at $1.75 each in quantities of 1,000 or more. A fully assembled evaluation board is available.



Maxim Integrated Products
Circle #162

VHF modular amplifier delivers 5 watts

Mini-Circuits' model ZHL-03-5WF is a 5-watt power amplifier for use in the 60 to 300 MHz frequency range. When operated from a +24 VDC supply, the broadband amplifier provides a typical gain of 35 dB ±1.0 dB, maximum power output of +36 dBm (P_{1dB}) and +47 dBm IP_3. The units can be used with up to 28 volt supplies and are equipped with a heat sink and built-in fan with thermal shutoff. In small quantities (1 to 9 units) the ZFL-03-5WF is priced at $495 each.



Mini-Circuits
Circle #163

InGaP HBT module covers 1920 to 1980 MHz

Celeritek announces the CHP2230-PM, a linear efficient 3-stage power amplifier, covering 1920 to 1980 MHz and designed for the requirements of 3G WCDMA handsets and infrastructure equipment. It offers 30 percent linear power added efficiency at 28 dBm output, under 3X WCDMA modulation. The amplifier operates from

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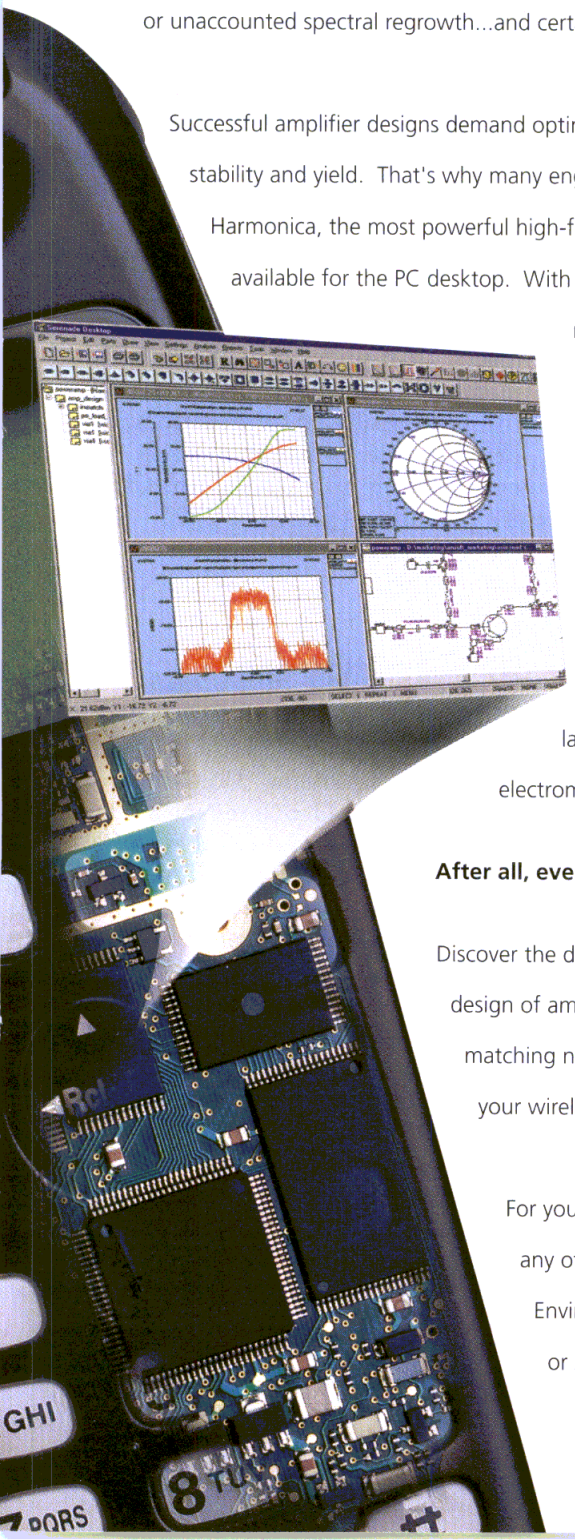

Successful amplifier designs demand optimal ACPR, power, IP3, nonlinear stability and yield. That's why many engineers are turning to Harmonica, the most powerful high-frequency circuit design solution available for the PC desktop. With physics-based distributed models and a time-tested Harmonic Balance engine, Harmonica delivers superior speed, accuracy, power and functionality. And as a part of Ansoft's Serenade Design Environment, Harmonica offers seamless links to layout, system simulation, electromagnetics, and third-party tools.

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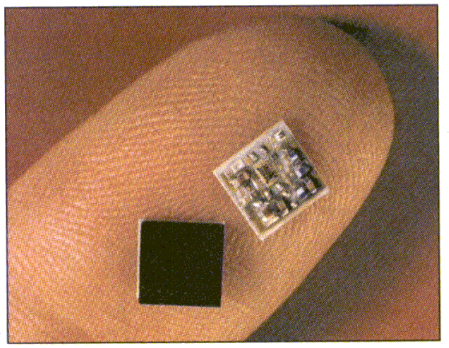
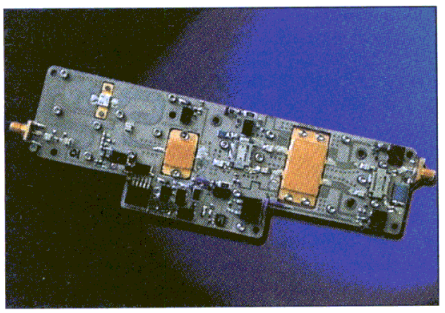


rated operating power output. The CHP2230-PM has a 6 mm square by 1.7 mm high package. Pricing is as low as $7.10 each in volume quantities.

Celeritek, Inc.
Circle #164

S-band amplifier delivers +49 dBm output

Aethercomm introduces the SSPA2.2-2.6-80, a high power solid state amplifier for commercial or military systems. The amplifier covers the 2.2 to 2.6 GHz frequency



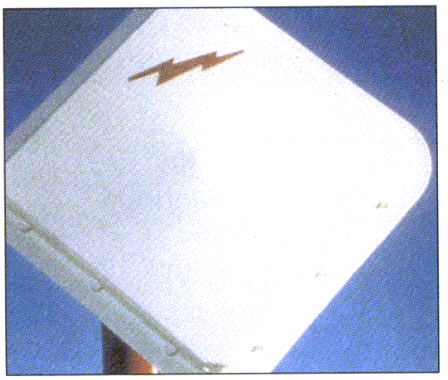
range with greater than 30 dB gain and a rated power output (P_{1dB}) of +49 dBm with power added efficiency of 35 percent (typical). The noise figure is less than 6 dB and input/output VSWR is better than 2.0:1. The amplifier operates from a 12 VDC supply.

Aethercomm, Inc.
Circle #165

ANTENNAS

23 GHz flat plate antenna

Andrew Corporation has announced the 0.3 meter 23 GHz ValuLine® flat plate antenna. The antenna gives wireless operators a new option for low visibility antennas in short haul point-to-point communications. Pattern performance matches that of shielded

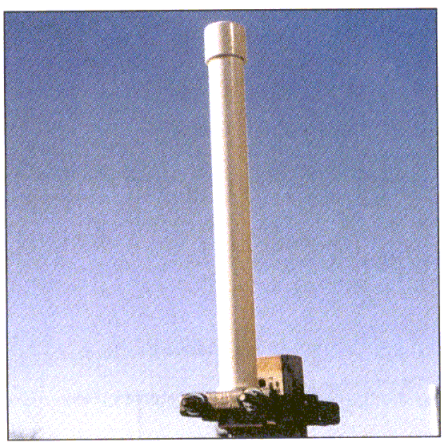


antennas, but in a package less that 46 mm deep. The ValuLine antenna weighs less than 33.6 kg and has a quick and easy mounting system with adjustment in both the azimuth and elevation planes.

Andrew Corporation
Circle #166

Omnidirectional antennas for 1.9 and 2.4 GHz

SuperPass offers new omnidirectional antennas for 2.4 GHz WLAN



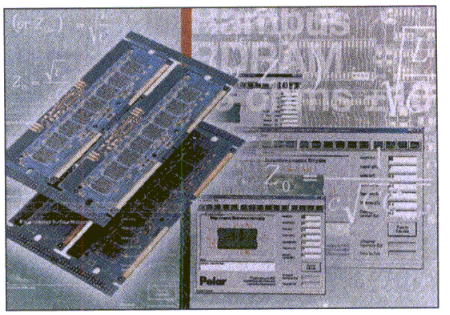
and 1.9 GHz PCS applications. The antennas are available with 2, 4.5, 5.5, 6.5 and 7.5 dBi gain and feature VSWR <1.5:1. They are supplied with SMA, TNC or type N connectors and may be customized for reverse polarized connectors. A UV protection radome permits indoor or outdoor installation.

SuperPass Company Inc.
Circle #167

SOFTWARE

Impedance calculator helps design PCBs

The CITS 25 field-solving Controlled Impedance Calculator from Polar Instruments has been



upgraded to include impedance calculation equations for coated, embedded, offset and other coplanar structures. High performance PCBs require controlled impedance traces to support high bandwidth memory. Fourteen coplanar structures are included, with automatic prediction of propagation delay for optimization of trace length. CITS 25 Version 2 is priced at £495.

Polar Instruments Ltd.
Circle #168

RF simulation and modeling tools

Xpedion Design Systems offers two EDA products, GoldenGate/SIM™ and GoldenGate/NN Model Compiler. GoldenGate SIM is an RF and subsystem simulation and analysis tool that offers linear RF, harmonic balance and envelope circuit simulation tools with unique stability and phase noise analysis capabilities. GoldenGate/NN Model Compiler is a behavioral modeling tool using a patent-pending neural network technique to accelerate runtimes. GoldenGate/SIM is priced at $55,000 list for Unix platforms, or $10,000 to $40,000 for Windows™ systems. GoldenGate/NN-Model Compiler is $75,000 for either UNIX or PC.

Xpedion Systems
Circle #169

NEW PRODUCTS

NO. 70

RF/IF MICROWAVE COMPONENTS

FROM $4.45

2 TO 500MHz RF TRANSFORMER HAS 3:1 IMPEDANCE

Mini-Circuits has unveiled the TCM3-1T, a 2 to 500MHz broad band surface mount RF transformer operating with a 3:1 impedance ratio. Referenced to midband loss (0.5dB typ), insertion loss is 1dB from 5MHz to 300MHz, and 2dB band wide. Maximum operating temperature is -20°C to +85°C. Open case design has plastic base with solder plated leads, and applications include impedance matching. RF power is 250mW (max.).

FROM $82.95

2.5 TO 6000MHz BIAS TEE HAS BROADBAND COVERAGE

Mini-Circuits has developed the ZNBT-60-1W, a new broadband bias tee for 2.5MHz to 6000MHz. Ruggedly constructed with Male-N and Female-N connectors standard, these high power 1W RF (0.5A dc current), low cost units typically provide low 0.6dB insertion loss and good 1.10:1 VSWR. Applications include biasing of laser diodes and active antennas, biasing amplifiers, and test accessory. Maximum operating temperature is -55°C to +100°C.

FEATURED PRODUCT

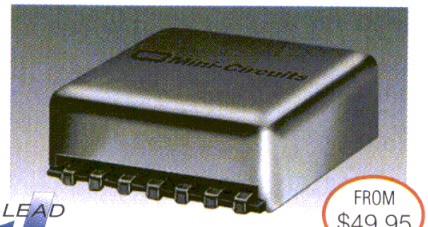
FROM $4.25

LEVEL 7 MIXER FOR CELLULAR AND VHF/UHF RECEIVERS

it™ Mini-Circuits has added a 200 to 1000MHz mixer to their low cost, low profile family of patent pending "Innovative Technology" surface mount mixers. The ADE-4 typically features low 6.8dB conversion loss, good 53dB L-R, 40dB L-I isolation, and 15dBm IP3 at center band. The ultra-low profile 0.112" package is equipped with solder plated leads for excellent solderability. A 5 year Ultra-Rel® guarantee is included.

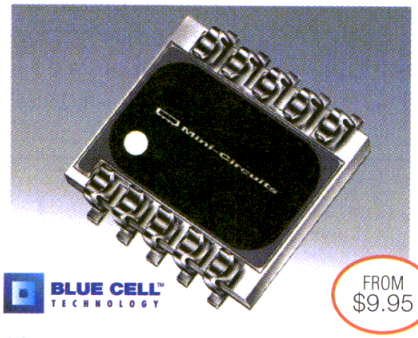
VHF VCO PERFORMS WITH LOW NOISE

This 125 to 175MHz JCOS-175LN voltage controlled oscillator from Mini-Circuits features low -158dBc/Hz phase noise at 1MHz offset, flat 3-5MHz/V typical tuning sensitivity, and operates from a 12V power supply (20mA max. current). The VCO is designed for 50 ohm VHF-TV applications requiring 1 to 17V (min. to max.) tuning voltage and 3.7dBm typical power output. Typical 3dB modulation bandwidth is 2900kHz. Available from stock.



J-LEAD

FROM $49.95

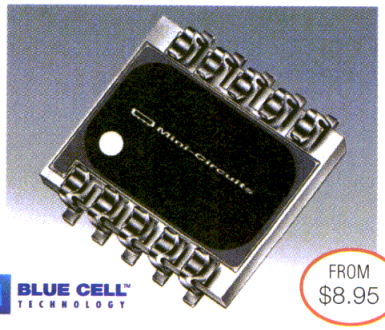


BLUE CELL™ TECHNOLOGY

FROM $9.95

800 TO 2500MHz MIXER HAS REPEATABLE PERFORMANCE

Mini-Circuits patented family of MBA model Blue Cell™ mixers deliver a unique combination of low conversion loss, superb temperature stability, thin 0.07" profile, and low cost. This level 17 (LO) MBA-12H model for 800MHz to 2500MHz operates with 30dB L-R, 13dB L-I isolation and low 6.8dB midband conversion loss (all typ). Wide ranging applications include satellite, ISM, PCMCIA, WLAN, PCN/PCS wideband LDMA, and cellular. Operating temperature is -40°C to +85°C.



BLUE CELL™ TECHNOLOGY

FROM $8.95

1.8 TO 2.2GHz 2WAY SPLITTER IS FEATURE RICH

Outstanding characteristics of Mini-Circuits patented 2way-0° SBA-2-2 Blue Cell™ power splitter/combiner includes superb temperature stability within the 1800 to 2200MHz band, low 0.07" height, ceramic multi-layer design, high repeatability, and low cost. Electrically, these 50 ohm units display low 0.5dB typical insertion loss and excellent 0.7dB amplitude, 7 degrees phase unbalance (max.). Typical isolation is 22dB. Applications include PCS.

Mini-Circuits®

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE

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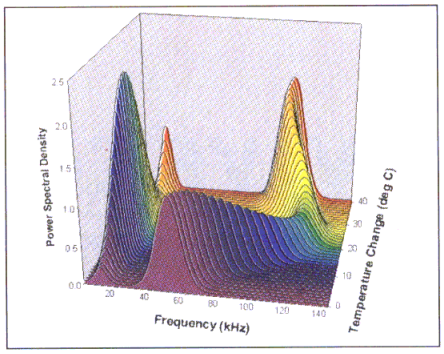
The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: **http://www.minicircuits.com**

ISO 9001 CERTIFIED

Plotting and graphing software for data analysis

SPSS Inc. now offers SigmaPlot 2000, graphing software for precise, high-quality graphs for analysis and presentation. New graph types cover a wide range of error analysis, including asymmetric error bars, range plots, quartile plots and high-low-close plots. Mathematical



data transformations are supported without programming, and a Function Plotter handles user-defined and parameterized equations. SigmaPlot 2000 runs under Windows™ 95, 98, 2000 or NT and is compatible with major word processing and presentation software, including HTML output. The software is priced at $599.

SPSS Inc.
Circle #170

EMI measurement program

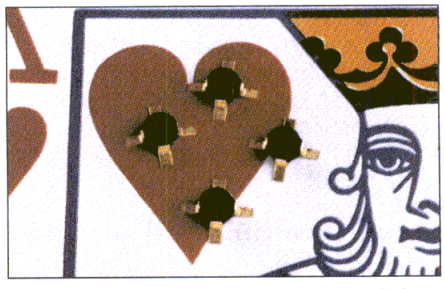
Version 2.5 of the EMI Commercial Measurement Program, EMICMP, for the Anritsu MS2601B spectrum analyzer includes both conducted measurements from 9 kHZ to 30 MHz and E-field measurements from 30 MHz to 2 GHz. EMICMP can measure trace data as well as individual signal data. Amplitude accuracy is enhanced beyond the spectrum analyzer's specifications. A Dual Site option facilitates measurements in the presence of ambient signals. Pricing is $750 for the E field Ex field module, $500 for H field, $600 for conducted FCC and VDE measurements and $300 for the analysis package.

EMC Consulting
Circle #171

SEMICONDUCTORS

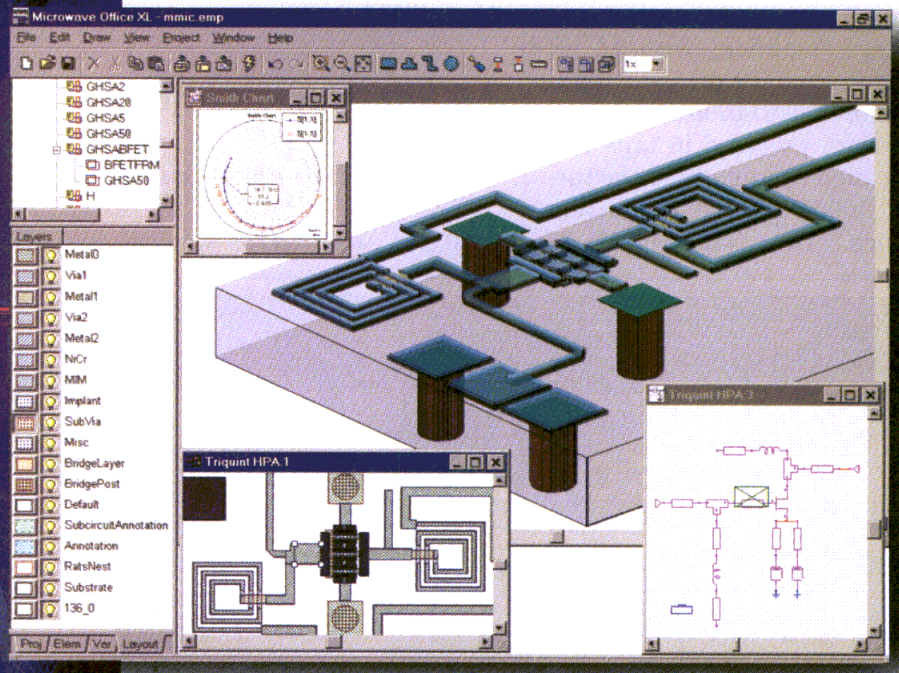
Low noise HJ FETs

California Eastern Laboratories announces availability of two heterojunction FETs from NEC,



designed for low noise amplifier stages in DBS receivers and other X- and Ku-band receiver designs. With a noise figure of 0.35 dB at 12

Microwave Office™ 2000



The World of RF & Microwave Design has Changed Forever!

Microwave Office 2000 is the revolutionary high-frequency design solution that is changing all the rules! This award winning design suite now includes the ultimate microwave layout solution, statistical design capabilities, yield optimization, MMIC foundry library support, plus new EM based discontinuity models for incredibly accurate simulations up to millimeterwave frequencies and beyond. New schematic data translators will import Agilent EEsof Series IV or ADS designs directly into Microwave Office. Finally you can say good bye to the expensive and cumbersome solutions of the past. For more information call your AWR sales representative!

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AWR

Applied Wave Research, Inc.
1960 E. Grand Avenue, Suite 530, El Segundo, CA 90245
Tel: (310) 726-3000 Fax: (310) 726-3005

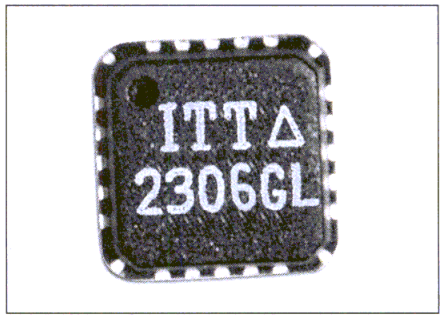
Circle 66

GHz, the NE3210S01 is a high performance first stage LNA with 13.5 dB gain. The NE4210S01 is a complementary choice for second and third stage amplifiers, with 0.5 dB noise figure and 13 dB gain. Both devices are housed in low cost plastic packages, provided in tape and reel for high volume manufacturing. In 100,000 piece production quantities, the NE3210S01 is priced at $0.75 each and the NE4210S01 is $0.71 each.

California Eastern Laboratories
Circle #172

2.4 GHz integrated RF front end

GaAsTEK has introduced the ITT2306GL integrated RF front end for 2.4 GHz applications including Bluetooth and HomeRF. The device includes a power amplifier, low noise amplifier and switch in one surface mount package. It



connects directly to popular single chip transceivers. The ITT2306GL features a single positive supply, 3.3 VDC operation and 100 percent duty cycle. It is provided in a 4 × 4 mm micro-leadframe package.

GaAsTEK
Circle #173

EL driver IC controls RF interference

Toko's TK659xx series of regulated electroluminescent lamp drivers is optimized to reduce RF and audio harmonic interference that can cause serious design problems in wireless phones, GPS receivers, PDAs and other portable devices.

The H-bridge output controls the charging and discharging of the EL lamp panel using a patented sequence control. Current limiting protects the system from large current spikes that can inject interference into nearby components. Three models cover drive requirements for panels of 1 to 2, 2 to 4, or 3 to 6 square inches. Pricing of al three starts at $1.99 each in 1,300-piece reels.

Toko America, Inc.
Circle #174

Teradyne helps STMicroelectronics connect our wireless world.

As a top worldwide wireless semiconductor manufacturer, STMicroelectronics develops leading edge technology that keeps up with the pace of the world, while still meeting demands for high-volume worldwide production of complex wireless devices. And that's exactly why STMicroelectronics relies on Teradyne's A5 Mixed-Signal Microwave™ Test Systems.

"The A585 microwave test systems are the only ATE that meet our stringent testing requirements for mixed-signal, RF/microwave devices with very fast rampup." – Marie-Hélène Sibille, General Manager, DPG ANACA Division.

Teradyne's microwave systems provide the flexibility and varied system options needed for high frequency testing at volume production of a broad range of cellular and other wireless devices. And, unlike focused RF/test systems, the A5 series and Catalyst are configurable with a full range of digital and analog capabilities – supporting the trend towards wireless systems-on-a-chip.

left to right: Gianmarco Riva, Marie-Hélène Sibille, Roberto Toscani

"Teradyne's ability to provide the best test solutions for our RF/microwave needs on a consistent basis at all our worldwide production sites, has been key to our success in this field." – Roberto Toscani, DPG Operations Central Engineering Director.

As an ATE supplier, Teradyne delivers the technology road map that matches STMicroelectronics' goals. That's done by forming a partnership reinforced by strong global support.

"In today's complex manufacturing environment, where time-to-market and cost-of-test are primary concerns, a close relationship with an expert ATE supplier is especially important for characterizing and testing RF/microwave devices." – Gianmarco Riva, DPG General Manager Operations.

To learn more about Teradyne's wireless test solutions, visit us at www.teradyne.com/icd or call Beth Sulak at 617-422-2746.

TERADYNE

Circle 18

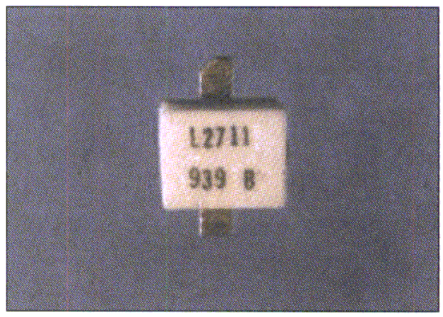
Reference design kit for wireless products

RF Micro Devices has announced the release of a reference design kit for remote keyless entry, wireless security systems and remote control. The kit is based on the RF2516 transmitter and RF2919 receiver and includes a rolling code encoder and decoder, printed antenna, LED indicators, activation pushbuttons buzzer indicator and battery. The kit is available for either 315 MHz or 433 MHz. The transmitter has been tested and found to be compliant with applicable FCC regulations at 315 MHz. Complete documentation is included with the kit, and is also available on the company's Web site.

RF Micro Devices
Circle #175

Low voltage LDMOS FET

Polyfet RF Devices has announced the development of a low voltage LDMOS FET, operating from a 7.5 volt supply and providing 6 watts power output and 10 dB gain at 500 MHz. The device is not internally matched and can be used down to DC. It is designed for both narrowband and wideband voice and data communications.



Polyfet RF Devices
Circle #176

Single-chip zero-IF ISM band transceiver

The NT2903 Chip-Ceiver™ from NUMA Technologies is a single-chip, FM/FSK transceiver using a direct-conversion zero-IF technique. The device offers full duplex operation in any 26 MHz band from 400 to 1000 MHz. Integrated on-chip are dual phase-locked loops, reference oscillator, quadrature mixer, baseband filters, AGC and a "tankless" discriminator. The modulator can accept either analog or digital signals. Pricing is $4.63 each in quantities of 100,000.

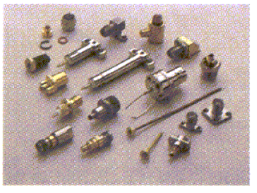
NUMA Technologies Inc.
Circle #177

THERE ARE TWO KINDS OF MICROWAVE AND RF CONNECTORS OUT THERE.

THEIRS.

OURS.

The cookie-cutter approach to engineering just doesn't cut it. We never took it with our founding military defense clients, and we don't take it with our wireless and telecomm customers. In fact, every connector, every cable assembly, has to be designed and built as if the entire system depended on it. That's the Dynawave way.



A team approach.

Balancing reliability with performance and cost is what our design engineers do best. They work with you, at no charge, to deliver CAD, CAD-CAM, fast-turn prototypes and complete documentation packages for solutions to your design challenges. And they will personally work with you for the life of your product.

High quality manufacturing.

Dynawave has been a leader in the design and manufacture of cost-effective RF and microwave cable assemblies, delay lines, harnesses, and connectors for over 15 years. All of our products undergo 100% functional performance verification. Data collection and product traceability are available to support your needs.

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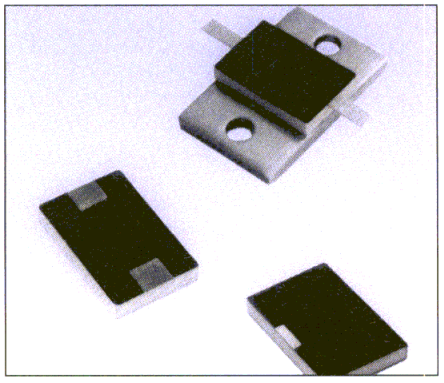
Circle 23

PASSIVE COMPONENTS

Resistive terminations and attenuators

BCP offers a line of attenuators and terminations manufactured with T^2 copper technology for increased temperature capabilities and greater tensile strength.

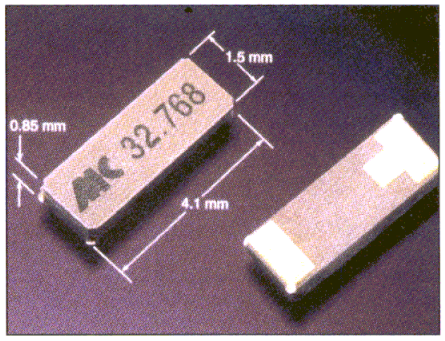


Copper thick film is directly bonded to thick film resistive materials for higher performance than conventional soldered connections.

BCP (Bird Component Products)
Circle #178

Miniature SMD crystal

Micro Crystal announces the CC5 series crystal, offered in a



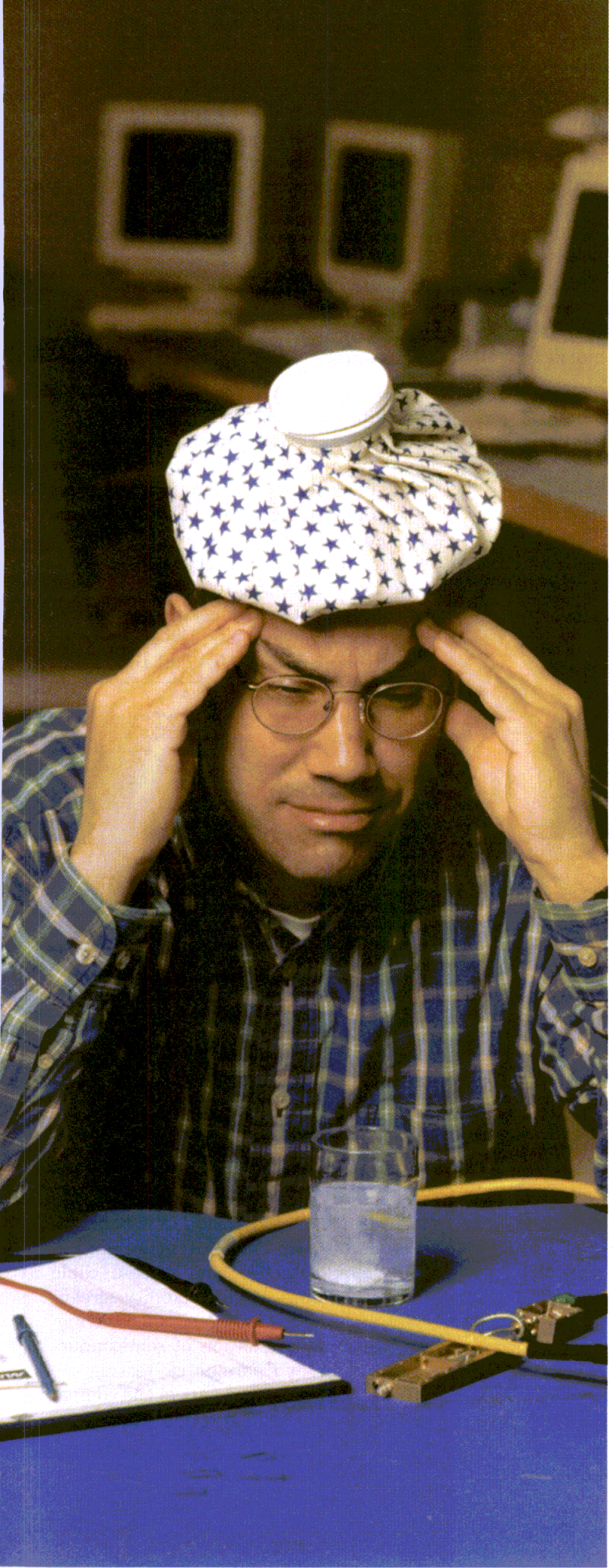
microminiature hermetically sealed ceramic package measuring 4.1 × 1.5 × 0.85 mm. The CC5 is currently available in a 32,768 kHz frequency and designed for use in portable wireless and computing devices. The CC5 requires a drive level of 1 μW with ±3 ppm aging typical and the frequency tolerance is ±30 ppm. Pricing for a 100,000 piece quantity in tape and reel is $1.66 each.

Micro Crystal
Circle #179

Precision resistor networks

A series of surface mount resistor networks in SOIC packages has

been announced by Vishay Intertechnology. The thin film net-



A lot Less Headaches

When you use Noise Com's **UFX-NPR** to test **Noise Power Ratio.**

If you need to test **Noise Power Ratio** without a complex, time consuming set up, look to Noise Com's **UFX-NPR** Noise Power Ratio Test Set. We offer customers a trouble-free solution... NPR test capability right out of the box!

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- **Wide Noise bandwidths up to 10 GHz.**
- **Superior measurement speed and notch depth.**
- **Self contained test solution. Calibration, configuration and set up not required.**
- **Automated measurement technique.**
- **Easy to use keypad or remote GPIB Control.**
- **Ongoing data storage within the Unit's memory capacity.**
- **Test TWTA's, Linearizers, Frequency converters, Amplifiers, CATV applications, Fiber Optic systems.**

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NOISE/COM

Circle 54

works offer temperature tracking of ±5 ppm/° C, resistance tolerance of ±0.1 percent and matching of ±0.05 percent. Resistance values range from 100 ohms to 100 kohms, with standard or custom interconnections available. The networks are packaged in 14- and 16-pin narrow-body molded SOICs.

Vishay Intertechnology, Inc.
Circle #180

Surface mount resonators for 315 and 433 MHz

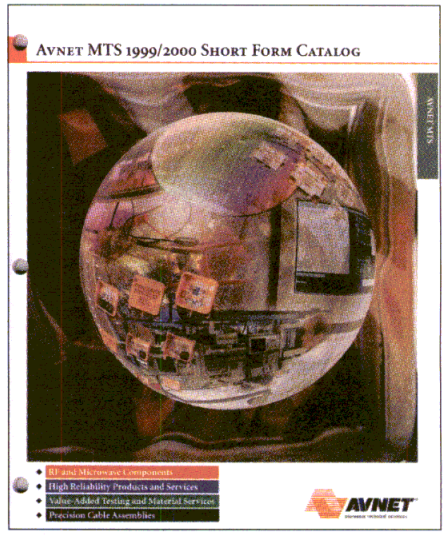
RF Monolithics now offers solder-seal surface mount SAW resonators at 315 and 433.92 MHz. The 4.8 × 5.2 mm package footprint is smaller than the standard RFM resonator package. The RO2179B (315.0 MHz) is produced for the U.S. market, while the RO2180B (433.92 MHz) is used in Europe. These resonators address numerous applications in wireless telemetry and control.

RF Monolithics
Circle #181

LITERATURE

New product catalog

Avnet's Microwave Technical Solutions (Avnet MTS) business unit has released its Year 2000 Short Form Catalog. Additions to the catalog include surface mount amplifiers, detectors and limiting amplifiers as well, as a series of MMIC-based microwave components in LTCC packages. The catalog is organized to provide data and specifications for the company's standard products, the majority of which are available "off the shelf."

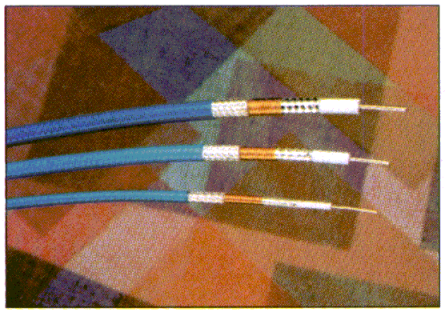


Custom solutions are also offered, with more than 5,000 configurations having been designed to address special customer requirements. Specifications and outline drawings are included for broadband amplifiers, limiting amplifiers, detectors and coaxial cable assemblies. High reliability screening services, lot acceptance testing, element evaluation of semiconductor die and parametric testing are also discussed as part of the company's value-added services.

Avnet MTS
Circle #182

Cable data sheet

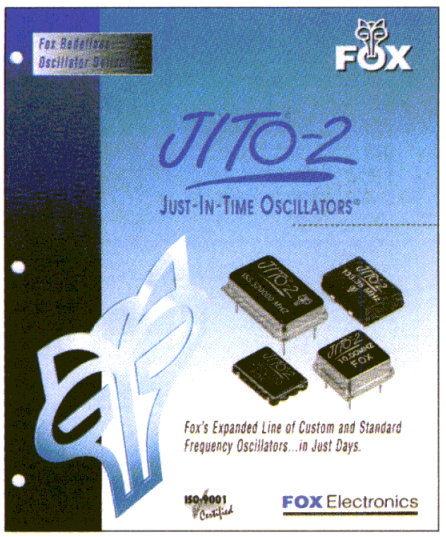
Times Microwave Systems has issued a new product data sheet covering its STRIPFlex®-II high temperature (200°) low loss flexible 50 ohm coaxial cable. STRIPFlex-II employs a low density PTFE dielectric and innovative shielding system, resulting in attenuation values up to 45 percent lower than conventional RG/M17 coax cable counterparts. With shielding effectiveness of >95 dB and low passive intermod (–155 dBc), STRIPFlex-II is a choice for high power interconnect and jumper cables in military and commercial applications including cellular, PCS, paging and mobile radio equipment.



Times Microwave Systems
Circle #183

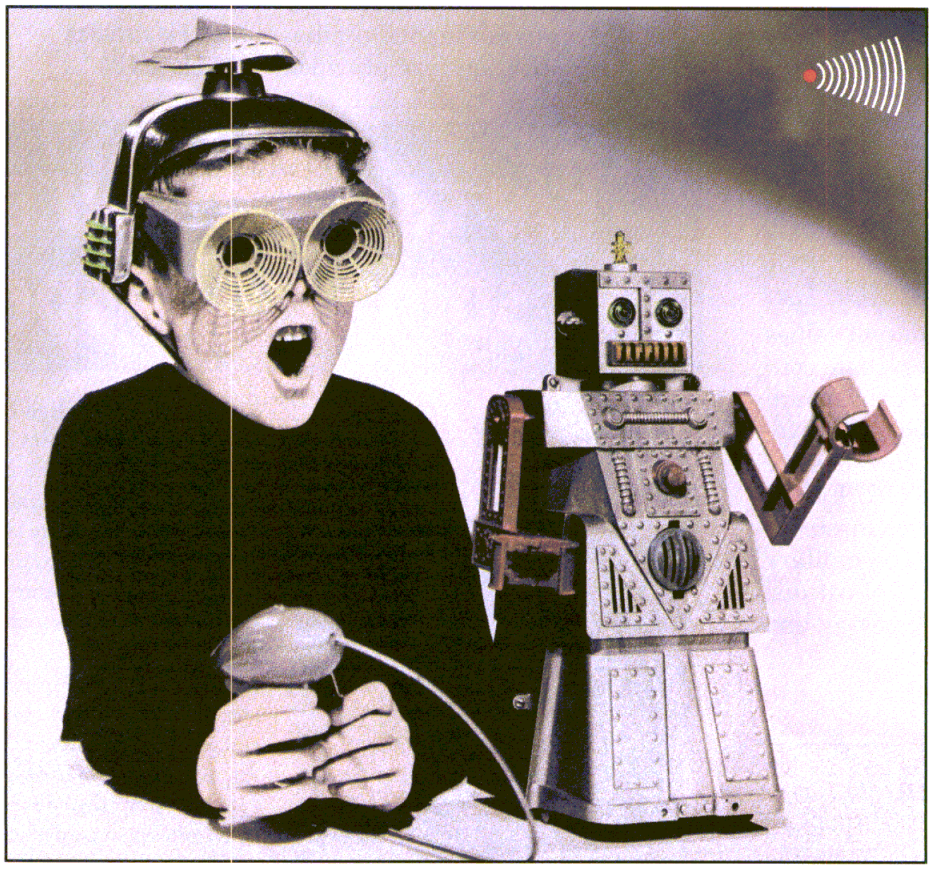
Oscillator brochure

An expanded range of JITO-2® Just-In-Time Oscillators, including a new line of plastic-encased programmable oscillators, is featured in a new technical data brochure from Fox Electronics. The brochure highlights Fox's JITO-2 program, which ships oscillators with standard or custom frequencies from 340 kHz to 250 MHz in ten working days or less. Featured are Fox's JITO-2P plastic-encased oscillators, which are designed as drop-in replacements for the Epson SG615 fixed frequency oscillator or SG8002JA programmable oscillator. Full specifications are provided on JITO-2 reduced phase jitter oscillators, which are available in PECL and HCMOS outputs; have supply voltages of +3.3 V or +5.0 V; frequency stability of ±25 ppm to ±100 ppm; a temperature range of either –40° C to +70° C or –40° C to +85° C; and are available in both SMD and thru-hole packaging.



Fox Electronics
Circle #184

TECHNOLOGY



CAPABILITIES

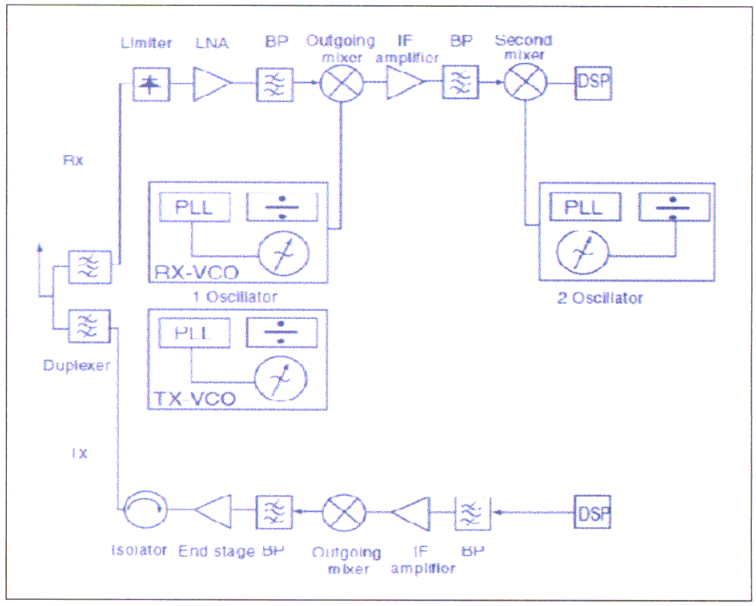
Low-Noise VCOs: Key Components for Base Stations

High performance communications systems require clean signal sources

By Frank Baberg
Tekelec Temex

The great economic success of modern mobile radio systems such as GSM and DCS means even greater utilization of the capacity of existing channels. It is therefore immensely important to exactly adhere to the GSM specifications.

In GSM systems, the available frequency range is divided according to the FDMA procedure] (frequency division multiple access) into radio channels of 200 kHz each [1], [2]. Each radio channel is further divided into eight traffic channels through a time multiplexing TDMA procedure (time division multiple access) [1], [2]. These channels contain the information (voice and data signals) in "bursts." In the case of a channel width of 200 kHz, this results in the typical GSM system channel number of 124 channels with bandwidths of 25 MHz (the first channel is not normally used). For DCS, there are 372 channels with a bandwidth of 75 MHz.



▲ **Figure 1. Block diagram of the RF portion of a typical wireless base station, showing frequency sources.**

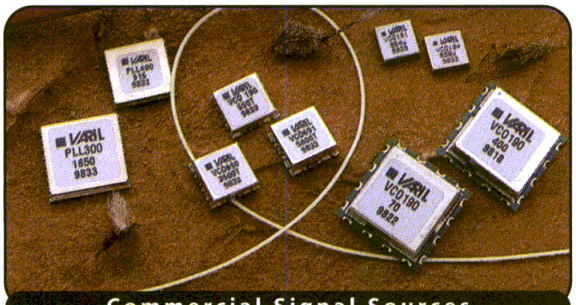
The block diagram in Figure 1 shows the frequency generating scheme in a base station. In the transmitter part (TX), the working signal must be converted into a RF signal. In the reception path (RX), the radio frequency signal received is converted into one (or two) fixed intermediate frequencies.

Each of the two conversion processes requires a local oscillator (LO). As a base station works in full duplex mode, the RX and TX paths are seprate and must have their own local oscillators. With mobile phones, a common local oscillator is sufficient because it they use half-duplex operation due to the time slots (TDMA).

Obviously, the specific scheme used in a particular radio can differ significantly from Figure 1. For example, the RX path can also be constructed using only one intermediate frequency.

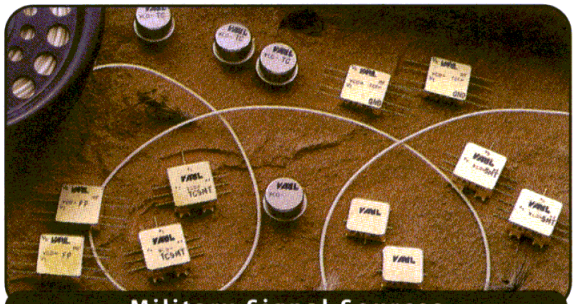
In modern communication systems, a synthesizer is normally used. An oscillator is typically synchronized with a reference via a phase-locked loop. There are a number of different ways to create a precise reference, such as deriving it from the fixed network clock or by synchronization via GPS.

A VCO is used as an oscillator, as its frequen-



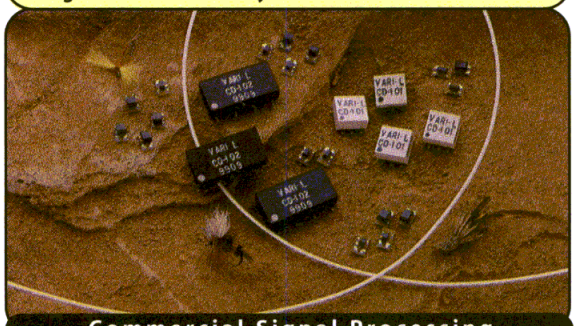
Commercial Signal Sources

- High Performance Voltage Controlled Oscillator Modules
- High Performance PLL Synthesizer Modules



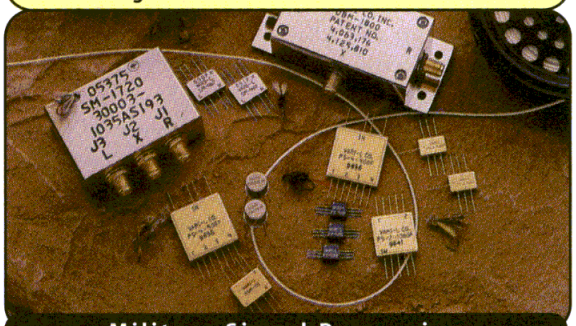
Military Signal Sources

- Ruggedized High Performance Hybrid
- Voltage Controlled Oscillators



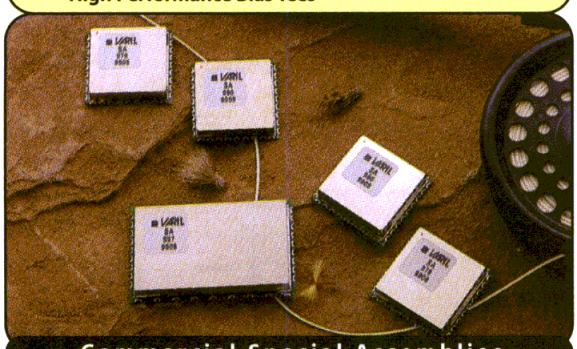
Commercial Signal Processing

- High Performance Wideband RF Transformers
- High Performance Power Dividers and Couplers
- High Performance Double Balanced Mixers
- High Performance RF Chokes
- High Performance Bias Tees



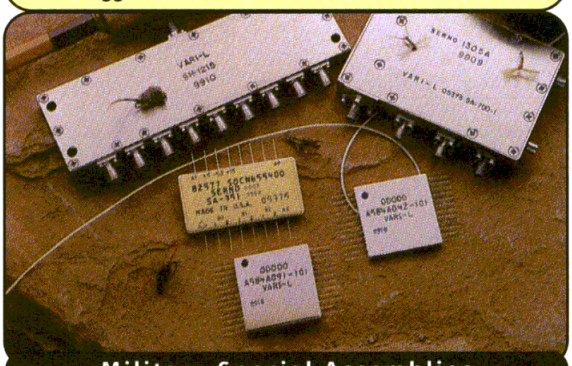
Military Signal Processing

- Ruggedized Double Balanced Mixers
- Ruggedized Wideband RF Transformers
- Ruggedized Power Dividers and Couplers
- Ruggedized I/Q Modulators and Demodulators



Commercial Special Assemblies

- Special Frequency Conversion Modules
- Special Frequency Generation Modules



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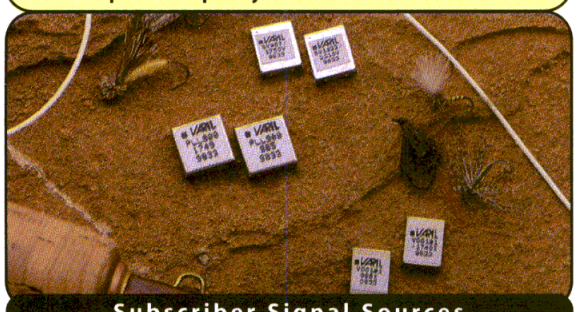

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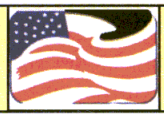

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cy is dependent on an applied voltage, so that the VCO can be tuned (switched) to the channel frequencies relatively simply and quickly.

Structure of the VCOs

Microwave oscillators are usually analyzed using the concept of "negative resistance" (e.g. [3]). In designing oscillators, various basic switching operations can be found in the literature, such as the Hartley-Meissner or Colpitts switching operations.

The so-called Clapp switching operation has proven itself in VCOs in particular. The Clapp switching operation is very similar to the Colpitts switching operation, only here the inductor is replaced by a resonant circuit (Figure 2a).

In Figure 2b, the Clapp oscillator in 2a is shown, includign only the RF components that are important for the operation. Figure 2c shows the equivalent circuit diagram, extremely simplified, as we are only interested in the principle here. The following applies to the impedance in the place of the serial resonant circuit:

$$Z = \frac{V}{i} = \frac{V_{be} + V_{c2}}{i} = \frac{\frac{i}{J\omega_{c1}} + \frac{i}{J\omega_{c2}} + \frac{Gn}{J\omega_{c3}}}{i} = \frac{L}{J\omega_{c1}} + \frac{L}{J\omega_{c2}} - \frac{Gn}{J\omega_{c3}} \quad (1)$$

Thus from Equation (1), the oscillation condition to produce a negative resistance is as follows:

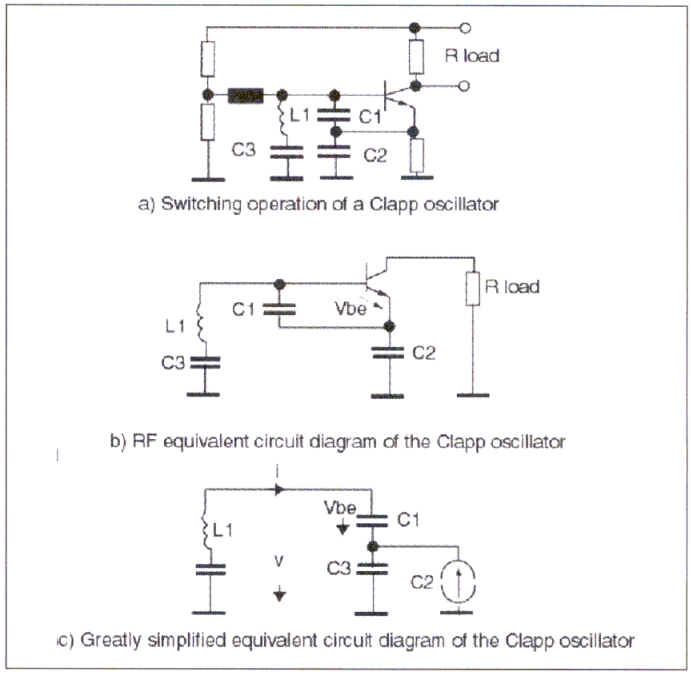
$$\frac{1}{J\omega_{c1}} + \frac{1}{J\omega_{c2}} \leq \frac{Gn}{\omega^2_{c1c2}} \quad (2)$$

The frequency is determined by the series connection of the three capacitors:

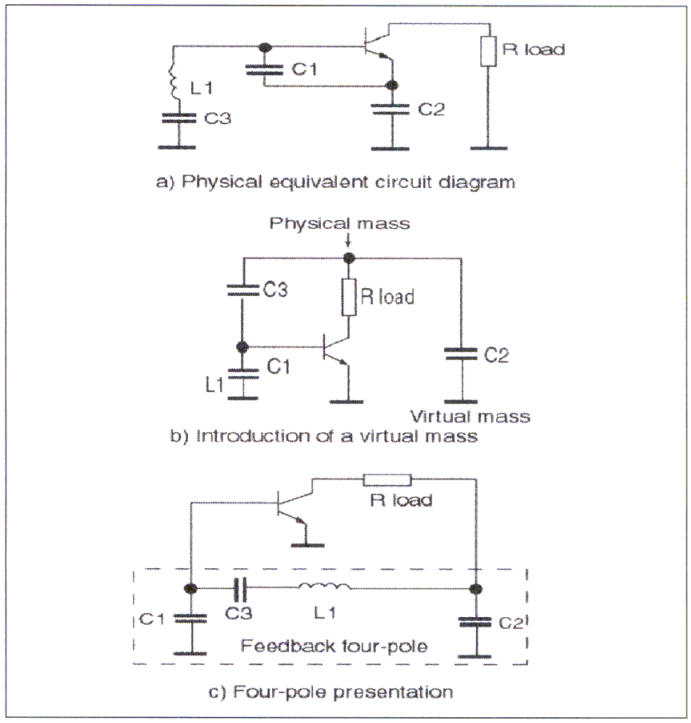
$$\omega^2 = \frac{1}{L_1}\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) \quad (3)$$

In radio frequency technology, the oscillator is often shown as a four-pole amplifier with amplification V, and its output voltage is fed back to the input via a feedback network. If one draws the Clapp oscillator in accordance with Figure 3, introducing a "virtual mass," then one will get the known four-pole switching operation.

In order to determine the frequency of the oscillator when tuned by a voltage, one of the capacitors is replaced by a varactor. This component exploits the junction capacitance of a diode operated in the junction direction, which is dependent on the reverse voltage applied.



▲ **Figure 2. Clapp oscillator operation and equivalent circuit diagrams.**



▲ **Figure 3. Clapp oscillator feedback repsented as a four-pole circuit.**

Analogous to the capacitor, the junction capacitance of a PN junction is dependent on the cross-section surface and the width of the junction. A theoretical analysis produces the following relationship for the voltage dependence of the junction capacitance [2]:

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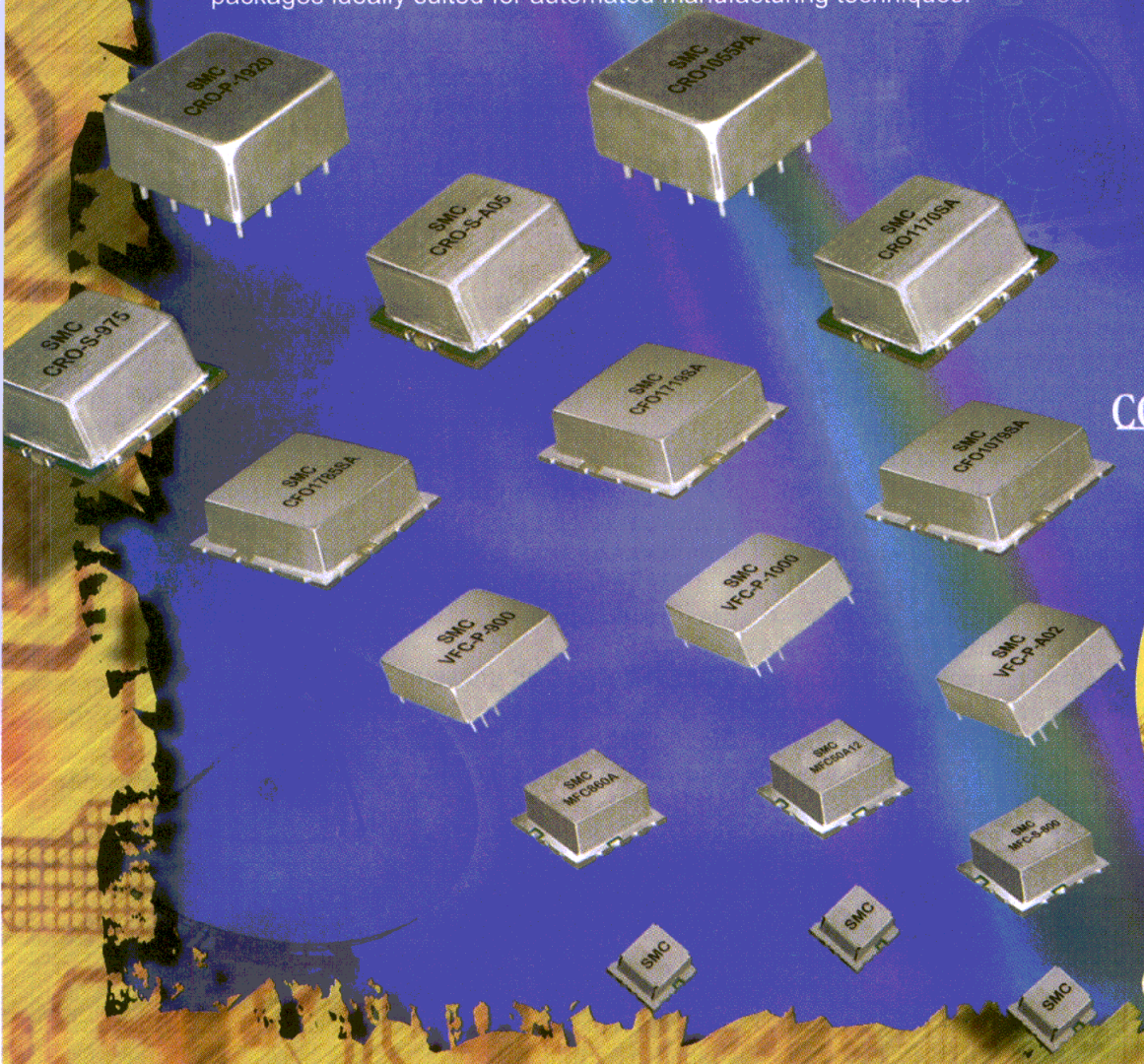

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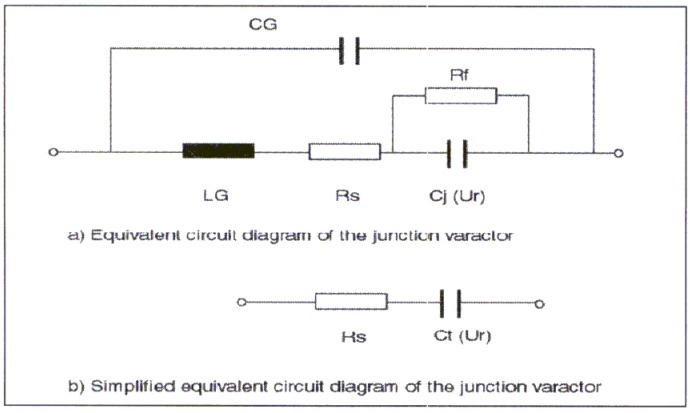


▲ **Figure 4. Equivalent circuit diagram of the junction varactor in the package.**

$$C_j = \frac{C_{j0}}{\left(1+\frac{V_r}{V_d}\right)^m} \approx C_{j0}\left(1+\frac{V_r}{V_d}\right)^m \text{ for } V_d << V_r \qquad (4)$$

In this equation, C_1 is the junction capacitance, where $V = V_r$, C_{j0} at $V_r = 0$ V, V_d is the diffusion potential (approx. 0.65 V for silicon) and V_r is the reverse voltage.

The exponent m depends on the course of doping and is decisive for the voltage dependency of the junction capacity. In a diffused junction, the junction of the acceptor density N_A (P area) is linear to the donor density N_D (N area); in this case $m = 0.33$. With an abrupt junction, the transfer is carried out suddenly; in this case $m = 0.5$.

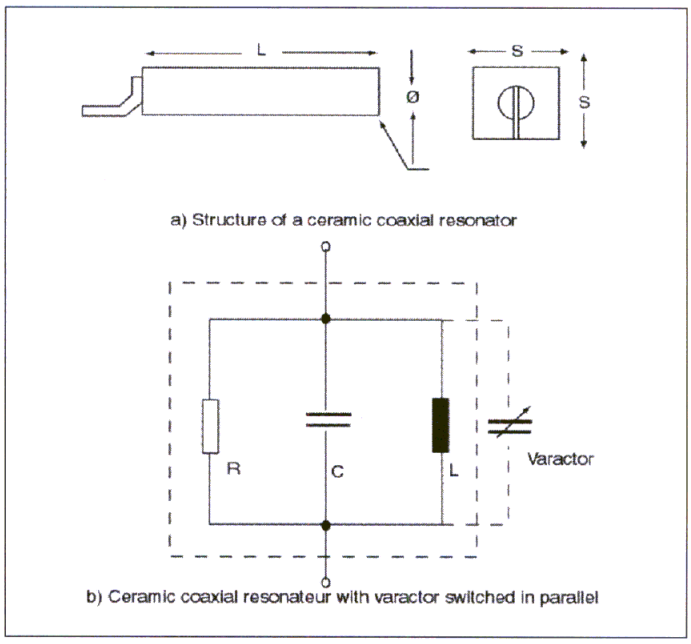
If one requires a particularly strong dependence of the junction capacitance on the voltage, m must be >0.5. In this case, doping density must again fall after the abrupt junction. Such doping profiles are called hyper-abrupt.

Figure 4 shows the small signal equivalent circuit diagram of a junction varactor. The resistance R_S takes into consideration the reverse current of the diode and should be as large as possible, in the interest of low noise (shot noise). In the case of higher frequencies, the bulk resistances above all become noticeable. The influence of the package is described by the line inductivity L_G as well as the package capacitance C_G.

In addition to the capacitance relationship C_1/C_{j0}, the quality factor Q is a decisive characteristic. Analogous to the capacitor, the quality of the varactor is also defined as the relationship between the reactive and the active performance. From the eqivalent circuit diagram 4b, ($C_T = C_j + C_G$), thus results:

$$Q = \frac{1}{\omega C_t(V_r)R_b} \qquad (5)$$

Basically, the quality of abrupt junction crossings are significantly better than those of hyper-abrupt crossings; however, very high reverse voltages of up to 90 volts are required to achieve sufficiently large capacitance variations.



▲ **Figure 5. Ceramic coaxial resonator as used in a high quality oscillating circuit.**

These high reverse voltages are also required because, in the case of voltages which lie significantly below the breakdown voltage, the reverse zone is only partially purged; while the ohmic resistance, which is in series with the capacitance, still lies within the non-purged zone.

For these reasons, hyper-abrupt junction varactors are most commonly used as oscillating circuit capacitances. In selecting a suitable varactor, it is also important that the relationship between the reverse voltage and the junction capacitance is defined over as wide a range as possible.

Q and its effect on phase noise

In the next section, we will state why the quality of the oscillating circuit is important for the phase noise. Since modern high Q capacitors offer excellent quality [4], [5], the selection of the inductor [L], as well as the varactor, determines the phase noise to a significant extent. With low demands on phase noise, one can create inductance through a coil printed onto the PCB. Better results are obtained in using air-core reactors in SMD packages.

The best characteristics are obtained by the use of coaxial resonators (Figure 5). Ceramic resonators are shaped as cuboids with a coaxial bore. The inner and outer surfaces are metallized. The capacitance, inductance and the resistance of the metallization create a resonant circuit which oscillates in TEM mode. Particularly space-saving are the one-quarter wave-

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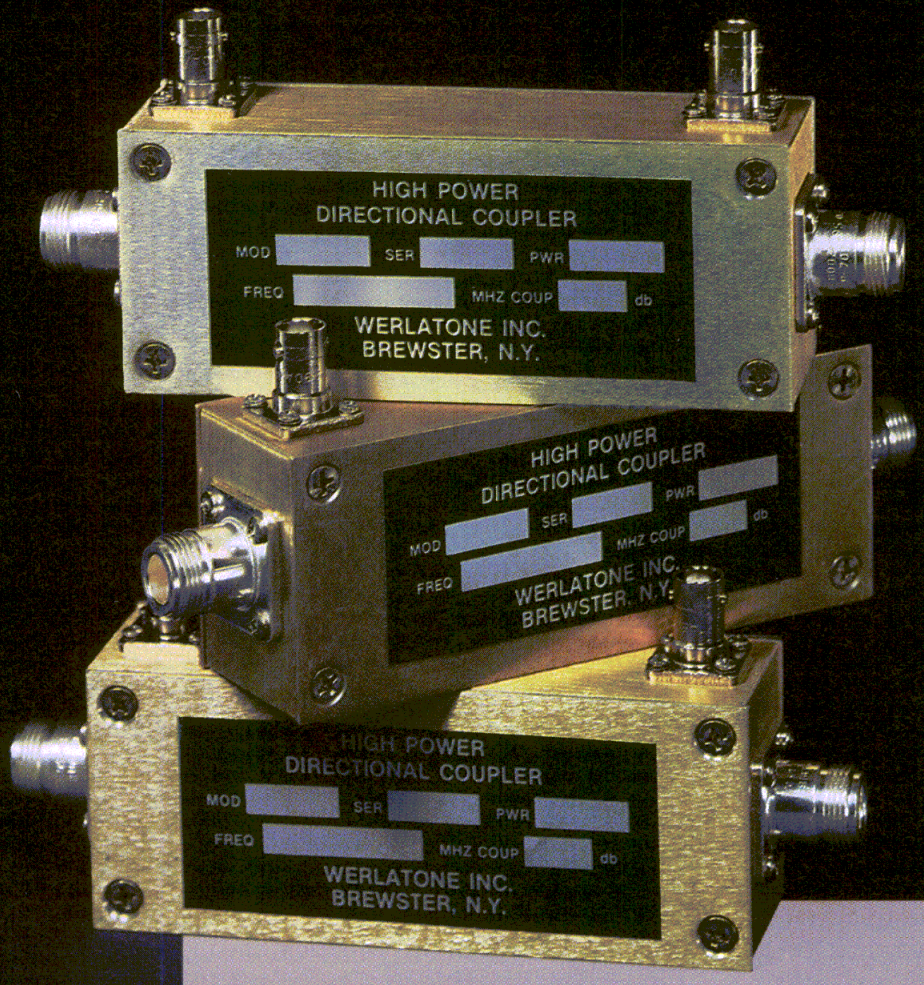

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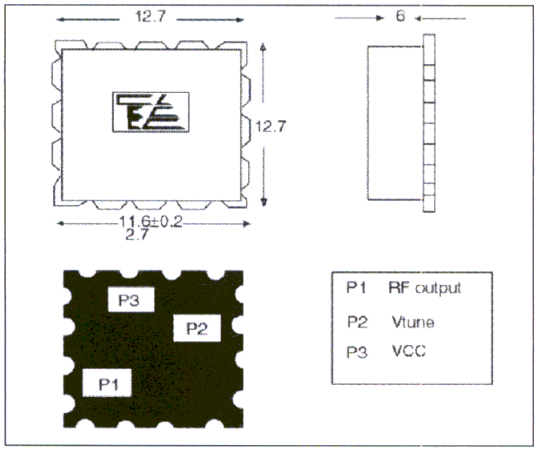
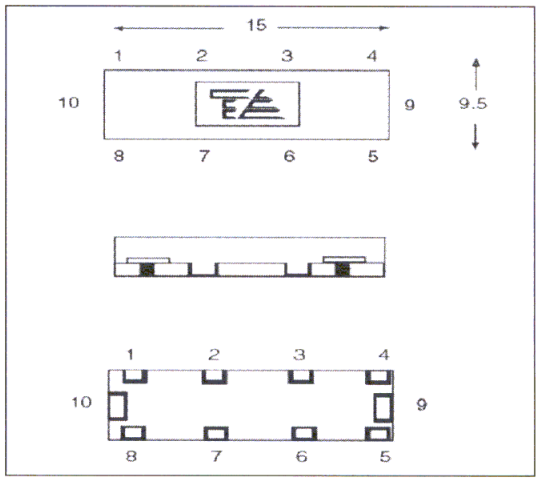


▲ **Figure 6. Approximately square VCO package, model SM1.**



▲ **Figure 7. Rectangular package, model SM4.**

length (λ/4) types. The additional metallization of an end face creates the required short-circuit.

The resonant frequency is obtained from the relative permittivity counter and the length of the resonator. Basically, the context for λ/4 resonators is as follows:

$$L = \frac{\lambda_0}{4} \times \frac{1}{\sqrt{\varepsilon_r}} \tag{6}$$

Dielectric values of ε_1 = 20 to 78 are available.

The Q is almost exclusively determined by the final conductivity of the metallization to a value of Q <800. Where higher quality is required, a special silver metallization is recommended; in the case of price-sensitive applications, a copper-plated metallization is preferred. The no-load operation quality Q_0 is defined as the quotient of the resonance frequency and the 3 dB bandwidth of the resonance curve:

$$Q_0 = \frac{f_r}{B3_{db}} \tag{7}$$

Q_0 increases in the first approximation by $\sqrt{f}$. Higher Q values can be achieved using larger cross-section measurements, where it is then critical to integrate the resonator into the normal very small VCO package.

Characteristics of the VCOs

Basically, VCOs are customer-specific modules; each user design is different and thus the VCO modules must be adapted to customer specifications. For example, typical values are stated in Table 1 [6]. Such details can only be used as guide values for sample deliveries; for series, customer-specific values are generally stated. In this section, an additional statement is made on the most important parameters of a VCO specification.

Phase noise— Phase noise is the most critical parameter in designing a VCO and must be specified with particular care. In the case of sensitive preamplifiers, normally only the amplitude noise is taken into consideration as it characterizes the sensitivity of the amplifier. With oscillators, the amplitude noise plays only a subordinate role. Decisive here are the stochastic changes in the zero transits of the sinusoidal oscillation created by the oscillator. The phase noise characteristic thus describes the relationship of the carrier magnitude to the noise magnitude in the region near the carrier frequency. This relationship is described by the function $\xi = F(f_m)$, dependent on the carrier offset.

The most obvious significance of the phase noise can be found in the case where phase noise creates interference in the neighboring channel. A typical VCO specification, therefore, states certain values depending on the carrier offset (see Table 1).

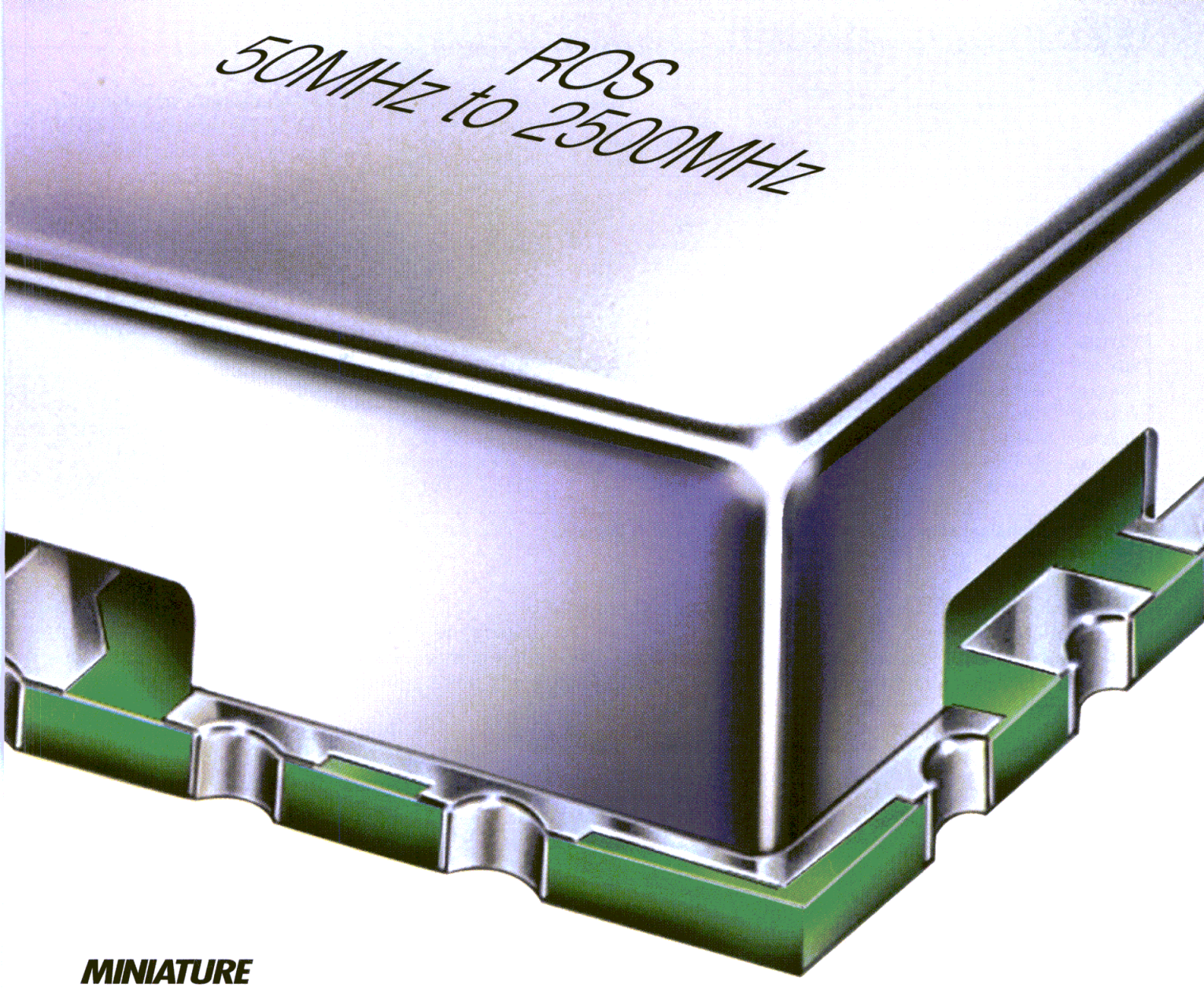
The phase noise of a VCO has been observed in numerous theoretical experiments, and without going into detail [7, 8], Equation (8) is determined:

$$\zeta(f_m) = 10 \log\left\{\left[1 + \frac{f_0^2}{(2f_m Q_{load})^2}\right]\left(1 + \frac{f_c}{f_m}\right)\frac{FkT}{f_m} + \frac{2kTRV_0^2}{f_m^2}\right\} \tag{8}$$

In this equation, the meanings are as follows:

- $\xi(f_m)$ Relationship of the magnitude of the phase noise at 1 Hz bandwidth to the common output magnitude of the VCO, stated in dBc/Hz
- f_m Offset from the carrier frequency
- f_0 Carrier frequency
- f_c Noise corner of the flicker or $1/f$ noise of the active oscillator
- Q_{load} Quality of the loaded resonator (resonance circuit with active load and parasitic elements)
- F Noise figure of active oscillator four-pole
- k Boltzmann constant ($k = 1.38 \times 10^{-23}$ J/K)
- T Temperature in Kelvins
- P_{av} Output magnitude of the oscillator
- R Equivalent noise resistance of the varactor
- V_0 Voltage amplification of the oscillator

Even if this relationship is based on idealized values, one can derive some important parameters for the design of VCOs.



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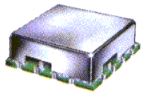

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ROS-960PV	890-960	5	-102	-27	5	12	19.95
ROS-1000PV	900-1000	5	-104	-33	5	22	19.95
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ROS-150	75-150	18	-103	-23	12	20	12.95
ROS-200	100-200	17	-105	-30	12	20	12.95
ROS-300	150-280	16	-102	-28	12	20	14.95
ROS-400	200-380	16	-100	-24	12	20	14.95
ROS-535	300-525	17	-98	-20	12	20	14.95
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VLA380	380-430	0	0 - 5	–112	–132		–8	12/20
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VLA1250	1250-1350	3	1 - 8	–100	–120		–12	8/25
VLA1450	1450-1550	3	1 - 8	–105	–125	–145	–12	5/25
VLA1500	1500-1650	1	1 - 8	–97	–117	–137	–12	5/25
VLA1594	1594-1669	3	1 - 6.5	–105	–125	–145	–15	5/25
VLA1750	1750-1900	1	1 - 8	–97	–117	–187	–12	8/16
VLW1800	1800-2700	1	0 - 19	–85	–105		–8	12/25
VLA2650	2650-2850	2	0 - 12	–90	–110		–12	8/20

▲ **Table 1. Technical characteristics of a selection of VCO models.**

1) The loaded Q of the resonator directly affects the phase noise; for this reason, coaxial resonators must be used in the case of very high performance requirements.

2) Low-noise oscillators require components with a low corner frequency of the flicker ($1/f$) noise. Bipolar transistors are normally used in VCOs instead of FETs. GaAs devices are not suitable, as they have a significantly higher noise corner.

3) The noise figure of the oscillator, which is internal to the switching, depends not only on the noise figure of the active component but also on the switching configuration. The setting of the capacity of the oscillator signal also influences the noise; in this, however, the current consumption must not be neglected.

One very important point, which is not taken into consideration in equation (8), is the voltage supply. Significant fluctuations can occur in the voltage supply. Unwanted modulation side bands, which lie outside the loop of the PLL are produced from these fluctuations in the bias of the VCO.

Tuning sensitivity

Tuning sensitivity describes the tuning frequency range, depending on the tuning voltage at the varactor input. The tuning sensitivity depends on the available capacity variation and is inversely proportional to the loaded quality of the resonance circuit.

The frequency dependence of the tuning sensitivity here must also be borne in mind. If this is too great, then the performance of the synthesizers is adversely affected.

Load pulling

Load pulling gives the sensitivity of the free-running VCOs compared to the load fluctuations at the VCO output. This load pulling is specified for a mismatched load with a defined VSWR (e.g. at VSWR = 2.0), where the phase angle can lie between 0° and 360°. At its simplest, this requirement may be achieved using an additional buffer amplifier. Such a buffer amplifier also improves the drive level of the VCO, which must also supply RF to the prescaler of the PLL synthesizer in addition to a mixer stage. However, a buffer

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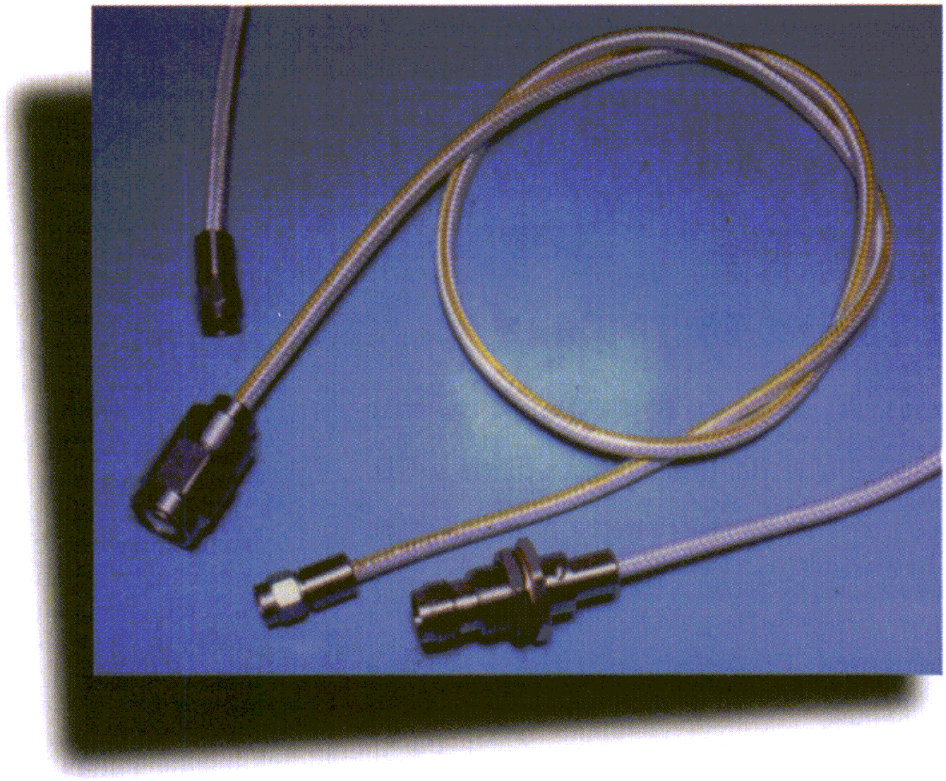

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amplifier increases the current required by the VCO. Because of the load associated with power amplifiers, the load pulling performance of the transmitter branch VCO can be of particular importance.

Packaging

Obviously, the design of the VCO must be such that it can be processed in modern manufacturing installations that assemble large quantities of products using SMD technology. In practice, two basic packages have been successful: the approximately square package of Figure 6 and the rectangular package shown in Figure 7.

Summary

In this article, I have attempted to present the fundamentals for the design and the use of VCOs. From what has been said, it is clear that the VCO, together with the PLL, represents an elementary unit that makes an important contribution to the design of a base station. It would therefore be sensible if the manufacturers of VCOs were also involved in the manufacture of suitable PLL components. Therefore, a later presentation is planned for PLLs. ■

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By Enver Krvavac, Dale Joersz, Nagaraj Dixit and Christopher P. Dragon
Motorola, Inc.

Motorola has developed new 220 watt (P_{3dB}) push-pull and 155 watt (P_{3dB}) single-ended transistors for base station power amplifiers.. The devices are internally matched, common-source, N-channel, enhancement-mode, laterally diffused metal-oxide semiconductor (LDMOS) FETs, designed for IMT2000/UMTS single or multicarrier applications covering the 2110-2170 MHz band and incorporating WCDMA digital modulation.

The two new devices, MRF21180 (push-pull) and MRF21125 (single-ended), feature exceptional P_{1dB} and P_{3dB} output power capabilities, which are essential for high peak to average ratio digital modulation signals such as WCDMA. Figures 1 and 2 show the MRF21180 and MRF21125 typical output power, efficiency, and gain vs. input power at 2120 MHz with V_{dd} (drain operating voltage) at 28 volts. At the respective P_{1dB} points of 170 watts and 135 watts, drain efficiencies of 42 and 49 percent are achieved. The respective P_{3dB} points are 220 watts and 155 watts.

Both parts are internally matched at the input and output for simplified matching over the 2110-2170 MHz band. The performance over this band is illustrated in Figures 3 and 4. The rule of thumb of –30 dBc IM_3 (third order intermodulation distortion) for 2-tones with 10 MHz spacing at the respective PEP (peak envelope power) ratings was used to show the broadband linearity of the two devices. A compromise among gain, efficiency, and IMD was made to achieve the best overall broadband performance. The resulting load and source impedances to achieve this best overall broadband performance is shown in Table 1 for both devices. For the MRF21180 at a PEP of 170 watts, an

IM_3 of better than –30 dBc is maintained across the band with an input return loss of better than –12 dB and drain efficiency and power gain in excess of 33 percent and 11.5 dB respectively.

Similarly, for the MRF21125, at a PEP of 125 watts, an IM_3 of better than –30 dBc is maintained across the band with input return loss of better than –12dB, drain efficiency greater than 34 percent, and a minimum gain of 12 dB.

While Figures 1 through 4 show high saturation power capability and very good linearity at rated PEP levels, Figures 5 and 6 show the IM_3 performance vs. output power, which is better than –45 dBc at 10 dB back-off power.

All three of these characteristics are essential for multicarrier power amplifiers used for WCDMA base stations.

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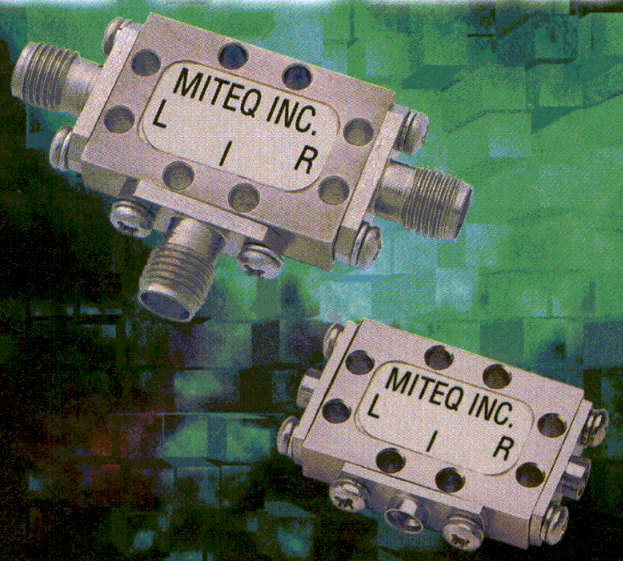

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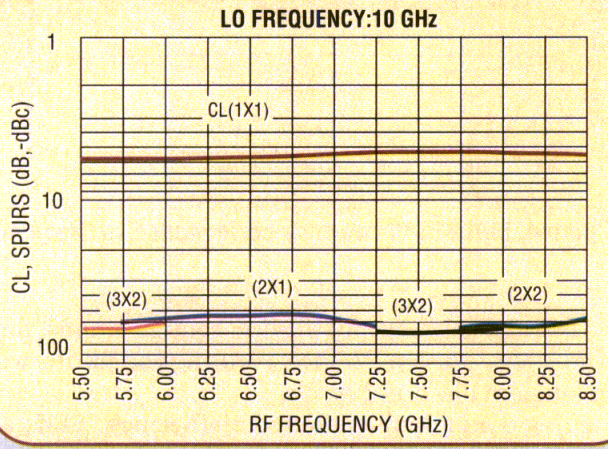

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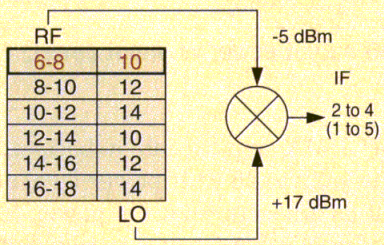

RF	LO
6-8	10
8-10	12
10-12	14
12-14	10
14-16	12
16-18	14

SPECIFICATIONS - Model TBR0618HA1/TBR0618HA1-S

RF/LO Input Frequency Range	6 to 18 GHz
IF Output Frequency Range	0.05 to 5 GHz
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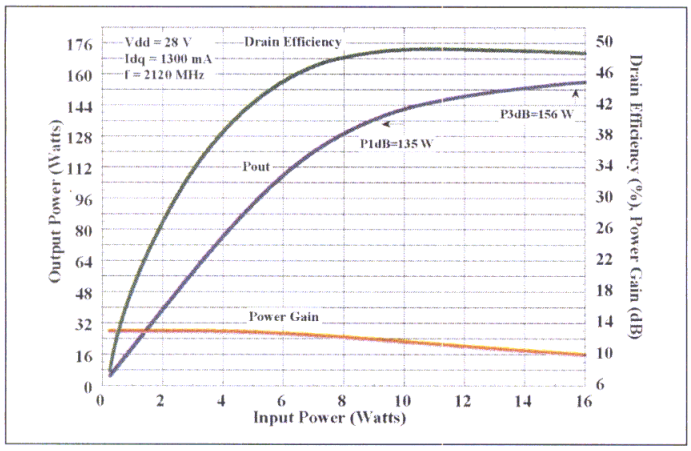
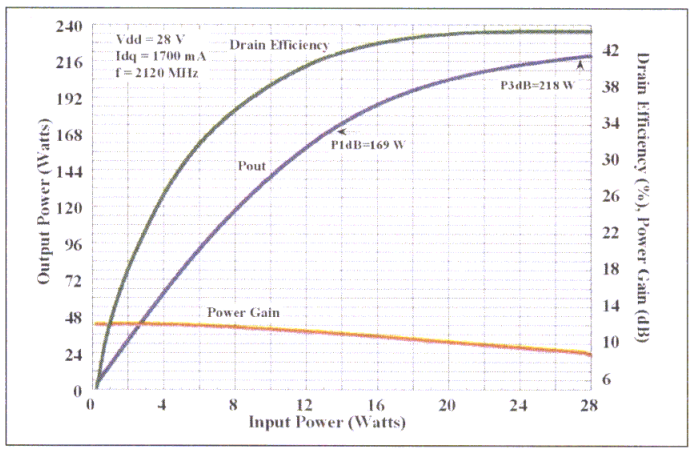
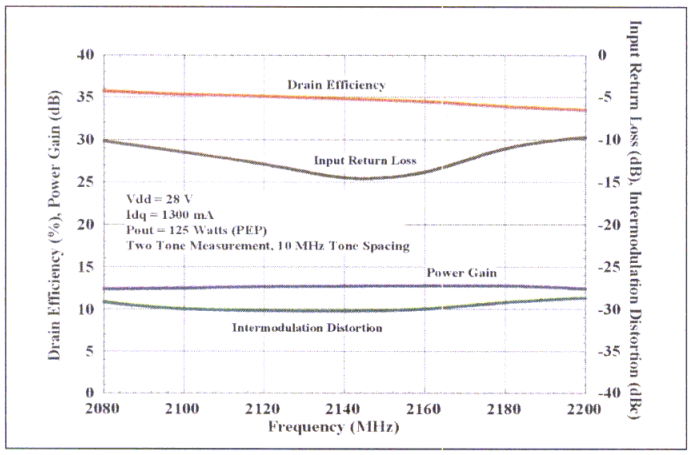


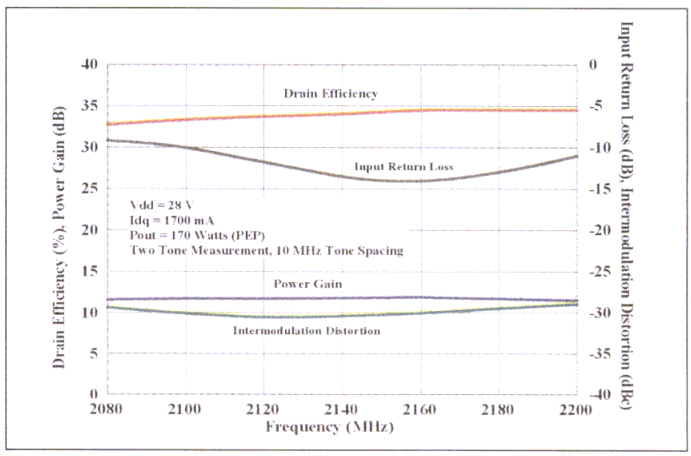
▲ **Figure 1. MRF21125 two-tone performance vs. frequency.**



▲ **Figure 2. MRF21125 output power vs. input power.**



▲ **Figure 3. MRF21180 output power vs. input power.**



▲ **Figure 4. MRF21180 two-tone performance vs. frequency.**

For a 2-carrier WCDMA application a base-station manufacturer requires a 20 to 25 watt power level at the antenna port, as well as adjacent channel power (ACP) and IM_3 that is –55 dB relative to the carrier channel power. Figure 7 shows a snapshot of a 2-carrier WCDMA spectrum 10 MHz apart. The bandwidth of a single channel is 3.84 MHz (chip rate of the digital signal) with the WCDMA signal at a peak-to-average ratio of 8.5 dB at .01 percent probability on the CCDF plot (complementary cumulative distribution function). The adjacent channels will be ±5 MHz away from each carrier center frequency and the ±ACP relative to each carrier's integrated power level is measured in a 3.84 MHz integration bandwidth. Likewise, the IM_3 products ($\pm IM_3$) will be ±10 MHz away and are also measured in a 3.84 MHz integrated bandwidth.

The most popular linearization technique used by manufacturers for WCDMA application is the feedforward correction loop. This technique achieves around 15 to 20 dB minimum adjacent channel and IM_3 rejection. Delay and coupling losses require about 2.5 to 3 dB higher power at the amplifier output than at the antenna port. Examples of output device configurations for a WCDMA base station PA incorporating the feedforward technique are discussed below.

Figures 8 and 9 show the gain, efficiency, $\pm IM_3$ and ±ACP vs. 2-carrier WCDMA power for each device. Most notably, the IM_3 is the determining factor in the rejection that is needed to achieve the –55 dBc level.

One MRF21180 device, running at 44 watts and –35 dBc IM_3, is sufficient to meet the 20 to 25 watt output power level at the antenna port, with overall system ACP and IM_3 55 dB below the carrier when combined with a linearization correction of better than 20 dB. The

	Freq.	Zin (Ω)	Zout (Ω)
MRF21125	2.11GHz	3.81 + j6.86	1.56 – j1.58
	2.14GHz	4.33 + j7.90	1.53 – j1.90
	2.17GHz	4.84 + j8.46	1.48 – j2.26
MRF21180	2.11GHz	4.03 – j3.71	3.79 – j4.04
	2.14GHz	3.57 – j4.11	3.52 – j4.33
	2.17GHz	3.20 – j4.57	3.30 – j4.77

▲ **Table 1. Device impedances across the WCDMA band.**

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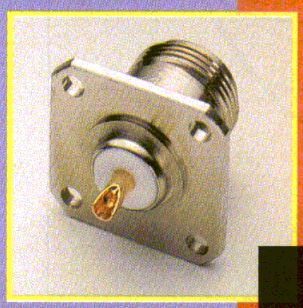

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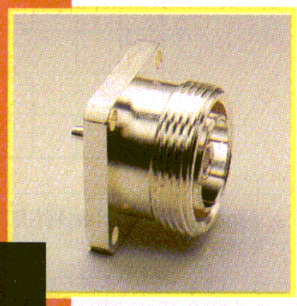

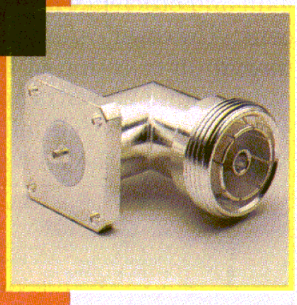

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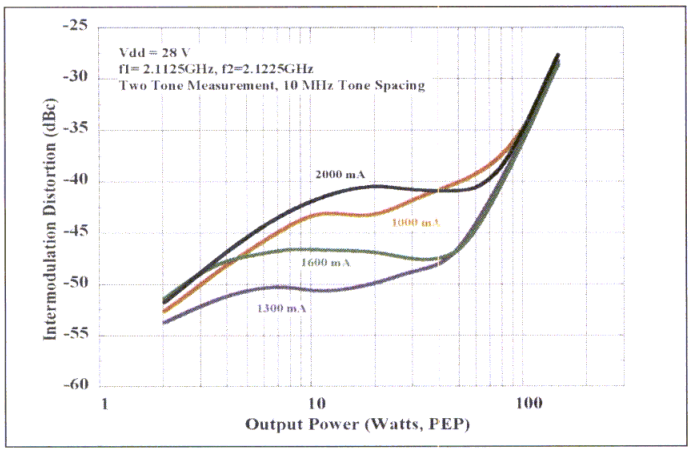
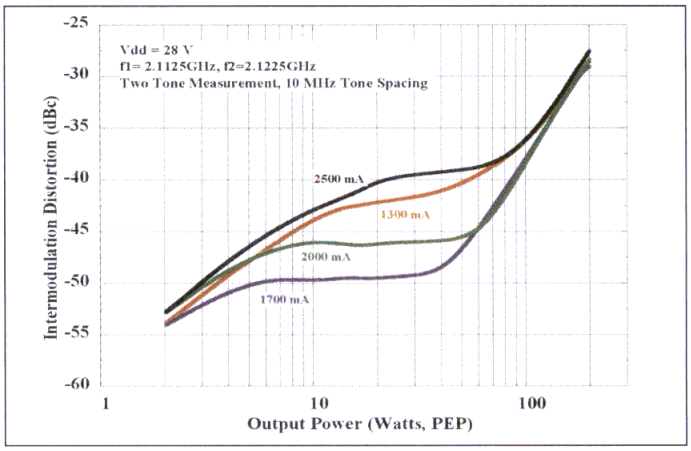
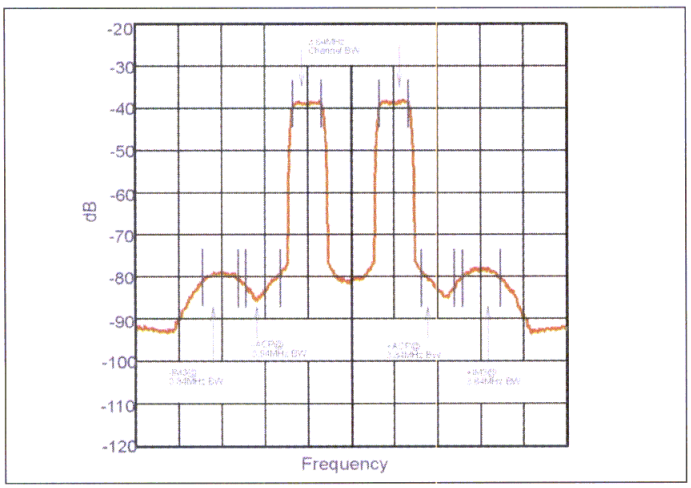


▲ **Figure 5. MRF21125 IMD vs. power and I_{dq}.**



▲ **Figure 6. MRF21180 IMD vs. power and I_{dq}.**



▲ **Figure 7. Carrier WCDMA spectrum.**

gain and efficiency at this level are 12.0 dB and 23.5 percent. However, should a manufacturer require some margin in rejection of IM_3, two MRF21125 devices running around 23 watts and –41 dBc IM_3 can be used at an expense of overall efficiency. The efficiency of the MRF21125 at the 23 watt level is typically 20.0 percent and the gain is 13 dB.

In conclusion, the MRF21180 and MRF21125 are very attractive for single or multicarrier WCDMA or other base station applications in the 2110 to 2170 MHz band which require high saturation power levels and low distortion requirements at peak and operating output power levels. Also, their ruggedness, consistency, ease of use, cost, and 100 percent production testing under WCDMA conditions make the MRF21180 and MRF21125 attractive for the WCDMA market. ■

References

1. B. Davidson, C. Dragon, E. Krvavac, W. Burger, D. Joersz, N. Dixit, "High Power RF-LDMOS Transistors for Wireless Communication Base Station Applications," Microwave Workshops and Exhibition (Japan), 1999.

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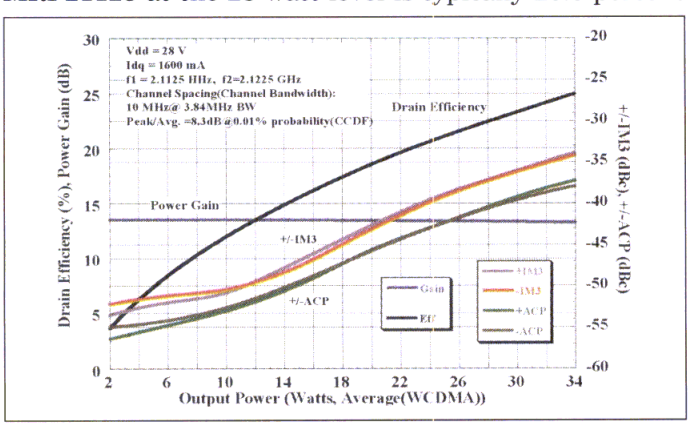
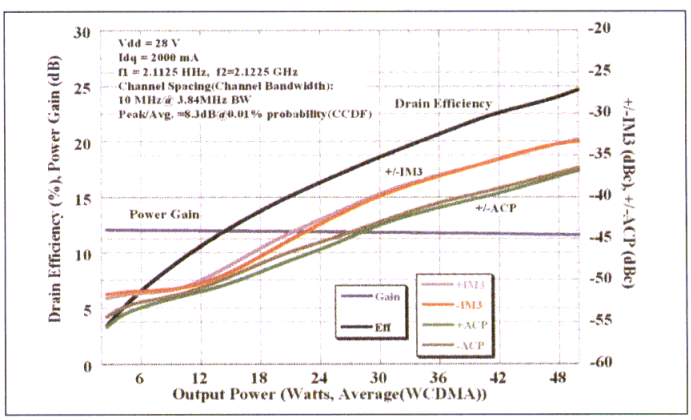


▲ **Figure 8. MRF21125 ACP and IM_3 performance vs. output power.**



▲ **Figure 8. MRF21180 ACP and IM_3 performance vs. output power.**

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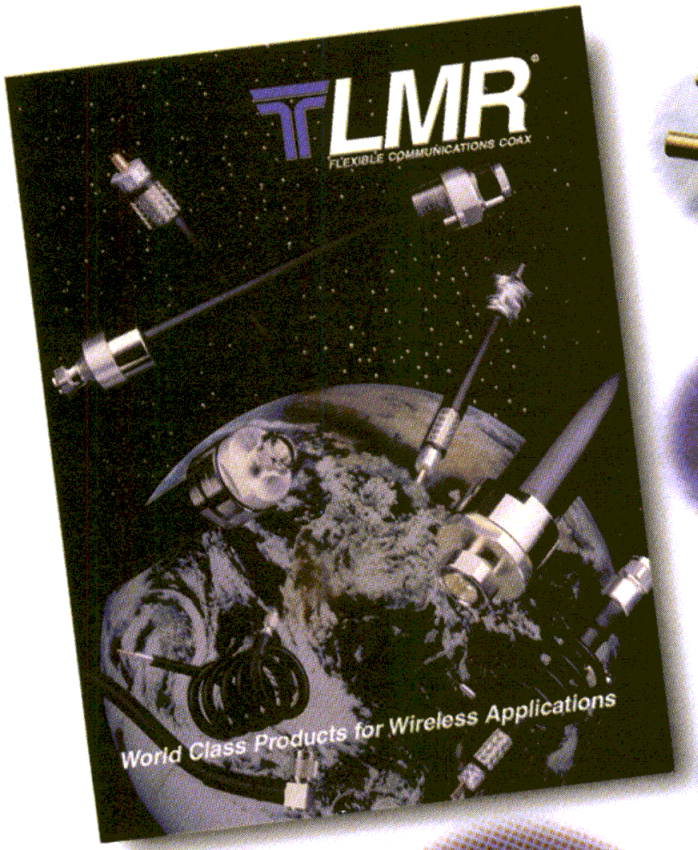

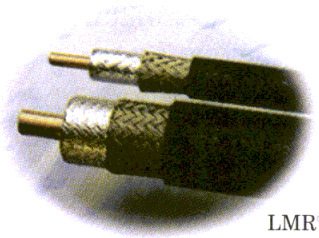

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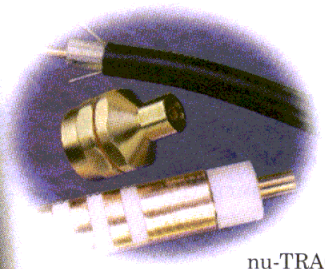

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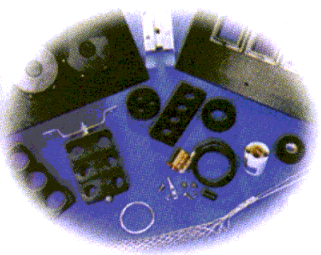

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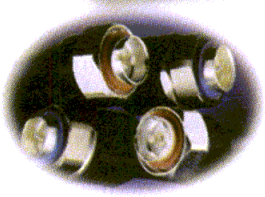

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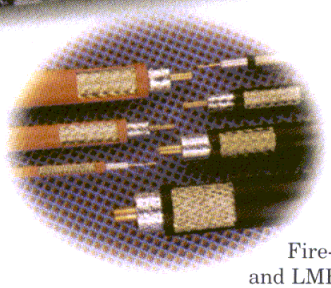

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Accurate Phase Noise Prediction in PLL Synthesizers

Part 2: Here is a method that uses more complete modeling for wireless applications

By Lance Lascari
Adaptive Broadband Corporation

As discussed in part one of this article, published in the April issue of *Applied Microwave & Wireless*, phase noise characteristics of the frequency synthesizer contribute greatly to system performance. In this concluding section, we will show and discuss experimental results for the op-amp in loop filter.

Design goals	Value	Comments
Output Frequency	865 MHz	
Reference Frequency	200 kHz	
Frequency Step Size	12.5 kHz	
PLL Loop bandwidth	750 Hz	Get as close as possible with available components
Phase Margin	55 degrees	
Additional Reference Frequency Attenuation Required from the Third Pole	10 dB	

▲ **Table 2. Design goals for the example loop filter design.**

Op-amp in loop filter

While the cases using the passive loop filter (no op-amp) are simply a matter of circuit analysis, the case using the active filter requires some explanation. This case will only be described here; the accompanying analysis can be found in the supporting MathCad documents.

With the op-amp in the loop, and the filter configuration shown in Figure 1, four different noise sources and important factors exist within the loop itself: R_2, the op amp itself, the gain of the op-amp, and R_3.

The noise within R_2 is the same as the cases previously mentioned. However once this noise is determined, the gain of the amplifier needs to be applied to it (amp_gain in Figure 1). The output of the op-amp is again filtered by R_3 and C_3. A schematic of this is pictured in Figure 2a.

The op-amp itself contributes noise, and this is one reason to place the op-amp after the second order filter section but before the third pole. The third pole can then provide some attenuation of the broadband noise. Manufacturer's data sheets will usually specify the input noise of the op-amp in $nV/\sqrt{Hz}$. This noise voltage is simply multiplied by the amplifier's gain (amp_gain), and then passed through the filter formed by R_3 and C_3.

Op-amps are usually regarded as very low-output-impedance devices. For this reason, the analysis of the noise due to R_3 can be greatly simplified if an op-amp is in the loop as shown in Figure 1. If it is assumed that the op-amp output impedance is virtually a short (which would be accurate, even if the op-amp output were a few hundred ohms), then the noise voltage generated in R_3 is simply connected to ground, then filtered through R_3 and C_3.

Practical design example

To show the effect of the resistor noise, two different loop filters were designed to meet the basic specifications outlined in the goals section of Table 2. The only differences between the filters were their implementation of the third

pole. The values used in each of the designs were typical of what one designer might choose over another.

Experimental setup

Equipment used in the lab setup included a Hewlett-Packard 8563E spectrum analyzer with the phase noise utility software (P/N HP85671A) installed; a PC running a custom application developed to gather tabular data after the phase noise utility was run; and the PLL synthesizer under test (modified standard product produced by Adaptive Broadband Corporation).

The results presented in Figures 9 and 10 represent five averages of each phase noise measurement. In order to show the limitations of the measuring system, (i.e. the spectrum analyzer), the phase noise of the extremely low noise HP 8642B signal generator was plotted for comparison purposes. At higher offset frequencies where the measurements and models begin to disagree, it is clear that that the noise floor of the spectrum analyzer is contributing to measurement error.

Component/Specification	Value	Comments
Synthesizer IC, National LMX2350 Fractional-N PLL	Allows 1/16th Fractional mode	
Phase Detector Noise Floor (Npd_ref from Equation 6)	–200 dBc/Hz	Data supplied by National Semiconductor.
Phase Detector Gain	1.6 mA/cycle	Set to maximum for this design.
VCO Tuning Sensitivity, K_{vco}	27 MHz/volt	Custom vendor supplied component, measured at frequency of interest.
VCO Phase Noise	–103 dBc/Hz at 10 kHz offset	Measured for this particular device using a very narrow and quiet loop.
TCXO reference oscillator Frequency	12 MHz	
TCXO reference oscillator Phase Noise (Ntxco_ref from Equation 7)	–125 dBc/Hz at 100 Hz offset	This number was estimated from measurement data from many PLLs. This is roughly 10 dB worse than published data on a similar product from the TCXO vendor. Measurements for the model used were unavailable.

▲ **Table 3. Specifications for the components available.**

Discussion of experimental results

Figures 9 and 10 show excellent agreement between the modeled phase noise of the synthesizers and the measured results. The conclusion that must be drawn is resistor noise can be a very significant contributor to synthesizer phase noise, and thus needs to be considered in all low-noise synthesizer designs. For the case of these experiments, and others performed by the author, the models presented accurately predict this noise, allowing the analysis of all of these degradations at the time the loop is designed [1].

Loop Filter Component Values	Value for Case 1	Value for Case 2
C1	0.1 μF	0.1 μF
R2	500 ohms	500 ohms
C2	1 μF	1 μF
R3	1 kohm	10 kohm
C3	1000 pF	100 pF

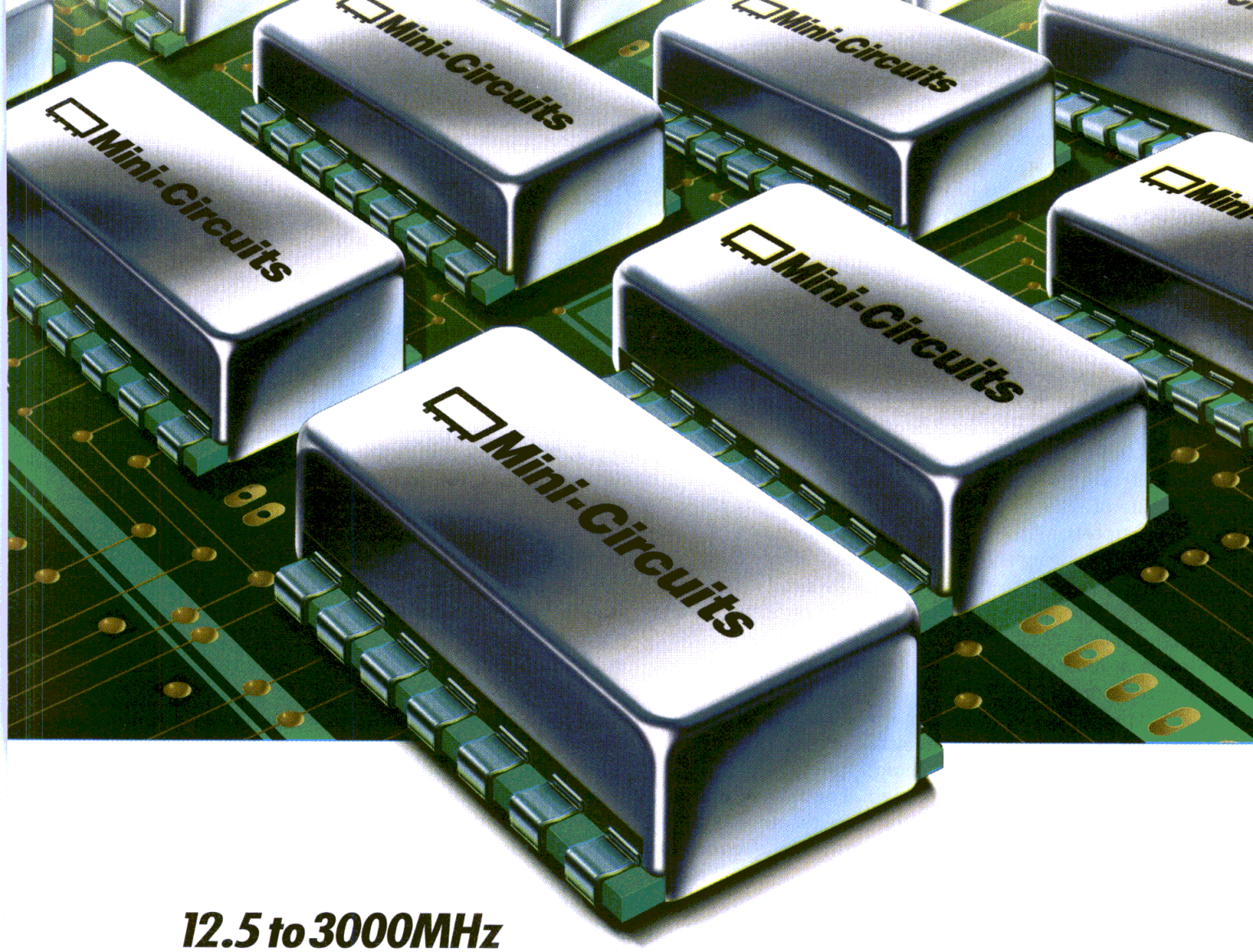
▲ **Table 4. Component values for the two loop filters studied.**

The loop filters for case 1 and case 2 both meet the basic requirements of the design but have drastically different phase noise characteristics. For instance, at the 10 kHz offset points, the two synthesizers differ in phase noise by almost 10 dB. For narrowband systems with channels spaced at this interval, this would equate to a difference in adjacent channel rejection of 10 dB when comparing case 1 to case 2. Although the resistors are much smaller in the case 1 analysis, the noise contribution should not be ignored.

Even more significant than the agreement well outside of the loop bandwidth is the agreement near the loop bandwidth. Since the magnitude of the noise that falls near the loop corner is much larger than the noise far outside of the loop bandwidth, it contributes significantly to the RMS phase error and residual FM metrics. These metrics are very indicative of the performance degradations caused by frequency synthesizers in QAM and FM/FSK systems respectively. If the synthesizer noise were modeled without resistor noise, the results would be dramatically different, especially for case 2.

Reducing resistor and op-amp noise contributions

When designing a frequency synthesizer, there are



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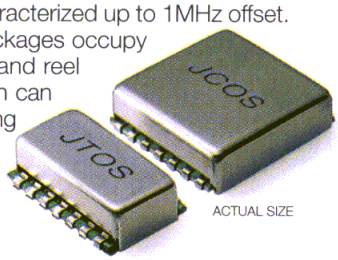

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JTOS-100	50-100	-108	-35	16V	18	13.95
JTOS-150	75-150	-106	-23	16V	20	13.95
JTOS-200	100-200	-105	-25	16V	20	13.95
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JTOS-1025	685-1025	-94	-28	16V	22	18.95
JTOS-1300	900-1300	-95	-28	20V	30	18.95
JTOS-1550	1150-1550	-101	-20	***	30	19.95
JTOS-1650	1200-1650	-95	-20	13V	30	19.95
JTOS-1750	1350-1750	-101	-16	***	30	19.95
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JTOS-1950	1550-1950	-103	-14	***	30	19.95
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Notes: *Prices for JCOS models are for 1 to 9 quantity. **Required to cover frequency range. ***Tuning Voltage for JTOS-3000 is 0.5 to 12V, JTOS-1550, JTOS-1750, and JTOS-1950 is 0.5 to 20V, and JCOS-820WLN and JCOS-1100LN is 0 to 20V. For additional spec information and details about 5V tuning models available, consult RF/IF Designer's Guide, our Internet Site, or call Mini-Circuits.

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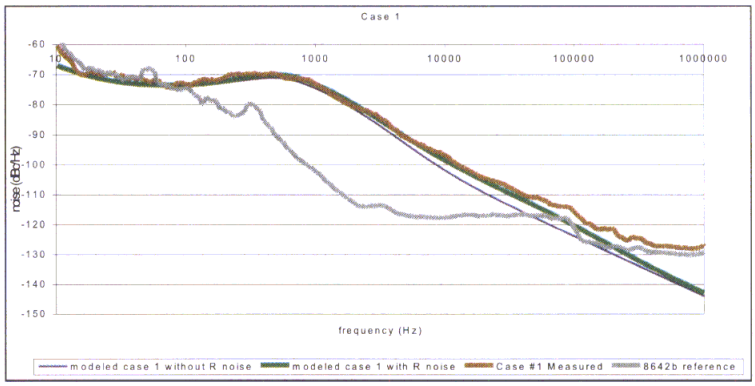
often several degrees of freedom that can be exercised in order to minimize the system phase noise. If there are no degrees of freedom, up-front design analysis will at least show an accurate prediction of the phase noise. This prediction may help to make system tradeoffs rather than sticking to a more stringent synthesizer specification.

In most synthesizer designs, it seems that R3 is typically the single most significant contributor to the resistor noise. This begs the question, "Is the third pole really needed?" If the reference suppression within the loop is sufficient without the third pole, it is in the designer's best interests to leave these parts out of the design. If this pole is required, the value of R_3 should be kept as small as possible without upsetting the basic filter response.



▲ **Figure 9. Measured and modeled phase noise of the example synthesizer, case 1.**

Some VCO designs themselves use resistors to supply the tuning voltage to the varactor (the similarity to the R_3 analysis is staggering). In many published VCO designs, large resistors are used to feed the varactor. This is a good choice for simple, and low-cost designs since resistors are inexpensive, resonance-free, and they don't typically degrade resonator Q if they're large relative to the other shunt resistances in the circuit. Resistors are hardly a good choice, however, if the tuning sensitivity (VCO gain) is high. The noise contribution by this resistor is proportional to its value alone in this case; a small resistor in series with a choke may be a good choice in many applications.

Op-amps, even if chosen carefully, represent significant contributions to phase noise. The synthesizer designer should be careful to determine whether an op-amp is truly required in order to meet the system requirements. If increased voltage is required, consider using an external charge pump with higher supply voltages (some synthesizer ICs still support the connections required for using an external charge pump). Obtaining good balance in an external charge pump can be difficult, leading to increased reference spurs and power supply noise at the reference frequency. A low noise charge pump potentially offers reduced noise over the op-amp, as the tuning voltage range can be increased with a designer-chosen charge pump current. This represents two degrees of freedom: lower tuning sensitivity and reduced resistor values due to potentially increased current. It would be excellent if the available synthesizer chips allowed for higher tuning voltages or specifically allowed for simple implementations of well-balanced external charge pumps.

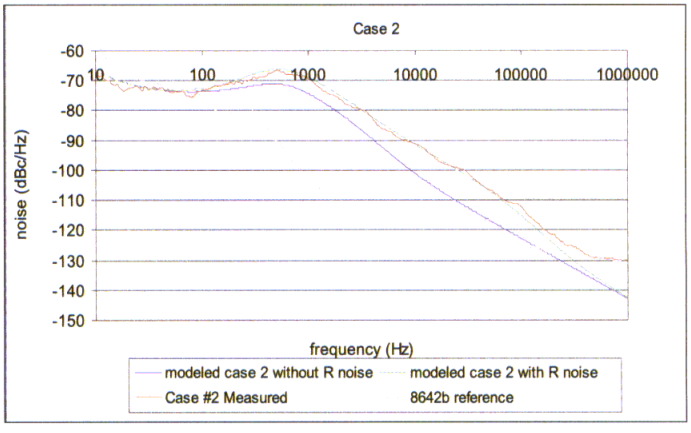
Reducing the VCO tuning sensitivity is another way to reduce the overall noise. This needs to be analyzed on a case-by-case basis, however, since the loop filter resistor values will increase with reduced tuning sensitivity. Any fixed magnitude noise sources in the loop will also drop proportionally with the VCO tuning sensitivity.

One particular option the author feels worthy of exploration is increasing charge pump current. With increased charge-pump current, the impedance (hence resistance) in the loop drops. If your synthesizer has a programmable charge pump current setting, leaving it at maximum is best in order to reduce the resistor noise contribution.

Each of the suggestions presented carries with it some design implication that needs to be carefully evaluated before tradeoffs are made. In some designs, simply increasing charge-pump current or eliminating the 3rd pole used for reference attenuation could yield dramatic improvement.

Conclusion

In order for designs to meet the increasingly demanding performance requirements in the wireless arena, a detailed understanding of every component is critical. While relatively simple, the models presented have demonstrated excellent accuracy when compared to experimental data. These circuit models represent new tools that enable the designer to make important tradeoffs during the initial synthesizer design phase, rather than on the bench using empirical and time-consuming techniques. ■



▲ **Figure 10. Measured and modeled phase noise of the example synthesizer, case 2.**

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Acknowledgements

I would like to thank John Barenys of Adaptive Broadband for writing the phase noise curve acquisition program for the PC, which were invaluable in the preparation of this article. Thanks also to Dean Banerjee of National Semiconductor for providing many insightful email discussions and critiques of the work presented here. The support of Adaptive Broadband and numerous discussions with my fellow employees were very valuable during the preparation of this work. I also appreciate the efforts of the many people who helped by reviewing this article.

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Author information

Lance Lascari is a Principal Engineer at Adaptive Broadband Corporation in Rochester, NY. He has been working as an RF designer on the company's QAM Point-Point and FSK Point-Multipoint products for the past five years. He earned a BSEE from the Rensselaer Polytechnic Institute in 1995. His professional interests include low-noise synthesizer and VCO design, design for high linearity, and low-cost transceiver design. He may be reached via email at llascari@adaptivebroadband.com, or through his web page: http://home.rochester.rr.com/lascari.

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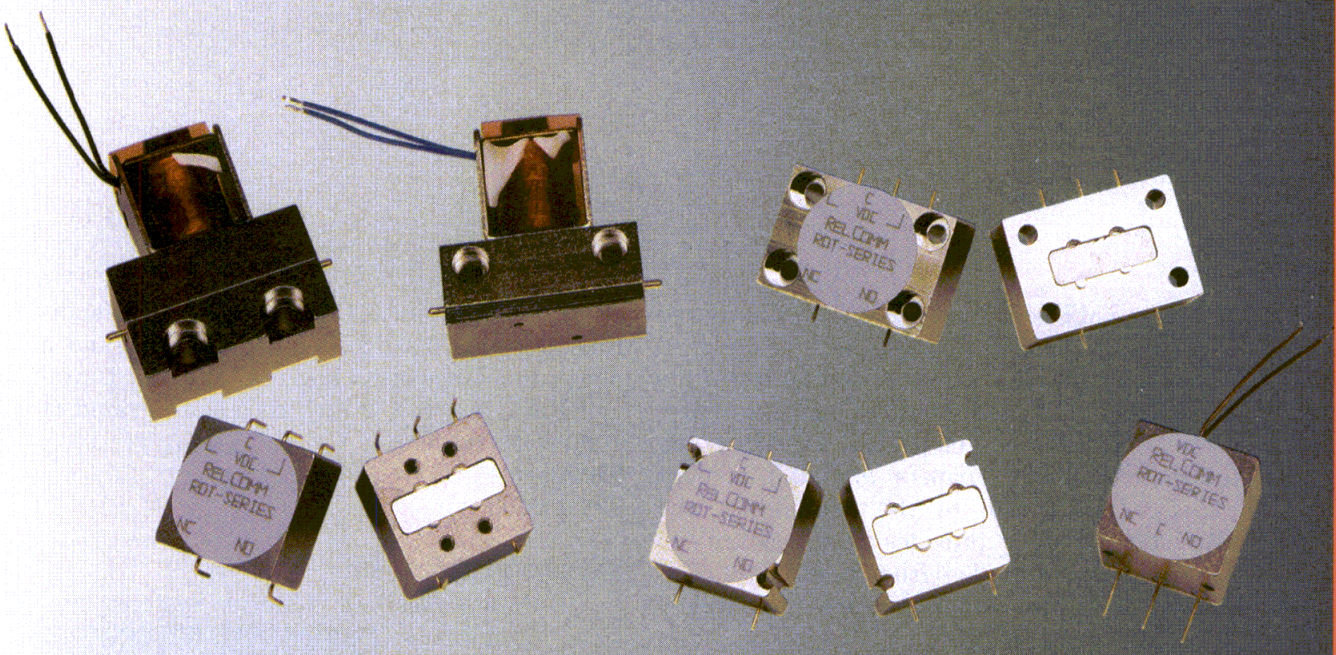

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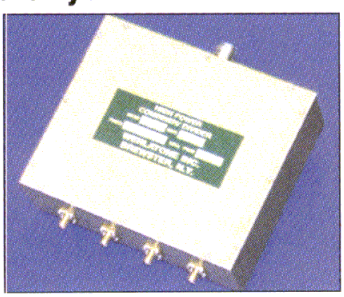

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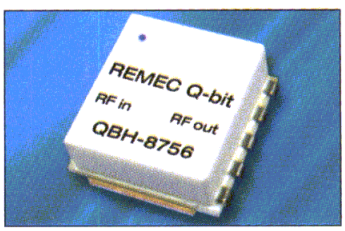

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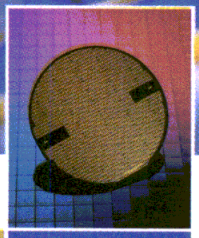

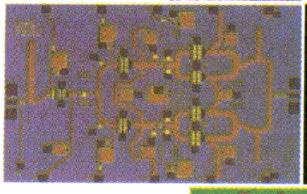

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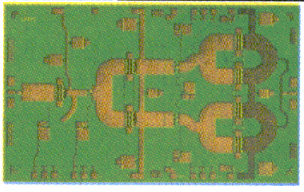

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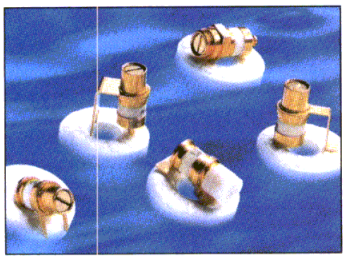

Johanson Manufacturing
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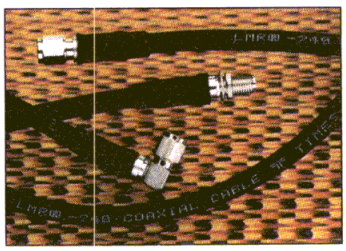
SMA connectors fit LMR-240 cables

Times Microwave Systems now offers SMA male straight and right angle and SMA female bulkhead connectors for its LMR-240 flexible coaxial cable. The connectors are fabricated from passivated stainless steel with gold-plated solder-pin contacts and crimp-style outer conductor attachment rings. The connectors are designed to operate at frequencies up to 18 GHz. LMR-240 cables are flexible, non-kinking RF transmission lines suitable for antenna feeders, system jumpers and interconnects.



Times Microwave Systems
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75 ohm directional couplers

Mini-Circuits announces immediate availability of the new 5 MHz to 1000 MHz ADC-16-4-75 directional couplers. These wideband 1-watt (max.) units provide a nominal coupling value of 16.2 dB ±0.5 dB and ±0.1 dB flatness for CAV applications. The couplers are water-washable and feature a low 0.108 inch profile. Typical insertion loss is 0.6 dB and midband directivity is 30 dB. The ADC-16-4-75 is priced at $6.95 each in quantities of 10 to 49 units.

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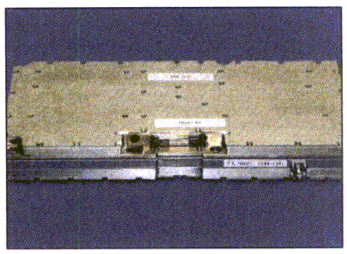

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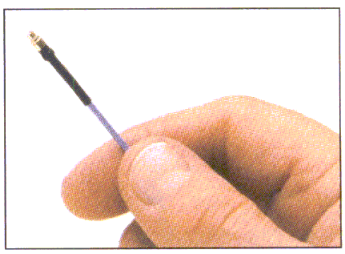

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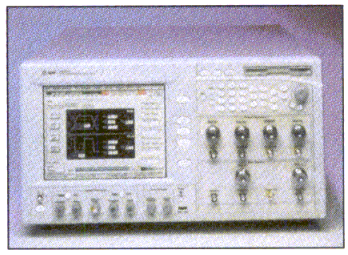

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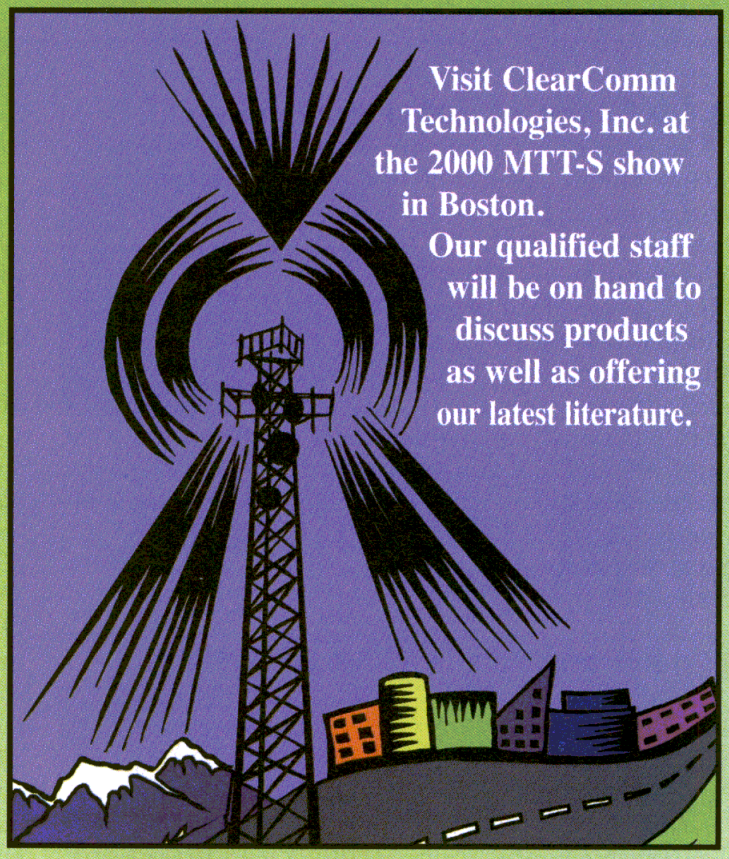

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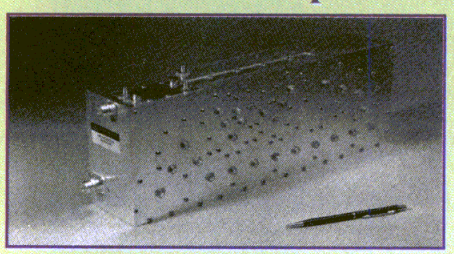

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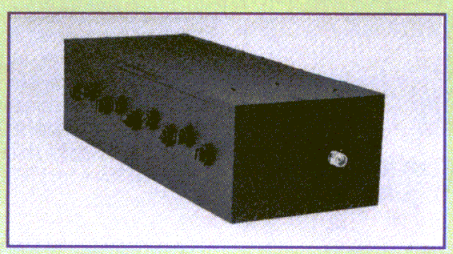
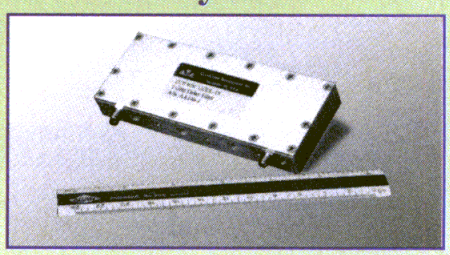


Delay Filter



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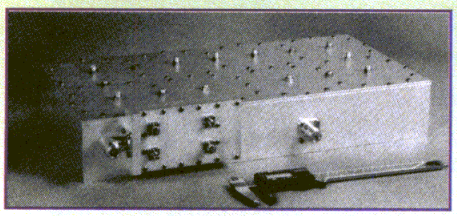
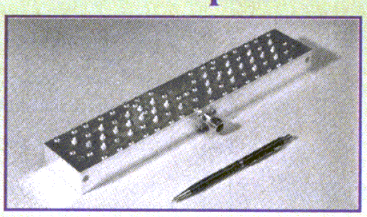
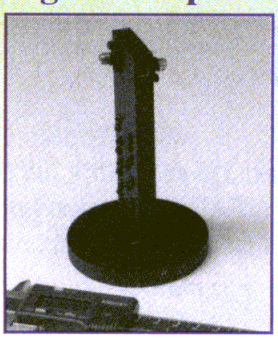


2.4/5.8 Duplexers



Waveguide/Duplexers



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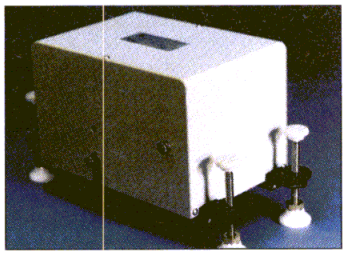
Circle 62

50 GHz 2.4 mm automated tuner

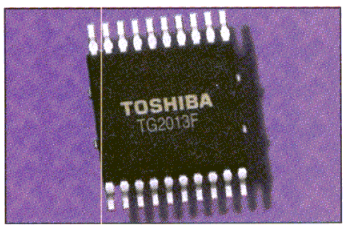
Maury Microwave announces the MT984A, a high frequency tuner capable of presenting a high mismatch of 15:1 over the frequency range of 8 to 50 GHz. Designed to work with the MT980 series of automated tuner system (ATS), the new tuner provides additional capabilities for high mismatch. The tuner systems are designed to perform noise, power, intermodulation and adjacent channel measurements used for device characterization and circuit design.



Maury Microwave
Circle #197

GaAs HBT amplifiers for PCS-band CDMA

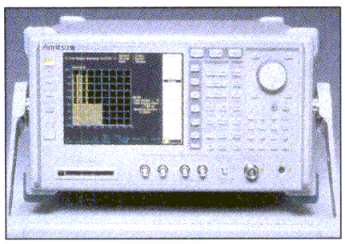
Toshiba has introduced the TG2013F, a GaAs HBT MMIC device providing +29 dBm power for 1.9 GHz CDMA systems. The device operates from a single 3.6 volt supply with 24 dB gain and efficiency up to 30 percent. The combination of HBT power amplifier and bias circuit maintains a low VSWR and minimizes total parts count in the application circuit. The TG2013F is housed in a 20-pin high power HSOP package and is priced at $4.50 each in quantities of 1,000.



Toshiba America Electronic Components
Circle #198

Single-instrument tester for 3GPP W-CDMA

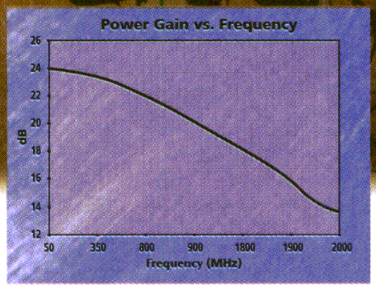
Anritsu Company announces the MS8608A, an instrument that combines a transmitter tester, power meter and spectrum analyzer for the analysis of 3GPP W-CDMA signals. The MS8606A covers 9 kHz to 7.8 GHz and features an analysis bandwidth of 20 MHz, power measurement accuracy of ±0.4 dB and adjacent channel power of –68 dBc at 5 kHz and –75 dBc at 10 MHz offset. Power measurement can use either the sweep or filter method.

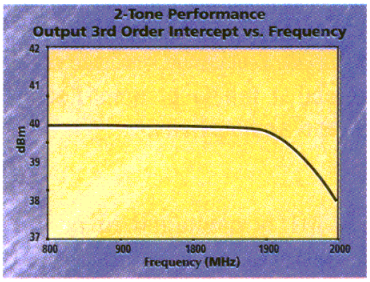


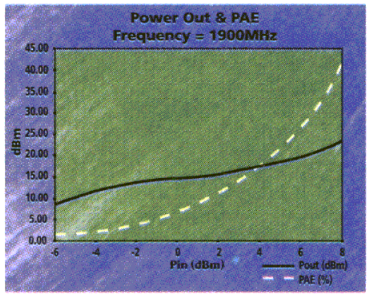
Anritsu Company
Circle #199

NEW! SXH-1 High Linearity Power Amplifier

Stanford Microdevices







Stanford Microdevices produces the highest performance products utilizing cutting edge technology at the lowest possible cost. All Stanford MMICs are 100% tested and qualified annually to ensure reliable field performance even under the harshest environments, making Stanford Microdevices a favorite among major OEMs worldwide. Over the past five years Stanford Microdevices has become the preeminent leader in the design and manufacturing of GaAs, LDMOS and SiGe amplifier and switch products.

Offering significant advantages over existing competitive MESFET technology, the SXH-1 is a highly efficient GaAs Heterojunction Bipolar Transistor power amplifier housed in a low-cost surface-mountable plastic package.

This GaAsHBT amplifier is fabricated using molecular beam epitaxial growth technology, which produces reliable and consistent performance from wafer to wafer and lot to lot. The SXH-1 was specifically designed for use as drivers stages for infrastructure equipment in the 50-2000MHz cellular, ISM and narrowband PCS bands. Operating at a stingy 95ma of current, the SXH-1 is an ideal choice for multi-carrier as well as digital applications.

Performance Matrix
SXH-1

Freq. (MHz)	Gain (dB) Typ.	S11 Typ.	S22 Typ.	P1dB (dBm)	TOIP (dBm)	Voltage	Current (mA) Typ.
800-960	20.0	1.5:1	1.9:1	22.0	39.0	5.0	95.0
1800-2000	14.5	1.5:1	1.7:1	22.0	39.0	5.0	95.0

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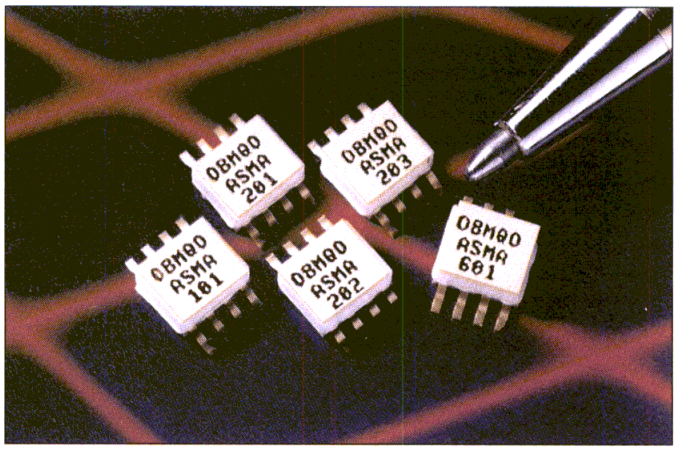
Hybrid Amplifiers Simplify 1 to 1000 MHz Medium Power Applications

A new family of hybrid amplifiers from Avnet Microwave Technical Solutions (Avnet MTS) allows designers to obtain up to +30 dBm P_{1dB} in a single impedance-matched surface mount package. With broad bandwidths extending from 1 MHz to beyond 1 GHz, the amplifiers fit into many wireless applications in digital radios, base stations and repeaters.

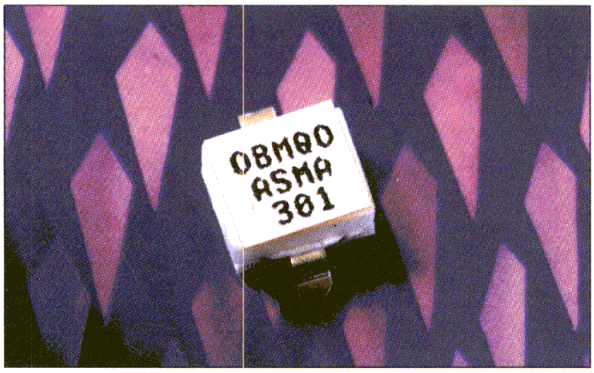
Five amplifier models are offered in an 8-pin SOIC ceramic package. Models ASMA-101 and ASMA-201 cover 1 to 500 MHz, ASMA-202 covers 1 to 200 MHz, ASMA-203 covers 1 to 300 MHz and ASMA-601 covers 1 to 500 MHz. Depending on the model, nominal gain ranges from 11 to 13 dB, with typical power output (P_{1dB}) from +22 to +30 dBm.

For higher frequencies, the ASMA-301 covers 1 to 1000 MHz, or higher frequencies with external matching. The device offers 10.5 dB nominal power gain with a typical P_{1dB} of +28 dBm. The ASMA-301 is packaged in an industry-standard 2-lead ceramic surface mount package. Pricing of this amplifier model is as low as $41 in quantity.

All amplifiers are available in tape-and-reel for automated manufacturing, with most models available from stock. Data sheets can be downloaded from the company's Web site. ■



▲ **Avnet MTS has introduced a family of amplifiers well-suited for many broadband applications.**



▲ **The ASMA-301 covers 1 to 1000 MHz as a 50-ohm matched part, and is usable to beyond 2000 MHz with simple external matching.**

For more information, contact:

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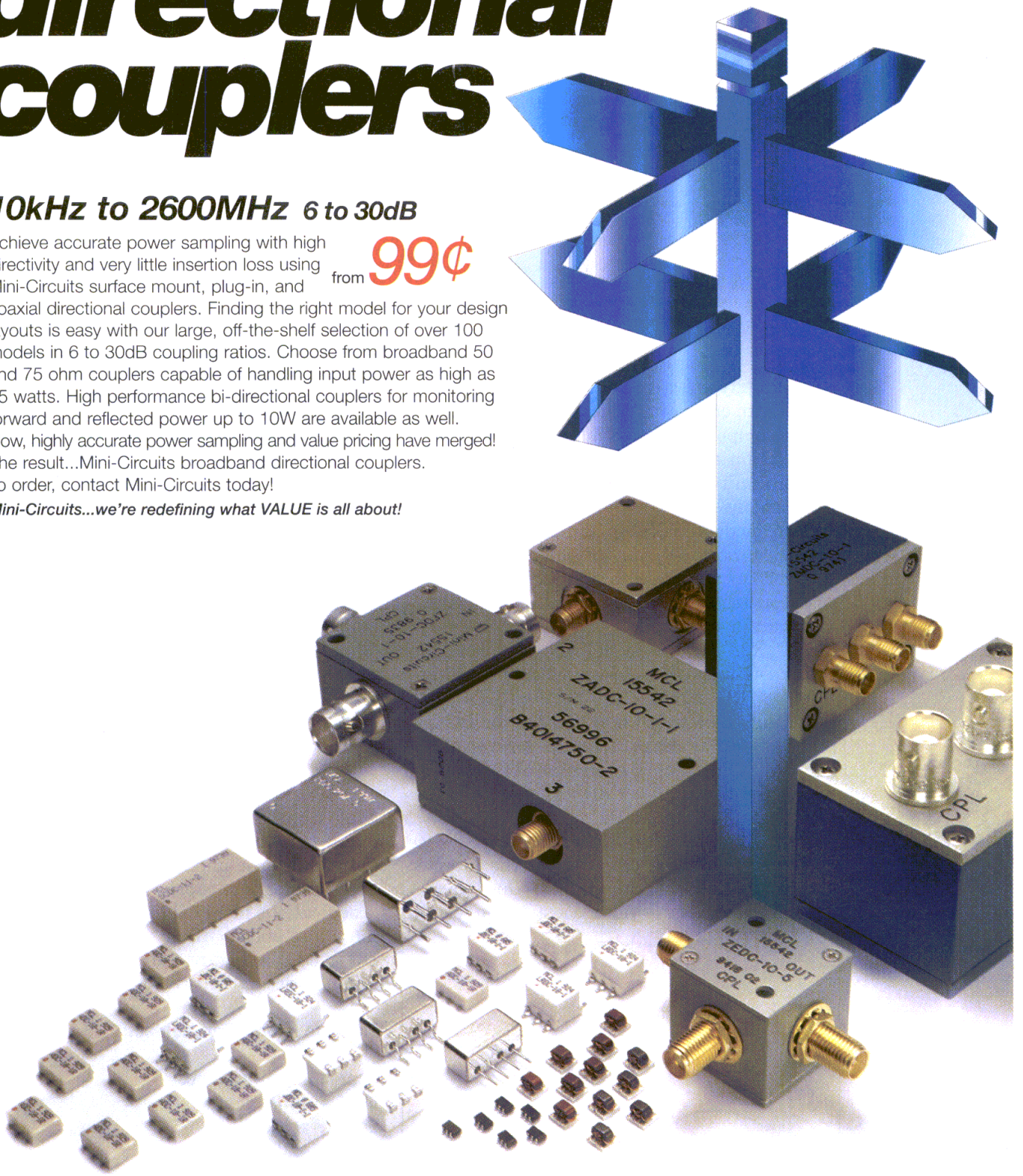

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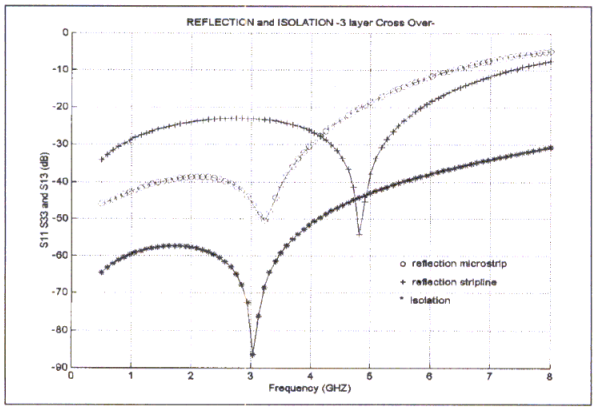
Chip RF Crossovers can Eliminate Need for Multi-Layer P.C. Boards

Anaren Microwave announces a simple, yet highly effective solution for DC and RF path crossovers. The Xinger® crossover is a chip component with a matched transmission line section that provides low loss, repeatable RF continuity with the convenience of automated assembly.

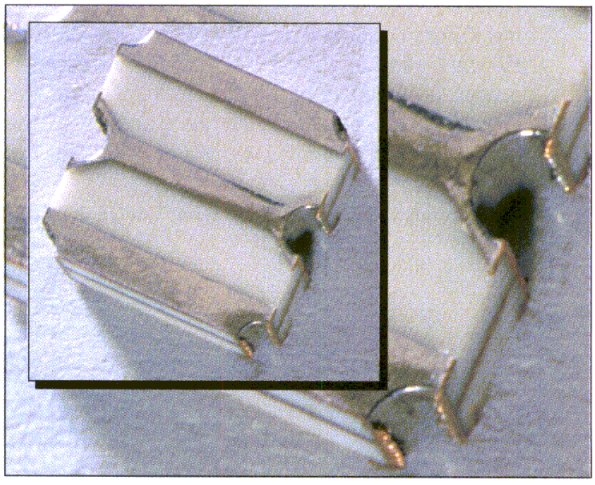
Two models make up the Xinger crossover line, a 50 ohm RF-over-RF component and an RF-over-DC model. Both are 0.2 × 0.2 inch in size, constructed using Rogers® 4350 dielectric and multilayer design.

The X2A RF-DC model allows normal on-board DC lines to be used, while providing a shielded RF signal path over the DC line. Sufficient trace width is permitted for DC current up to 10 amps. The RF travels on a microstrip line with a minimum return loss of 20 dB and less than 0.1 dB loss over the specified range of DC to 6 GHz.

Model X2B is the RF-RF version of the device, enabling an isolated crossover at the intersection of two RF-carrying traces. One trace is routed through the device via a stripline section, while the other is routed over the top on a microstrip line. Normally, the higher power signal will use the microstrip path, with its better heat dissipation capability. The X2B has RF specifications identical to the X2A: 0.1 dB maximum loss and 20 dB or better return loss from DC to 6 GHz. Figure 1 shows the measured isolation between the two RF signal paths. ■



▲ **Figure 1. Isolation between the X2B signal paths.**



▲ **Anaren's Xinger crossover is a simple solution for RF and microwave board layout problems.**

For more information, contact:

Anaren Microwave, Inc.
6635 Kirkville Road
East Syracuse, NY 13057
Tel: 315-432-8909
Fax: 315-432-9121
Internet: www.anaren.com

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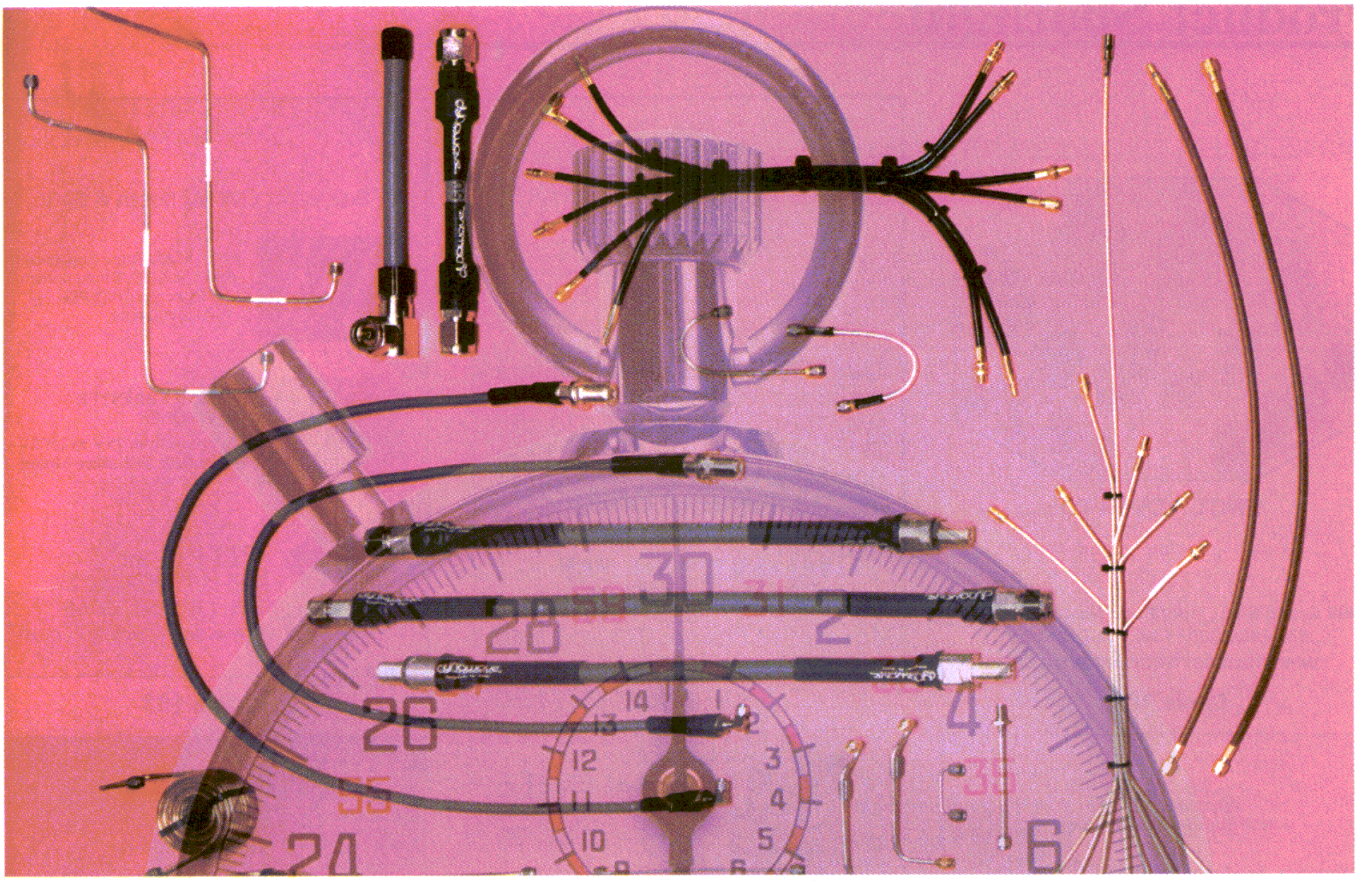

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Our Classifieds section is the place to advertise career opportunities, consulting services, used test equipment and just about anything else. Special Classifieds rates are available and are agency-commissionable if material is supplied. Or, if you prefer, our staff can make up the ad for you.

Classified display ads are available in color or black and white in standard ad sizes, or in black and white by column inch. (Column-inch ads are 2-1/4 inches wide.)

For more information on advertising in these two sections, please contact Applied Microwave & Wireless, 4772 Stone Drive, Tucker, GA 30084; Tel: (770) 908-2320; Fax: (770) 939-0157; E-mail: amw@amwireless.com

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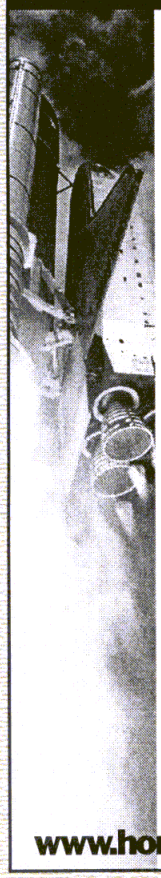

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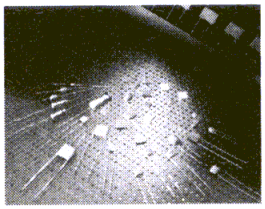

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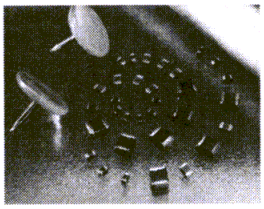

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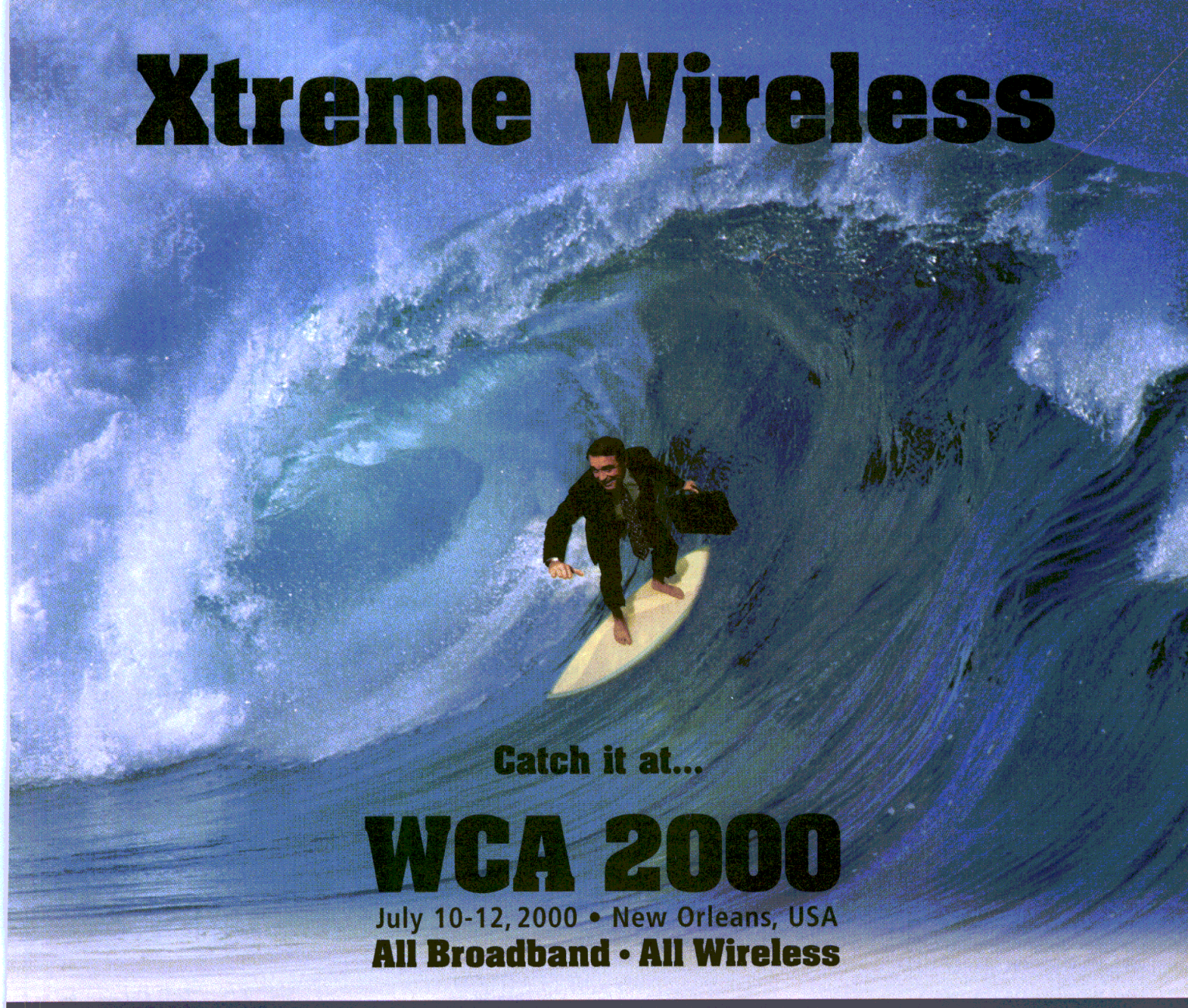
July	6-1-2000	Wireless Data Impedance Matching GaAs and SiGe Technologies	
August	7-3-2000	Wireless Broadcasting Oscillator Products, Using Distributors	RAWCON 2000
September	8-1-2000	Wireless Chipsets Noise Analysis Education Update	European Microwave

Materials due one week following space deadline

Xtreme Wireless



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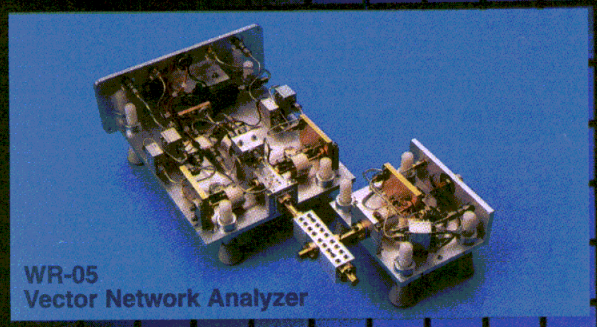

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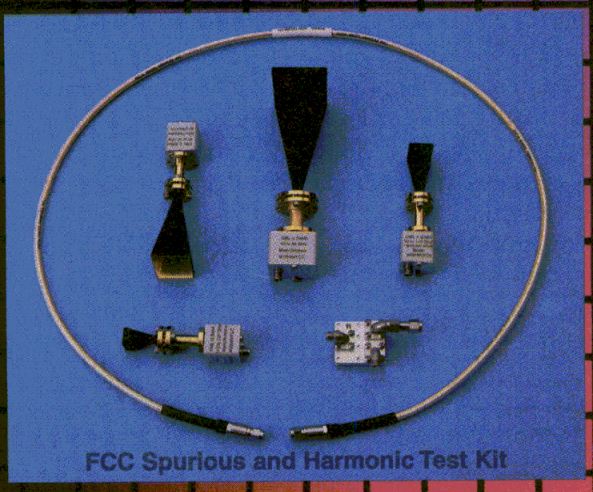
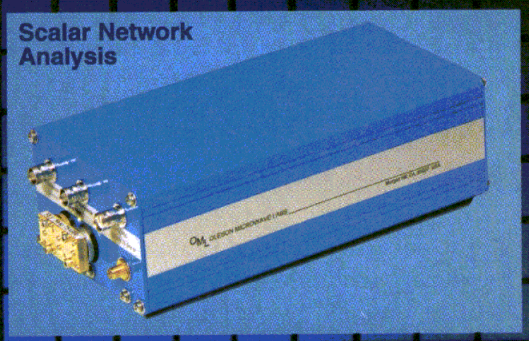
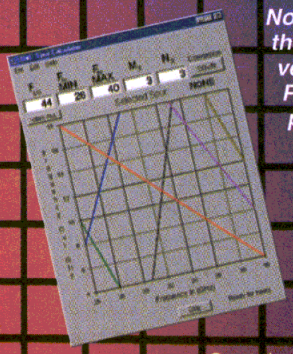


FCC Spurious and Harmonic Test Kit for use with popular Spectrum Analyzers. Each kit contains four mixers providing continuous coverage from 40 to 220 GHz. Each mixer is equipped with an appropriate horn antenna for accomplishing the FCC desired radiated spurious level measurement. Shown with optional diplexer and cable.



Scalar Network Analysis (SNA) Systems and Multiplier Sources Complete SNA systems containing filtered multipliers with –50 dBc spurs and harmonics. Included are a dual directional coupler and detectors for reference, reflection and transmission. Available for WR-22 through WR-10. Filtered Multiplier Sources are also available without the coupler or detectors. Multiplier Sources are available without filtering for the WR-08 through WR-05 waveguide bands. All of these products are engineered to extend the user's 8 to 20 GHz equipment.

Harmonic Mixers Use with popular Spectrum Analyzers to achieve millimeter wave spectrum analysis. Mixers are available for all waveguide bands from 18 to 325 GHz. LO/IF diplexers are available for most modern spectrum analyzers. Measured conversion loss data supplied with emulation of most modern spectrum analyzers for WR-42 through WR-10.



Now available free at the OML Web Site is the Windows™ compatible, block converter "Spurious Product Prediction Program" illustrated to the left. With this program, engineers can examine their block converter designs for harmful spurious responses.

Also contained on the Web Site are complete specifications for all of the above millimeter wave frequency extension products as well as technical papers addressing many of the more common millimeter wave testing problems. Contained in these papers are many useful millimeter wave charts and graphs not found elsewhere.

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The Software Defined Radio: A New Technology Challenge

The software defined radio (SDR) is a "next generation" technology that is already seeing limited use, enabled by recent advances in the computational power and/or power consumption of digital signal processing (DSP) devices. The value of SDR is that it can be reconfigured at any time to match the transmission standards of any communication system.

SDR is the ultimate in flexibility, allowing access to multiple standards. For example, it may be implemented in a wireless handset that can operate with any cellular standard. With this technology, true nationwide or worldwide coverage is possible. Improvements and upgrades can also be accommodated by simple software changes that can be automatically downloaded via the service network whenever necessary.

A more powerful use of SDR is in adaptive systems. During times of heavy usage, a base station could change to a more spectrum-efficient or interference-resistant mode, instructing each handset to change programming to be compatible. During times of low usage, a mode with wider bandwidth would be available for increased data capabilities or faster Internet access.

DSP is the enabling technology

Reprogrammability of complex digital transmission formats requires a great deal of computing power. DSP devices from major semiconductor vendors are now being developed with SDR in mind. Fortunately, other communications services such digital television (DTV), digital cable and digital subscriber line (DSL) also require powerful DSP to make them work effectively. The leverage of several key applications is a great incentive for DSP manufacturers to push development.

DSP development is proceeding in three directions — raw power, low cost and low power consumption. The maximum processing power is needed for base stations and central processing locations for all the services just mentioned. Low power consumption is necessary for portable devices that need significant computational power, but also must keep customers happy with long talk time and standby time. Of course, the lowest cost is a necessity for mass-market products, from handsets to set-top boxes to DSL user modems.

SDR is a regulatory challenge

At present, technical regulations (by the Federal Communications in the U.S.) address single transmission formats and equipment configured specifically for one service, such as a DTV transmitter or CDMA PCS base station. To address new SDR technology, the FCC has issued a Notice of Inquiry, inviting interested parties to contribute to these specific areas of discussion:

- How does SDR improve "interoperability" among communications systems operating in multiple frequency bands using different transmission standards?
- How would SDR improve spectrum efficiency and spectrum sharing? For example, can such equipment monitor activity and choose an open frequency? If so, how does it identify itself to other users regarding the frequency and modulation scheme it is using?
- What are the implications of SDR on equipment authorization systems and interference control? Should the radio hardware, software or both be required to show compliance with FCC standards?
- How will SDR require changes in the FCC's traditional approaches to spectrum management? How should the FCC facilitate experimentation and eventual deployment of these devices?

In an address to the IEEE Radio and Wireless Conference (RAWCON) in August 1999, FCC Chief of the Office of Engineering and Technology, Dale Hatfield stated that the software defined radio was one of two great technical challenges that the FCC must address in the near future (the other is ultra-wideband technology). Hatfield observed that SDR will unquestionably require changes to the FCC's traditional approach to technical regulations.

The magnitude of this revelation should not be understated — SDR is a developing technology that will alter the way the radio spectrum is utilized for both existing and new communications needs.

How soon will changes occur?

The technical means are now available. Systems have been demonstrated that can adapt to two or more similar wireless modulation schemes. In the past six months, advances in DSP technology have been announced that would support most practical SDR implementations. Wideband radio front-ends have been around for many years in test equipment, military systems and scientific equipment. Like all wireless developments, SDR will find that its practical implementation will follow technical and regulatory issues, with its market acceptance controlled by cost and perceived value. ■

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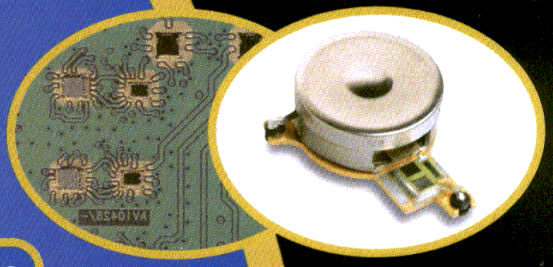

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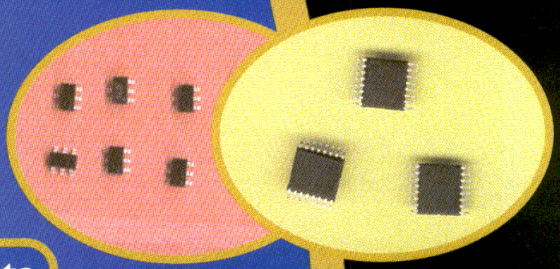

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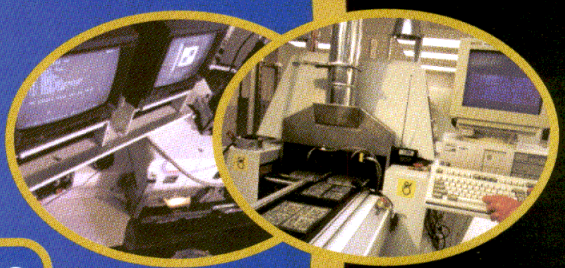

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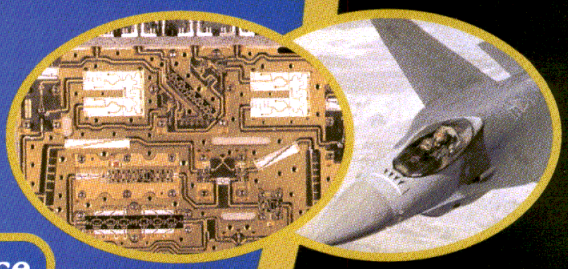

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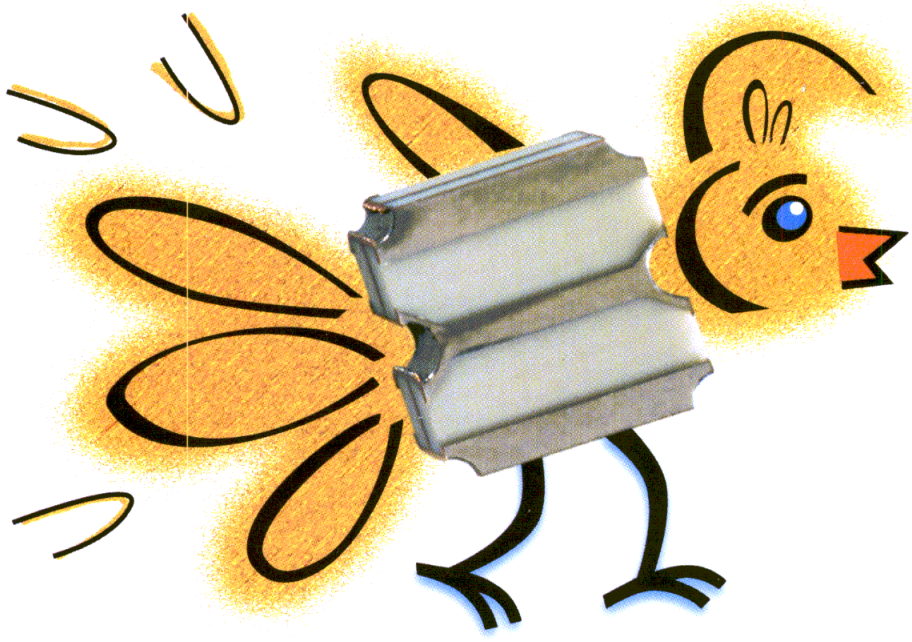

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