April 2000

Applied MICROWAVE & WIRELESS

www.amwireless.com

Product Focus — New Test Equipment for RF, Microwave and Wireless Communications

Design Case History

Design of PHEMT Frequency Triplers with Conversion Gain

Analytical Techniques

Accurate Phase Noise Prediction in PLL Synthesizers

Circuit Design

Design of Baluns Using Backward Wave Couplers

What Do These Numbers Mean to You?

2.4 2.9 3.5 7.0

- ❑ A. Legal Alcohol Content in California Beer?
- ❑ B. Your College Grade Point Average?
- ❑ C. Designations for Hard-to-Find High-Frequency Connectors and Adapters!

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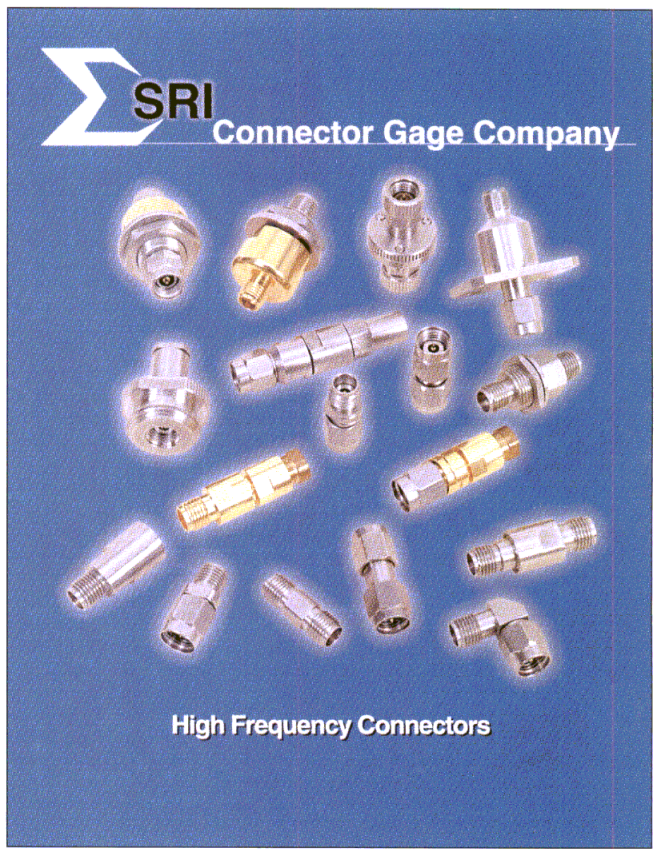

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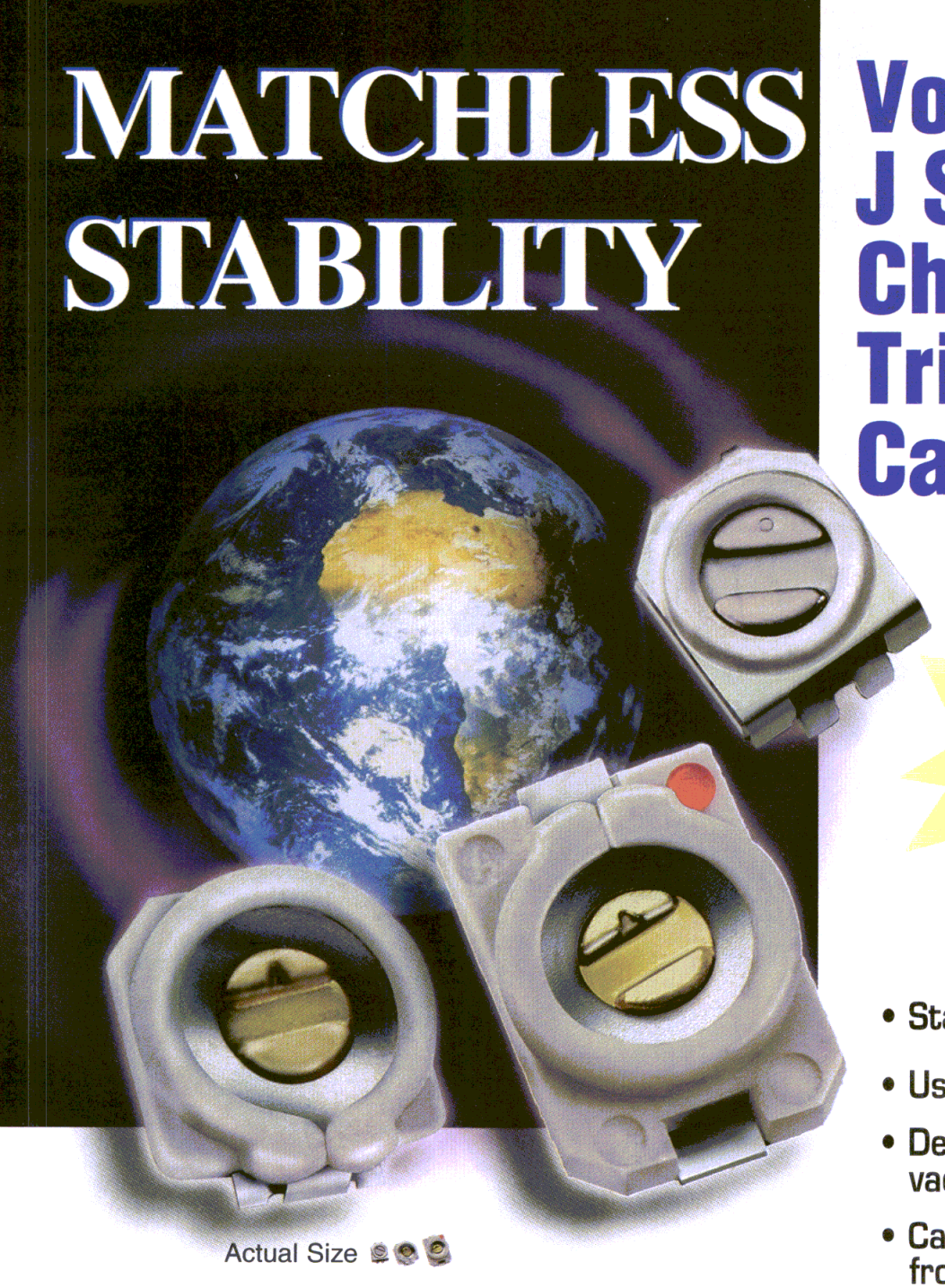
Circle 10

MATCHLESS STABILITY

Voltronics J Series Chip Trimmer Capacitors



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- Usable to over 1 GHz
- Designed for reliable vacuum pickup
- Capacitance ranges from 0.4 - to 40 pF

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Circle 17

THE WORLD'S LARGEST SELECTION

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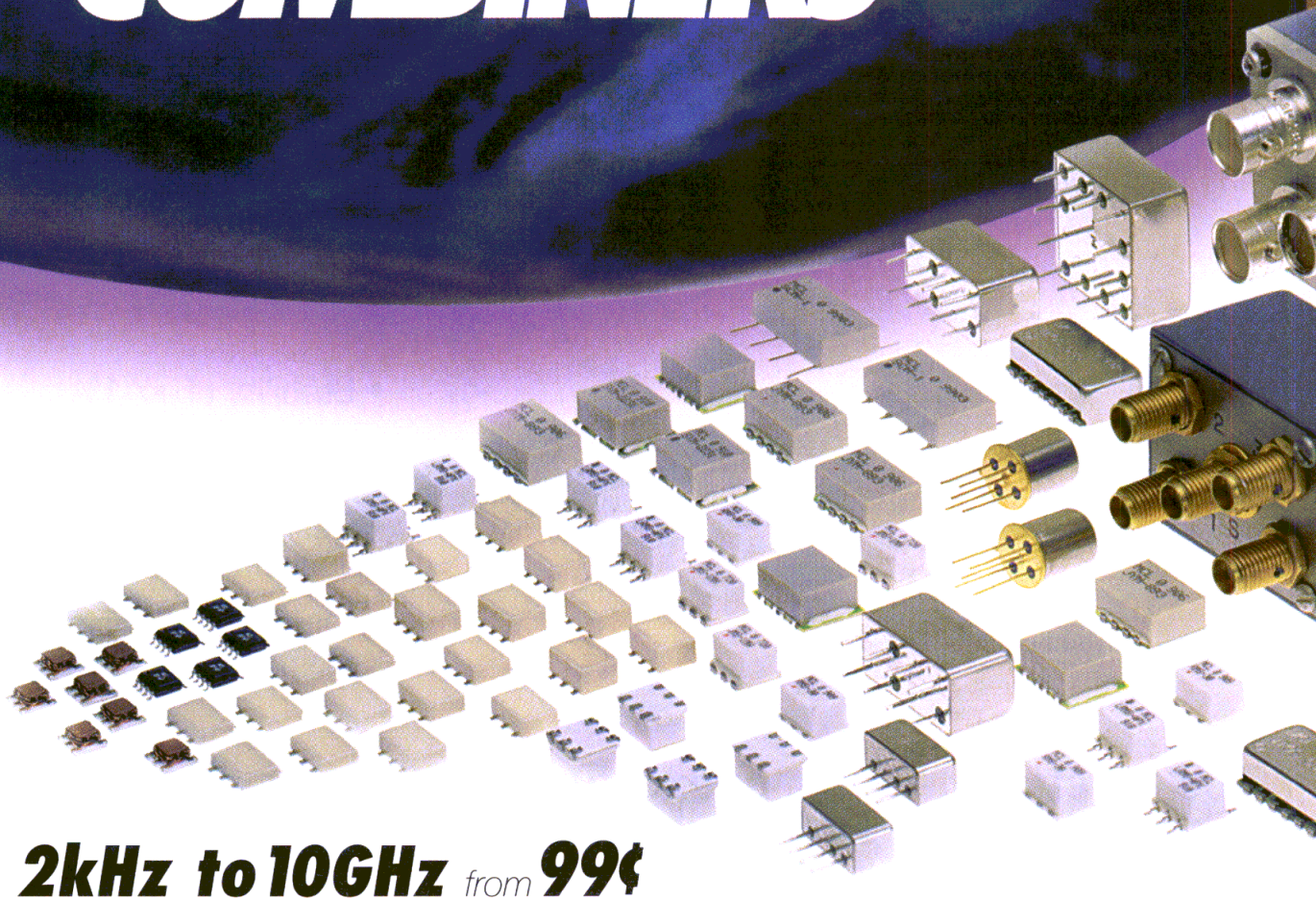

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Choose from over 550 standard off-the-shelf models from 2way and 3way to 48way; 0°, 90°, and 180°; 50 and 75 ohms covering 2kHz to 10GHz. Mini-Circuits will also supply your special needs and custom designs such as wider bandwidths, higher isolation, lower insertion loss and phase matched ports...all at catalog prices with rapid turnaround time. Case styles include surface mount, plug-in, flat pack, and coaxial connectorized... and custom case styles are no problem! Super-miniature and ultra-low profile surface mount units provide excellent solutions in cellular communications, cable systems, and countless wireless applications. And all units come with a 1 year guarantee and skinny 4.5 sigma performance repeatability unit-to-unit and production run to production run. Add fast delivery, unsurpassed applications support and value pricing, and the decision is easy. Call Mini-Circuits today!

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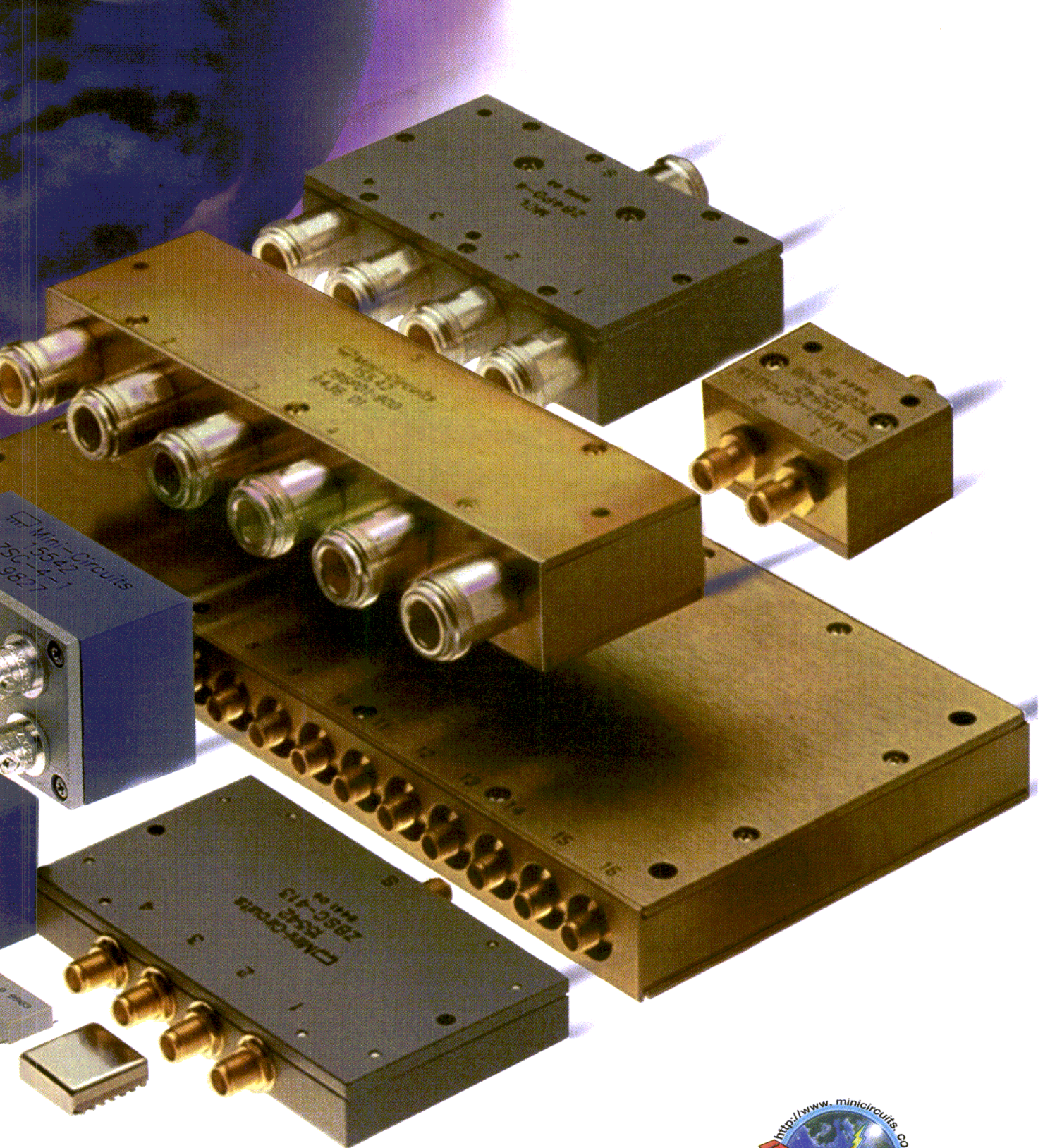

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For detailed specs on all Mini-Circuits products refer to • 760- pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM

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F 194 Rev B

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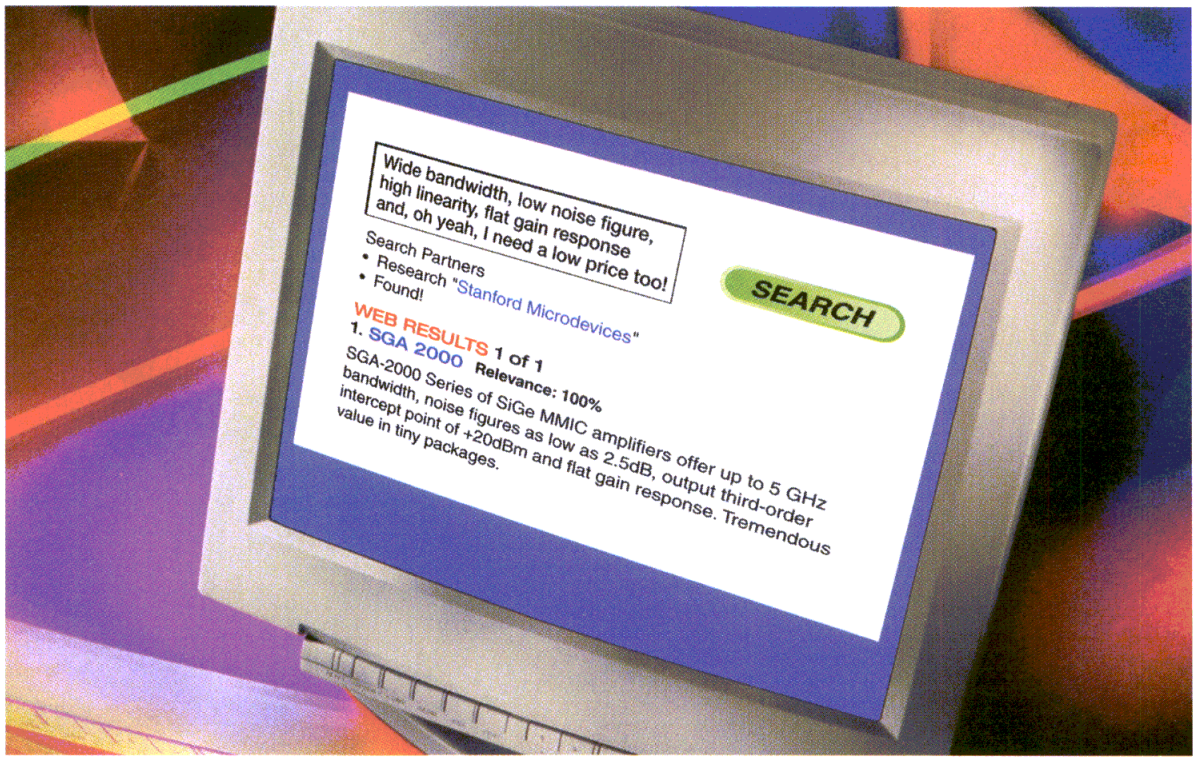

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Stanford Microdevices, Inc. (SMI) is a leading supplier of RF integrated circuits for the wireless and wired telecommunications markets and a supplier of choice of OEMs worldwide. Stanford Microdevices continues to be on the industry's leading edge because of our superior quality, outstanding value and innovative technological advances. SMI develops and markets the components needed to create wireless communications equipment that is smaller, lighter, more powerful and priced right.

SGA-2000 product family offers wideband operation of up to 5 GHz, high output linearity, flat gain response and low noise figure with very low power consumption. These devices are available in industry standard SOT-363 and 85mil plastic packages from stock to eight weeks.

SPECIFICATION MATRIX

	SGA-2163 SGA-2186	SGA-2263 SGA-2286	SGA-2363 SGA-2386	SGA-2463 SGA-2486
Frequency (GHz)	DC-5.0	DC-3.5	DC-2.8	DC-2.0
Gain (dB)	10.5	15.0	17.4	19.6
TOIP (dBm)	20.0	20.0	20.0	20.0
P1dB (dBm)	7.0	7.0	7.0	7.0
N.F. (dB)	4.1	3.2	2.9	2.5
Supply Voltage (Vdc)	2.2	2.2	2.7	2.7
Supply Current (mA)	20	20	20	20

All data measured at 1GHz and is typical. MTTF @ 150C T_j = 1 million hrs. (R_{TH} = 97C/W typ)

SiGe HBT MMIC
features include:

- Cascadable 50Ω
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86 package


SOT-363 package

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Circle 36

NEW! SXH-1 High Linearity Power Amplifier

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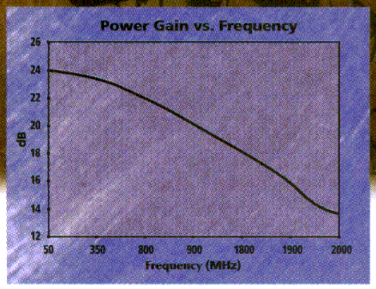

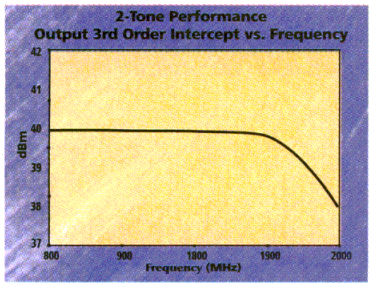

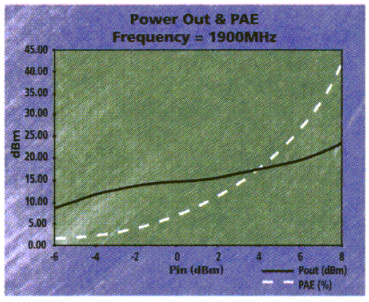

Stanford Microdevices produces the highest performance products utilizing cutting edge technology at the lowest possible cost. All Stanford MMICs are 100% tested and qualified annually to ensure reliable field performance even under the harshest environments, making Stanford Microdevices a favorite among 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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Circle 56

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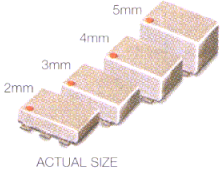
innovative technology

Searching high and low for a better frequency mixer? Then take a closer look at the Innovative Technology built into Mini-Circuits ADE mixers. ***Smaller size*** is achieved using an ultra-slim, patent pending package with a profile as low as 0.080 inches (2mm) in height. Electrically, ADE mixers deliver ***better performance*** than previous generation mixers through all welded connections and unique assembly construction which reduces parasitic inductance. The result is dramatically improved high frequency and IP2-IP3 performance. Plus, ADE's innovative package design allows water wash to drain and eliminates the possibility of residue entrapment. Another ADE high point is the ***lower cost***...priced from only $1.99 each (qty.10-49). So, if you've been searching high and low for a mixer to exceed expectations...ADE is it™



ACTUAL SIZE

ADE Mixers...Innovations Without Traditional Limitations!

ADE* TYPICAL SPECIFICATIONS:

Model	Height (mm)	Freq. (MHz)	LO (dBm)	Conv. Loss Midband (dB)	L-R Isol. Bandwide (dB)	IP3 (dBm) @ Midband	Price ($ea.) Qty. 10-49
ADE-1L	3	2-500	+3	5.2	55**	16	3.95
ADE-3L	4	0.2-400	+3	5.3	47**	10	4.25
ADE-1	4	0.5-500	+7	5.0	55**	15	1.99
ADE-1ASK	3	2-600	+7	5.3	50**	16	3.95
ADE-2ASK	3	1-1000	+7	5.4	45**	12	4.25
ADE-6	5	0.05-250	+7	4.6	40	10	4.95
ADE-12	2	50-1000	+7	7.0	35	17	2.95
ADE-4	3	200-1000	+7	6.8	53**	15	4.25
ADE-14	2	800-1000	+7	7.4	32	17	3.25
ADE-901	3	800-1000	+7	5.9	32	13	2.95
ADE-5	3	5-1500	+7	6.6	40**	15	3.45
ADE-13	2	50-1600	+7	8.1	40**	11	3.10
ADE-20	3	1500-2000	+7	5.4	31	14	4.95
ADE-18	3	1700-2500	+7	4.9	27	10	3.45
ADE-3GL	2	2100-2600	+7	6.0	34	17	4.95
ADE-3G	3	2300-2700	+7	5.6	36	13	3.45
ADE-28	3	1500-2800	+7	5.1	30	8	5.95
ADE-30	3	200-3000	+7	4.5	35	14	6.95
ADE-32	3	2500-3200	+7	5.4	29	15	6.95
ADE-35	3	1600-3500	+7	6.3	25	11	4.95
ADE-18W	3	1750-3500	+7	5.4	33	11	3.95
ADE-30W	3	300-4000	+7	6.8	35	12	8.95
ADE-1LH	4	0.5-500	+10	5.0	55**	15	2.99
ADE-1LHW	3	2-750	+10	5.3	52**	15	4.95
ADE-1MH	3	2-500	+13	5.2	50**	17	5.95
ADE-1MHW	4	0.5-600	+13	5.2	53**	17	6.45
ADE-12MH	3	10-1200	+13	6.3	45**	22	6.45
ADE-25MH	3	5-2500	+13	6.9	34**	18	6.95
ADE-35MH	3	5-3500	+13	6.9	33**	18	9.95
ADE-42MH	3	5-4200	+13	7.5	29**	17	14.95
ADE-1H	4	0.5-500	+17	5.3	52**	23	4.95
ADE-10H	3	400-1000	+17	7.0	39	30	7.95
ADE-12H	3	500-1200	+17	6.7	34	28	8.95
ADE-17H	3	100-1700	+17	7.2	36	25	8.95
ADE-20H	3	1500-2000	+17	5.2	29	24	8.95

Component mounting area on customer PC board is 0.320"x 0.290".
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April 2000
Vol. 12 No. 4

CONTENTS

TECHNICAL FEATURES

PRODUCTS & TECHNOLOGIES

Applied MICROWAVE & WIRELESS

April 2000
Vol. 12 No. 4

PRODUCTS & TECHNOLOGIES

MARKET UPDATE

DEPARTMENTS

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AMPLIFIERS

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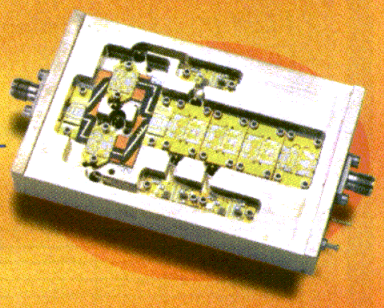
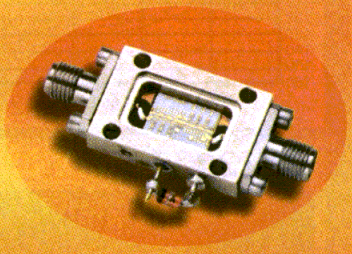
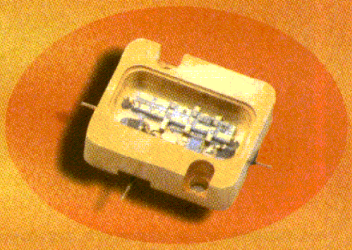
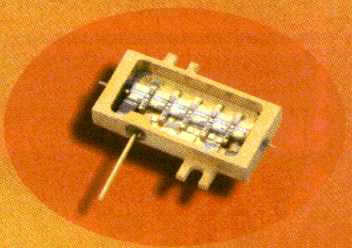
Model#	Freq Range (GHz)	Gain (dB min)	N/F (dB max)	Gain Flat (+/-dB)	1 dB comp. pt. (dBm min)	3rd Order ICP min	VSWR In/Out max	DC Current (mA)
MEDIUM POWER AMPLIFIERS (UP TO 2 WATTS)								
JCA01-P01	0.5-1.0	25	3.5	1	30	40	2.0:1	250
JCA12-P01	1.0-2.0	32	3	1	30	40	2.0:1	800
JCA34-P01	3.7-4.2	30	3	1	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

Wireless Communications and the Internet — A Marriage of Convenience

By Gary A. Breed
Publisher

The marriage of wireless and Internet communications is today's "hot topic" in the wireless industry. For a while, it seemed that every conversation I had referred to Wireless Access Protocol, IP data formats or Internet services designed for the small screen of a palm computer or PDA, or the even smaller screen of a cell phone.

Microsoft has even joined in, offering a Windows®-compatible operating system for wireless appliances — much simpler than its Windows CE for palm computing — that supports operation without a host computer. Part of the cell phone's internal microprocessor power is all that is required to acquire and display Internet-based information.

Like me, you might be thinking, "What useful information will fit on a tiny display like a wireless handset?" The first (and I think best) answer is location-based services. New technology required for E911 (Enhanced 911 for wireless calls) will compute the location of each wireless phone user. It requires only a small extra step to use that information to provide data on the nearest restaurants, hotels, police stations, tram stops or retail shops. E-mail to the home office can include your exact location in addition to the contents of the message. Taxi or car rental services can find you even if you don't know the city you are visiting. Delivery and transportation services can track their personnel via cell phone and the Internet instead of using a more costly GPS-based system.

Development of new services like these is extremely important to the growth of wireless communications. We have chosen to give this trend some extra attention, even though it is not circuit-level technology and involves data transmission protocols rather than emphasizing the RF/microwave portion of the system. Just inside the back cover, look for a report on recent announcements on services and technologies that expand the utility of wireless devices by giving them access to the Internet.

From time to time, we have used our Guest Editorial column as a forum for presenting business or regulatory news with greater detail than is possible in our regular News section. We decided that these news updates are important enough to give them a name of their own. From now on, the last page of most issues will offer a Market Update, with that space also available for a timely Guest Editorial whenever an industry leader has an urgent or important message. ■

The reason you should never have to choose between quality of test and speed of test.

People everywhere depend on the products you test. Yet your company depends on you to get those same products tested and out the door at once.

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new **HP 8722ET**	50 MHz to 40 GHz
HP 8719ES	50 MHz to 13.5 GHz
HP 8720ES	50 MHz to 20 GHz
HP 8722ES	50 MHz to 40 GHz
HP 8757D	10 MHz to 110 GHz
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ET *indicates Transmission Reflection*
ES *indicates S-parameter*

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Information: IEEE Ultrasonics, Ferroelectrics and Frequency Control Society
E-mail: pwalsh@eia.org
Internet: http://www.ieee.org/uffc/fc

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 27-30, 2000
15th International Wroclaw Symposium and Exhibition on Electromagnetic Compatibility
Wroclaw, Poland
Information: W. Moron or Dr. W. Sega
Tel: + 4971 348 3051
Fax: + 4871 372 8878 or 372 9375
E-mail: emc@il.wroc.pl
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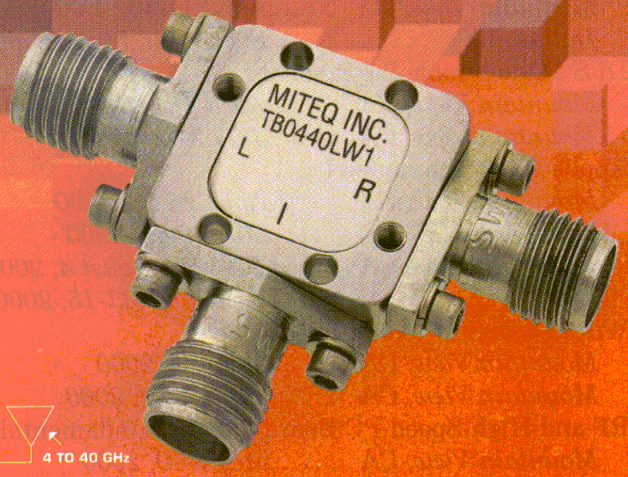
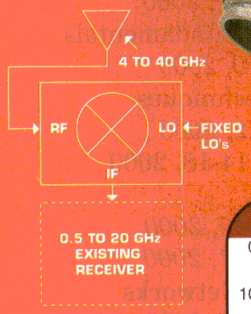
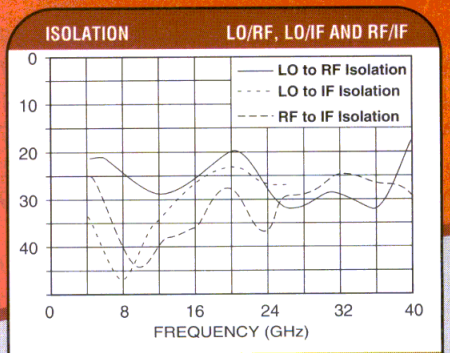


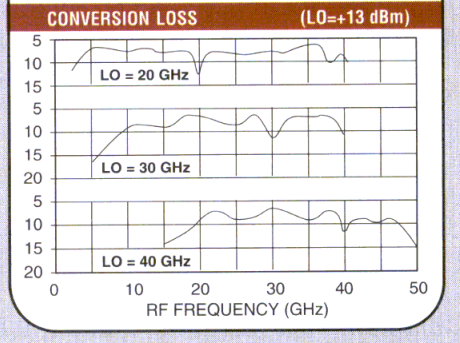
FEATURES:

- RF/LO Coverage..... 4 to 40/4 to 42 GHz
- IF Operation..... 0.5 to 20 GHz
- LO Power Range ..... +10 to +15 dBm (usable at +7 dBm)
- RF to IF Isolation..... 25 dB
- Removable K Connectors
- From Stock



INPUT PARAMETERS	MIN.	TYP.	MAX.
RF frequency range (GHz)	4		40
RF VSWR (RF = -10 dBm, LO = +13 dBm)		2.5:1	
LO frequency range (GHz)	4		42
LO power range (dBm)	+10	+13	+15
LO VSWR (RF = -10 dBm, LO = +13 dBm)		2.0:1	
TRANSFER CHARACTERISTICS	**MIN.**	**TYP.**	**MAX.**
Conversion loss (dB)		10	12
Single sideband noise figure (dB, at +25° C)		10.5	
Isolation - LO to RF (dB)	18	20	
Isolation - LO to IF (dB)	20	25	
Isolation - RF to IF (dB)	20	30	
Input power at 1 dB compression (dBm)		+5	
Input two-tone 3rd order intercept point (dBm)		+15	
OUTPUT PARAMETERS	**MIN.**	**TYP.**	**MAX.**
IF frequency range (GHz)	0.5		20
IF VSWR (RF = -10 dBm, LO = +13 dBm)		2.5:1	





For additional information, please contact Mary Becker at (631) 439-9423 or e-mail mbecker@miteq.com

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Circle 14

Calendar

SHORT COURSES

Besser Associates

RFIC Techniques for Wireless Applications
Mountain View, CA . . . . . .April 10-12, 2000
RF CMOS Design
Mountain View, CA . . . . . .April 13-14, 2000
Frequency Synthesis Technology and Applications in Wireless Systems
Mountain View, CA . . . . . .April 17-19, 2000
Dallas, TX . . . . . .September 13-15, 2000
DPS Made Simple for Engineers
Mountain View, CA . . . . . .April 18-20, 2000
Mountain View, CA . . . . . .July 24-26, 2000
Applied RF Techniques I
Mountain View, CA . . . . . .April 24-28, 2000
New York, NY . . . . . .May 15-19, 2000
Mountain View, CA . . . . . .July 31-August 4, 2000
Dallas, TX . . . . . .September 11-15, 2000
Wireless Digital Communications
Mountain View, CA . . . . . .May 2-5, 2000
Mountain View, CA . . . . . .July 11-14, 2000
RF and High-Speed PC Board Design Fundamentals
Mountain View, CA . . . . . .May 8-10, 2000
Advanced Wireless and Microwave Techniques
Mountain View, CA . . . . . .May 8-12, 2000
*Mountain View, CA . . . . . .*August 14-18, 2000
High Efficiency Power Amplifiers
New York NY . . . . . .May 15-27, 2000
Mountain View, CA . . . . . .July 19-21, 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
Dallas, TX . . . . . .September 11-12, 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
Dallas, TX . . . . . .September 6-8, 2000
Behavioral Modeling
Mountain View, CA . . . . . .May 31-June 2, 2000
Mountain View, CA . . . . . .September 11-13, 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
Mountain View, CA . . . . . .August 21, 2000
RF Testing for the Wireless Age (laboratory course)
Mountain View, CA . . . . . .June 20-22, 2000
Mountain View, CA . . . . . .August 22-24, 2000
Short Range Wireless and Bluetooth
Mountain View, CA . . . . . .June 21-23, 2000
Mountain View, CA . . . . . .September 13-15, 2000
Electromagnetic Shielding for Wired and Wireless Technology
Mountain View, CA . . . . . .June 26-29, 2000
Microwave Materials and Fabrication Techniques
Mountain View, CA . . . . . .June 29-30, 2000
Multitone Amplifier Design
Mountain View, CA . . . . . .August 7-8, 2000
Minimizing Degradation of Wireless System Performance
Mountain View, CA . . . . . .August 10-11, 2000
RF Power Amplifier Linearization Techniques
Mountain View, CA . . . . . .September 6-8, 2000
Information: Annie Wong, Tel: 415-949-3300; Fax: 415-949-4400; E-mail: info@bessercourse.com; Internet: www.bessercourse.com.

Georgia Institute of Technology

RF and Wireless Principles and Practice
Atlanta, GA . . . . . .April 10-14, 2000
Phased-Array Radar System Design
Smyrna, GA . . . . . .April 18-21, 2000
CMOS Analog Integrated Circuits
Milpitas, CA . . . . . .May 15-19, 2000
Atlanta, GA . . . . . .August 7-11, 2000
Principles of Enhanced Radar Resolution
Smyrna, GA . . . . . .May 23-26, 2000
Near-Field Antenna Measurements and Microwave Holography
Boulder, CO . . . . . .Aug. 28-Sept. 1, 2000
Information: Georgia Tech Distance Learning, Continuing Education and Outreach, Tel: 404-894-2547; Fax: 404-894-7398; E-mail: conted@gatech.edu; Internet: www.conted.gatech.edu.

University of California at Berkeley Extension

Phase-Locked Loop (PLL) Systems
San Francisco, CA . . . . . .April 20-22, 2000
Design of Analog Integrated Circuits for Mixed-Signal Integrated Systems
San Francisco, CA . . . . . .April 27-29, 2000
Low-Power Circuits and Systems for Digital Wireless Communications
San Francisco, CA . . . . . .May 4-5, 2000
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

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Part Number	Frequency	Power Out Watts	Gain dB	Supply Volts	IMD dBc	Efficiency %	Features
PTF 10049	470–860MHz	85	12.0	32	–32	50	Input Matched
PTF 10159	470–860MHz	120	12.0	32	–35	58	Input Matched
PTF 10160	860–960MHz	85	16.0	26	–30	54	I/O Matched
PTF 10036	860–960MHz	85	11.0	28	–30	55	Input Matched
PTF 10020	860–960MHz	125	11.0	28	–30	55	Push Pull
PTF 10100	860–960MHz	165	12.0	28	–30	47	Input Matched
PTF 10149	925–960MHz	70	16.0	26	–30	50	Input Matched
PTF 10021	1.4–1.6 GHz	30	11.0	28	–30	48	I/O Matched
PTF 10125	1.4–1.6 GHz	135	11.5	28	–30	45	I/O Matched
PTF 10035	1.9–2.0 GHz	30	11.0	28	–30	35	I/O Matched
PTF 10112	1.8–2.0 GHz	60	11.0	28	–28	41	I/O Matched
PTF 10120	1.8–2.0 GHz	120	10.0	28	–30	40	I/O Matched
PTF 10048	2.1–2.2 GHz	30	10.0	28	–30	39	I/O Matched
PTF 10122	2.1–2.2 GHz	50	9.5	28	–30	39	I/O Matched
PTF 10134	2.1–2.2 GHz	100	10.0	28	–30	36	I/O Matched

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Calendar

BSIM — Standard MOSFET Model for Circuit Simulation
Berkeley, CA . . . . . .June 29-30, 2000
Wireless Systems: From Algorithms to Implementations
Berkeley, CA . . . . . .July 10-12, 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; Internet: www.unex.berkeley.edu/ enroll.

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.

Henry Ott Consultants

Electromagnetic Compatibility Engineering
East Hanover, NJ . . . . . .April 26-28, 2000
Information: Henry Ott Consultants, Tel: 973-992-1793; Fax: 973-533-1442.

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.

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/.

Companies, organizations and institutions may submit information for our Conference and Short Courses Calendar to: Shannon O'Connor, Managing Editor, *Applied Microwave & Wireless*, 4772 Stone Drive, Tucker, GA; Fax: 770-939-0157; E-mail: amw@amwireless.com

More courses listed at www.amwireless.com

USB Transceiver for Less

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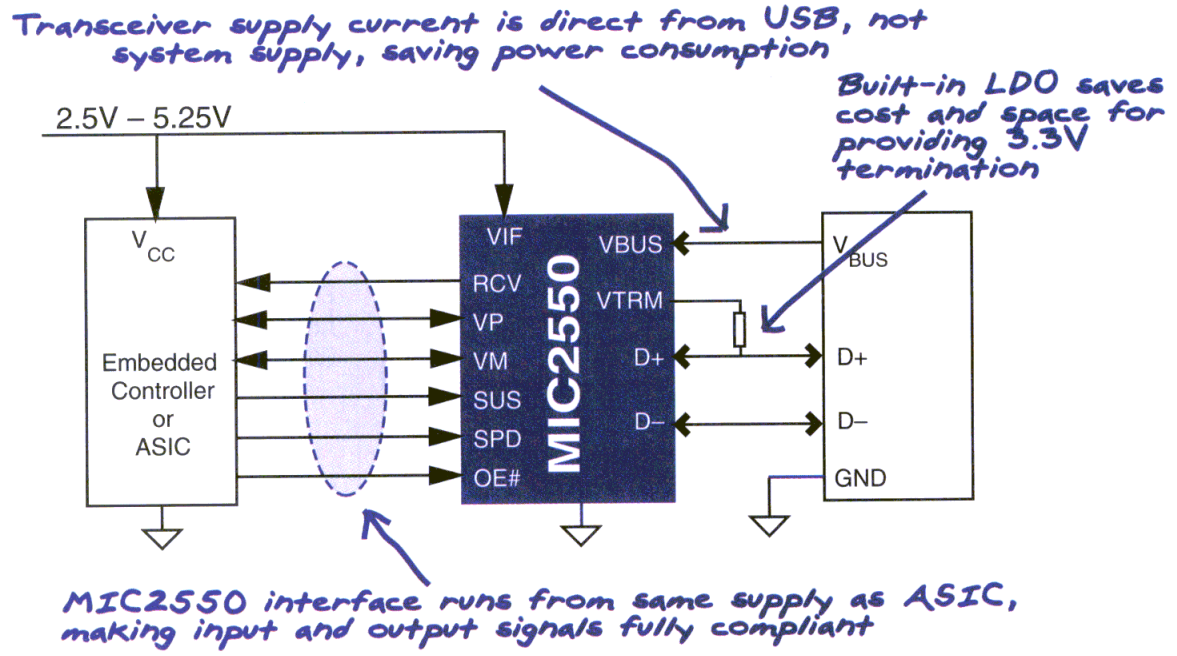

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With the MIC2550, you can operate your embedded controller or ASIC from 2.5V to 5.5V without additional voltage translation circuitry or special I/O cells to support USB's 3.3V signalling.

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Calendar

CALLS FOR PAPERS

The Applied Computational Electromagnetics Society

Special issue of the ACES Journal on Computational Electromagnetic Techniques in Mobile Wireless Communications

Topics: Smart and adaptive antennas, PCS, mobile, gateways, satellite antennas, propagation models, atmospheric models, systems design, correlation of measurement techniques and models, electromagnetic interference, bioelectromagnetics, LEO, MEO, satellite communications, digital/analog components design, RF components design.

Authors should submit four copies to:

Ray Perez
Lockheed Martin Astronautics
P.O. Box 179, M/S S8800
Denver, CO 80201
Tel: 303-977-5845
Fax: 303-971-4306
E-mail: ray.j.perez@lmco.com
OR
Chris Holloway
NTIA/ITS.T
325 Broadway
Boulder, CO 80303
Tel: 303-497-6184
Fax: 303-497-3680
E-mail: cholloway@its.bldrdoc.gov

Deadline: March 28, 2000

2000 IEEE AP-S Conference on Antennas and Propagation for Wireless Communications

November 6-8, 2000
Waltham, MA

Topics: Military to commercial technology transition, trends in architecture in future wireless systems, adaptive and active wireless communication arrays, novel antennas and passive array configurations, multiband operation and polarization characteristics, antennas for PCS, WLAN, WLL and RFID, mobile antennas and vehicle modeling, package integration and portable devices, antenna CAD for wireless communication systems, human interactions with antennas, MEMS for wireless communications, and indoor and outdoor propagation and channel models.

Authors should submit a camera-ready original and three copies, no more than four pages including text, references and figures, with a cover letter indicating the topic area and contact information. A signed copyright form should be included. Complete information is available at the conference web site (URL below). Send to:

Professor Jennifer T. Bernhard
Technical Program Chair
Department of Electrical and Computer Engineering
University of Illinois at Urbana-

Champaign
1406 West Green Street
Urbana, IL 61801
E-mail: jbernhar@uius.edu
Internet: http://www.eece.unm.edu/apwc2000
Deadline: April 7, 2000

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

Feb. 20-22, 2001
Zurich, Switzerland

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

Authors should submit a preliminary manuscript of not more than 3,600 words (six pages including figures, tables and references); a 100-word abstract; a short summary of the contribution the paper provides and how it differs from or extends existing work; and a statement indicating which topic is most appropriate. Submissions are accepted electronically or by mail. Detailed 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

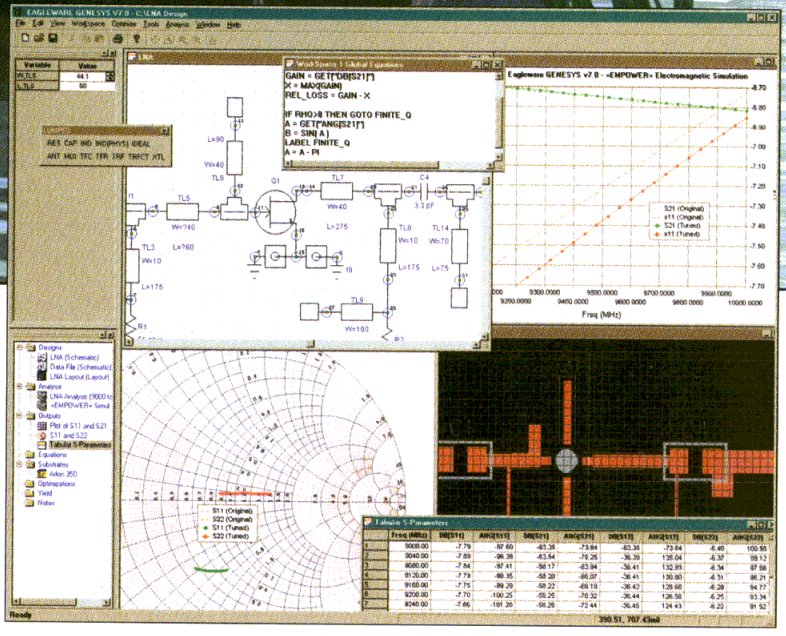
Special issue of the ACES Journal on Computational Bioelectromagnetics

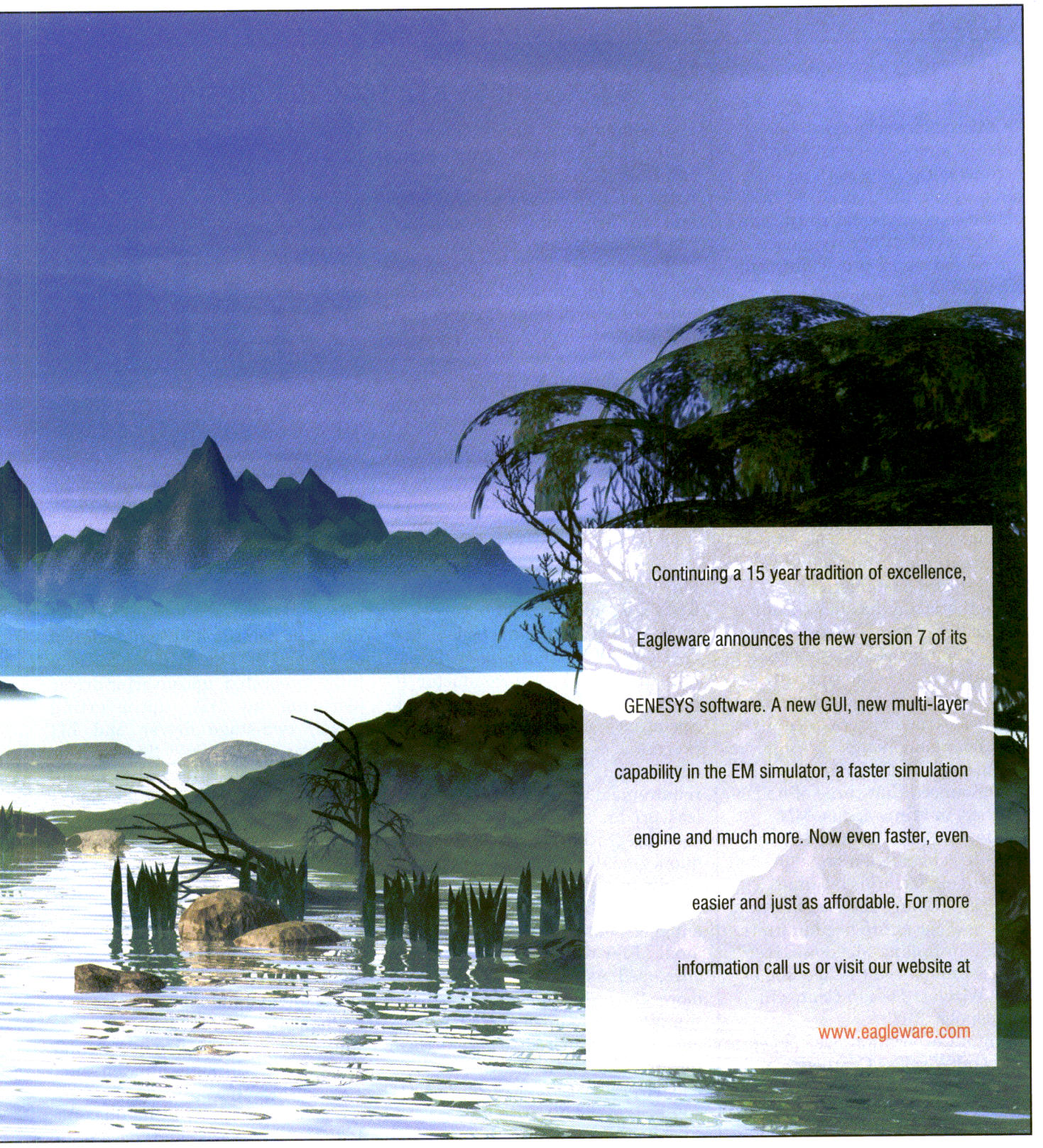
Topics: Cellular telephone analysis and design, medical imaging, EM safety analysis, finite-difference time-domain method, finite element method, high resolution human body models, electrical properties of human tissue, and comparisons of methods, models, or techniques.

Authors should contact one of the guest editors listed below:

Cythia Furse
Department of Electrical and Computer Engineering
Utah State University
Logan, UT 84322-4120
Tel: 435-797-2870
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

PREPARE FOR THE NEXT GENESYS





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BRIEFS

• Micro Networks Corp. has launched a new web site, www.micronetworks.com, with product search capabilities, specifications and the company's shortform catalog of microelectronic frequency sources and signal processing components and subsystems.

• EDX has launched a new web site, www.edx.com, that features product information, press releases, references, distributor information and technical support.

• Hitachi America Ltd., a subsidiary of Hitachi Ltd., has broken ground on a 71,688-square-foot semiconductor equipment center in Irving, TX. The building will house training, sales and support offices and a clean room and tool demo lab for U.S.-based customers.

• Aethercomm has moved into a new facility in San Marcos, CA. The location houses manufacturing and marketing for the company's RF, microwave and millimeterwave amplifiers, transmitters, receivers and other components.

• Intertek Testing Services (ITS) has announced that three of its laboratories, in Minneapolis, MN, Atlanta, GA, and Totowa, NJ, will complete construction on additional EMC testing facilities by June.

• PrairieComm Inc. has moved into a new corporate headquarters building in Rolling Meadows, IL, and has announced the opening of a new Wireless Design Center in Minneapolis, MN.

• Intel Corporation has opened its second Wireless Competence Center, in Tsukuba, Japan, part of a partnership with Japanese cellular providers to promote development of new wireless Internet access technologies.

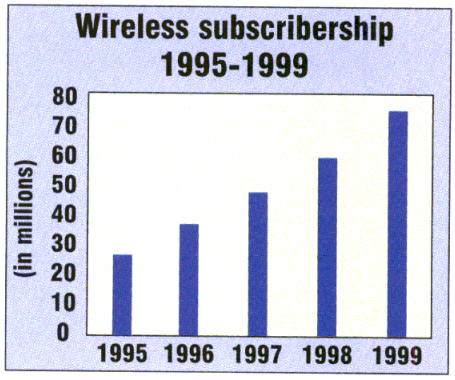
Companies, organizations and institutions may submit information for our News section to: Shannon O'Connor, Managing Editor, Applied Microwave & Wireless, 4772 Stone Drive, Tucker, GA, 30084; Fax: (770) 939-0157; E-mail: amw@amwireless.com.

Survey: Wireless use reaches all-time high

A semi-annual survey conducted by the Cellular Telecommunications Industry Association shows that both cellular subscriber numbers and average minutes of use have reached an all-time high.

The survey, covering the first half of 1999, found that nationwide, more than 28 percent of the population uses wireless phones. The total number of wireless customers in the U.S. reached 76.3 million by June 30, 1999, the survey said, up from 60.8 million in 1998.

In addition, the survey found that subscribers' average minutes of use are climbing rapidly as per-minute prices decline. In 1998, consumers used an average of 114 minutes for local calls each month. That rose to 159 minutes in the first half of 1999, an increase of 39 percent.



The survey also found that digital subscriber use is outpacing overall wireless growth, with more than 28 million subscribers in June 1999.

M/A-COM announces new GaAs E/D mode process

M/A-COM has launched a new GaAs-based Enhancement/Depletion (E/D) mode semiconductor IC process at its facilities in Colorado Springs, CO, and Roanoke, VA. The process was developed to meet linearity and single supply voltage requirements for 2G and 3G wireless products. It will also support the integration of both high-frequency analog and high-speed digital circuitry on the same chip.

The E/D process uses both enhancement mode and depletion mode FET devices. Transceivers developed using this process offer more than 50 percent lower consumption for equivalent RF performance, as compared to recent SiGe BiCMOS products.

The process offers Ft of 25 GHz and F_{min} of 0.3 db, with an associated gain of 16 dB at 2 GHz, and achieves an IP3 efficiency of 7.5, more than twice that of the best SiGe technology available.

M/A-COM's first two standard products based on the E/D process are now in volume production. The MD59-0021 features a fully integrated LNA/downconverter IC with LNA, RFA, downconverter floating FET mixer, IFA and LO buffer, offering low noise figure, high input intercept point and optional control of LNA IP3. The MD59-0022 is a fully integrated upconverter/driver featuring an IFA, upconverting mixer, two-stage driver and LO buffer, as well as a very linear power amplifier with a current saving mode. Both are designed for digital PCS applications and operate on a single 2.7 volt supply.

M/A-COM, based in Lowell, MA, supplies radio frequency, microwave and millimeterwave ICs and IP networks for wireless communications.

Penn State World Campus offers online antennas course

Penn State World Campus is offering an online course in Antenna Engineering through its web site, www.worldcampus.psu.edu.

The course covers techniques for analysis, synthesis and design of antenna configuration, as well as codes for accurate computation of antenna characteristics.

The course, led by Dr. Anthony J. Ferraro, is provided through a mix of CD-ROM and online lessons. Enrollment information is available on the World Campus web site, or by calling 1-800-252-3592.

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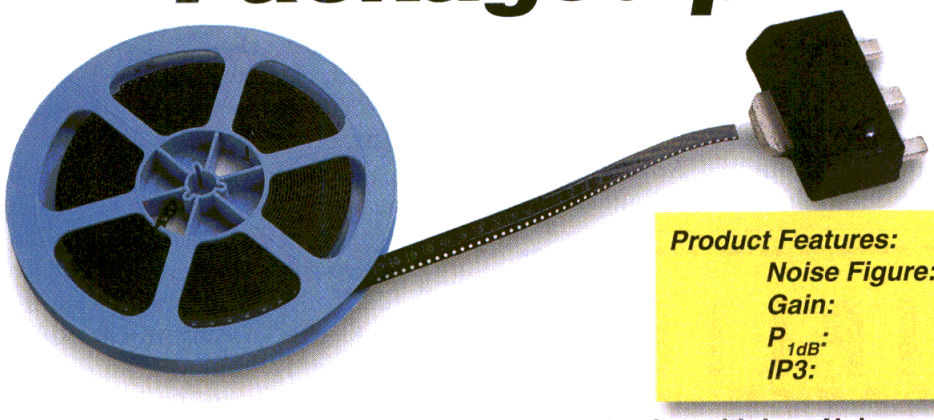

Product Features:

Noise Figure:	*0.5 dB @ 1800 MHz**
Gain:	*15 dB @ 1800 MHz*
P_{1dB}:	*29 dBm @ 1800 MHz*
IP3:	*46 dBm*

Filtronic Solid State is now in production with Low Noise and High Dynamic Range *low-cost* SOT-89 packaged pHEMTs. Filtronic Solid State is offering Millennium-leading technology for the year 2000 and beyond for Base Station, Wireless Local Loop, and W-CDMA applications from 500 MHz to 4 GHz.

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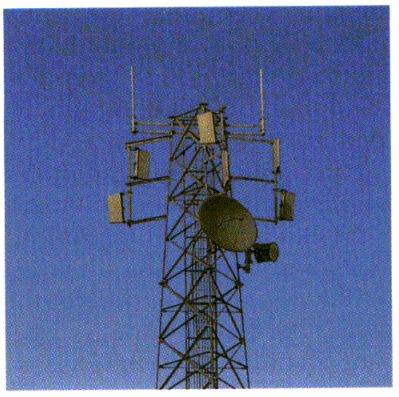
Model Number	Noise Figure	Gain	P_{1dB}	IP3
LP750SOT89	0.7 dB*	14 dB	24 dBm	40 dBm
LP1500SOT89	0.5 dB*	16 dB	27 dBm	44 dBm
LP3000SOT89	0.5 dB*	15 dB	29 dBm	46 dBm

*with optimum Noise Figure biasing

Base Stations



Wireless Local Loop

W-CDMA/IMT 2000

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Circle 48

TriQuint offers design kit for Agilent software

TriQuint Semiconductor Inc. and Agilent Technologies Inc. have announced the availability of the TQTRx foundry process design kit, including TriQuint's TOM3 advanced non-linear GaAs FET models, in Agilent's Advanced Design System electronic design automation (EDA) software.

The kit incorporates design rules into the circuit simulation and layout process, saving design time and improving the accuracy of the simulations. Support for the TOM3 model in TriQuint's TQTRx process, which is optimized for RF and microwave transceiver applications, is available now.

Agilent's Advanced Design System, developed and marketed by Agilent's EEsof EDA product group, provides an integrated solution to developers of wireless products including mobile phones, wireless networks and radar and satellite communications systems. The system includes RF, analog, DSP and electromagnetic tools integrated with accurate models.

TriQuint's TQTRx Process design library includes electrical and physical models for both passive and active devices and can be used for RFIC and MMIC design. The TOM3 GaAs FET models provide improved RF linear and non-linear characterization of devices under a variety of bias conditions.

Agilent, headquartered in Palo Alto, CA, is a subsidiary of Hewlett-Packard and provides test, measurement and monitoring solutions, semiconductors and optical components. TriQuint, based in Hillsboro, OR, supplies a range of high performance gallium arsenide (GaAs) integrated circuits for wireless communications markets.

Elanix, Xpedion team up for integrated software suite

Elanix and Xpedion have introduced a new integrated software suite consisting of SystemView® by Elanix system design software and Xpedion's GoldenGate/Sim™ RF and microwave simulation software.

The software, targeted to designers developing products for 2G, 3G and Bluetooth communications standards, is designed to save time by offering a single overview of the impact of design changes at both component and system levels.

Through the partnership, Elanix will resell GoldenGate/Sim as part of its Wireless Design Suite, which also contains SystemView and several application libraries.

Elanix, based in Westlake Village, CA, provides system-level design tools for wireless communications. Xpedion, headquartered in Santa Clara, CA, offers EDA solutions for the design of wireless communications circuits and systems.

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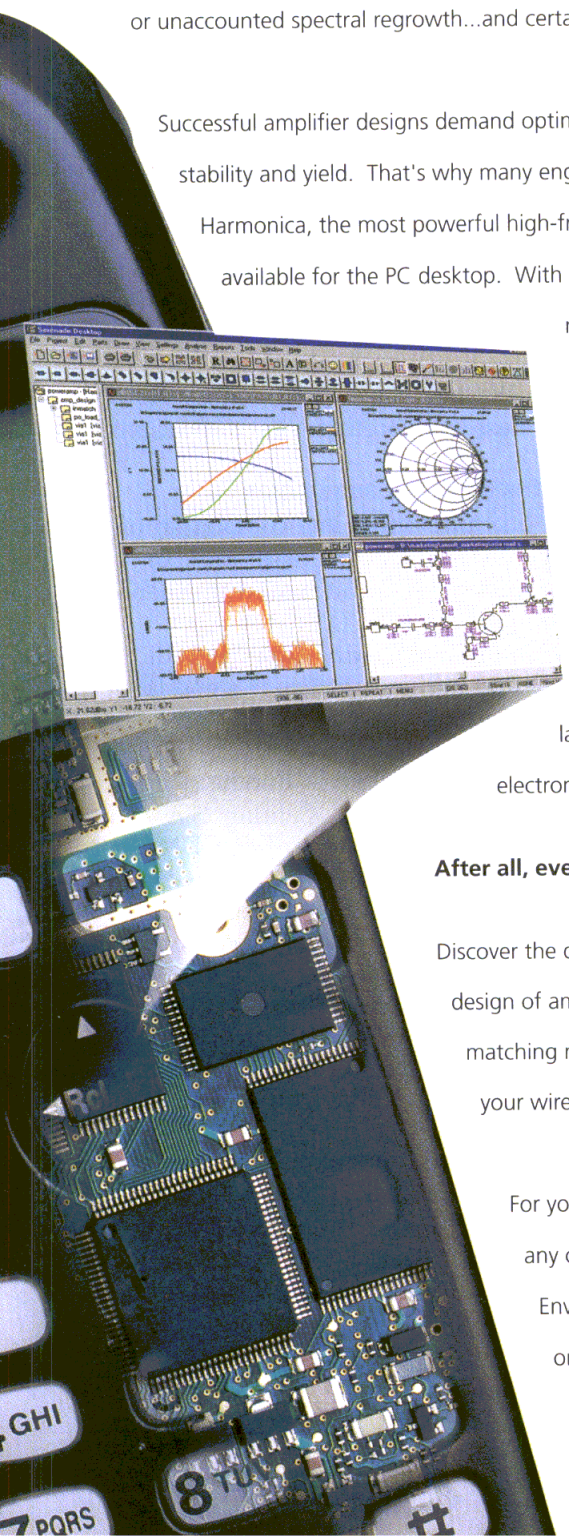

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BUSINESS AND FINANCE

TRW Milliwave, Endgate announce merger plans

TRW Inc. and Endgate Corp. have signed a definitive agreement to merge Endgate and TRW Milliwave Inc., a wholly owned TRW subsidiary, to create a new company, Endwave Corporation.

Endwave products will include transceivers, antennas and ODUs already being produced by Endgate and TRW, as well as additional products to be developed by the new company. Headquarters will be in Sunnyvale, CA, with design and manufacturing facilities in Sunnyvale, Santa Clara and Diamond Springs, CA.

Endgate manufactures wireless broadband access products including integrated transceivers, high-performance outdoor units and specialized gateway antennas. TRW Inc. provides advanced technology products and services to the automotive, aerospace and information technology markets worldwide. TRW Milliwave Inc., a subsidiary of TRW Space & Electronics Group, manufactures high-performance, MMIC-based modules for telecommunications systems.

Wireless Facilities, Ericsson Mexico sign contract

Wireless Facilities, Inc. has announced a multi-year contract with Ericsson Mexico to perform network deployment services including radio frequency (RF) engineering and network optimization services. Financial terms were not released.

The project will expand the CDMA-based digital/PCS network for Pegaso PCS, a leading Mexican wireless service provider, by more than 400 sites through 2001. Pegaso is expanding its CDMA-based network to provide coverage in Mexico's top markets and plans to deliver nationwide digital coverage by 2001.

Based in San Diego, CA, Wireless Facilities Inc. designs and manages wireless networks worldwide. Ericsson, based in Stockholm, Sweden, provides communications products and services worldwide.

Adaptive Broadband awarded $140 million contract

Adaptive Broadband Corp. has received a five-year contract to provide its AB-Access™ fixed wireless broadband equipment to DataCentric Communications Corp. The contract is valued at $140 million.

DataCentric, based in Houston, TX, provides Internet connectivity, data, voice and multimedia services. Adaptive Broadband, headquartered in Sunnyvale, CA, offers technology for the deployment of broadband wireless communications.

AeroComm to coordinate wireless access system

International FiberCom Inc.'s wireless solutions division, AeroComm Inc., has received a contract from Bell Atlantic Mobile to serve as as the Cellular/PCS Carrier Coordinator for New York City's Queens Midtown and Brooklyn Battery Tunnels. The contract is valued at more than $5 million.

Under the contract, AeroComm will coordinate with Nextel, Omnipoint, Sprint and AT&T to install AeroComm's proprietary system, which will allow transmission of cellular, AM and FM signals in areas where connectivity is a problem, such as tunnels.

International FiberCom, based in Phoenix, AZ, provides engineering, development and maintenance services for broadband networks, public local and wide area networks and specialized wireless applications.

dBm purchases product line from TAS

dBm LLC has completed an agreement to purchase the Satellite Link Emulator (SLE) product line from Telecom Analysis Systems of Eatontown, NJ. Financial terms were not disclosed.

The SLE is used to simulate satellite to ground station RF link testing, allowing systems engineers to create realistic, full-duplex path scenarios for closed-loop testing of satellites, ground processing equipment and mobile transceivers.

dBm, based in Wayne, NJ, manufactures RF test equipment for wireless and satellite communications.

M/A-COM completes GaAsTEK acquisition

M/A-COM Inc. has announced the completion of its acquisition of the GaAsTEK business unit of ITT Industries Inc. The GaAsTEK unit, based in Roanoke, VA, will operate as part of M/A-COM.

M/A-COM, based in Lowell, MA, supplies radio frequency, microwave and millimeterwave ICs and IP networks for wireless communications.

Motorola CDMA network launched in Honduras

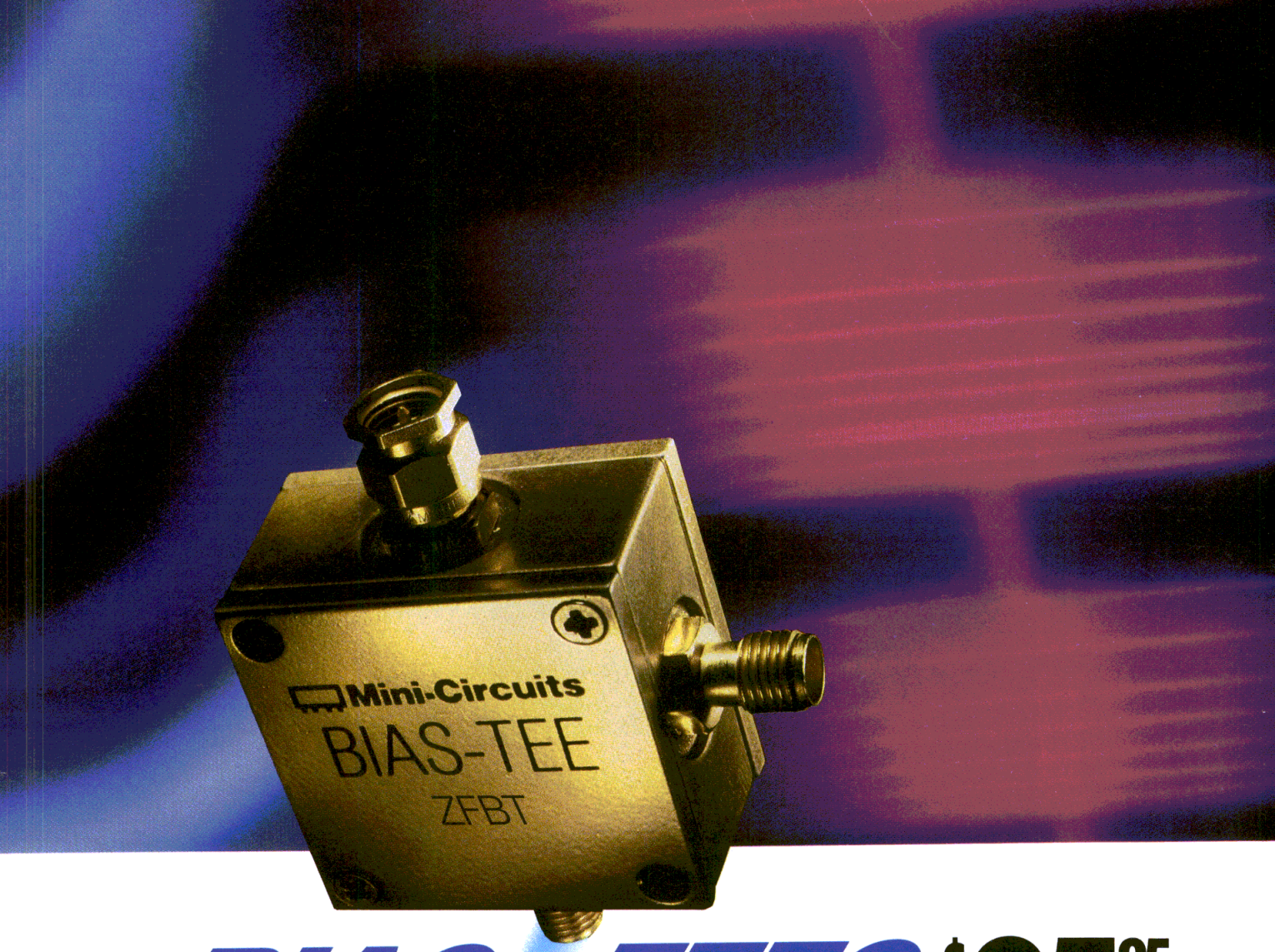
Motorola Inc. and Telefonica Celular S.A. have announced the deployment of a $15 million CDMA network in Honduras that includes network infrastructure and dual mode wireless phones. Motorola's end-to-end solution includes switching, radio frequency equipment, handsets, deployment services and ongoing operations and maintenance support.

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

Stratos agrees to purchase Datacom

Stratos Global Corporation has signed a definitive agreement to acquire Datacom Inc. for $65 million.

Datacom, based in Lafayette, LA, operates a digital microwave system and a Ku-band satellite teleport, providing voice and data communications services. Stratos, based in Toronto, Ontario, Canada, offers wireless IP, data and voice solutions.



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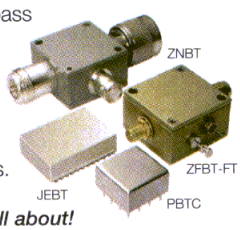

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▲ZFBT-6G	10-6000	0.15	0.6	1.0	32	40	30	1.13:1	79.95
▲ZFBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	50	1.13:1	79.95
▲ZFBT-6GW	0.1-6000	0.15	0.6	1.0	25	40	30	1.13:1	89.95
▲ZFBT-4R2G-FT	10-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	59.95
▲ZFBT-6G-FT	10-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-4R2GW-FT	0.1-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-6GW-FT	0.1-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	89.95
★ZNBT-60-1W	2.5-6000	0.2	0.6	1.6	75	45	35	1.35:1	82.95
■PBTC-1G	10-1000	0.15	0.3	0.3	27	33	30	1.10:1	25.95
■PBTC-3G	10-3000	0.15	0.3	1.0	27	30	35	1.60:1	35.95
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■PBTC-3GW	0.1-3000	0.15	0.3	1.0	25	30	35	1.60:1	46.95
•JEBT-4R2G	10-4200	0.15	0.6	0.6	32	40	40	-	39.95
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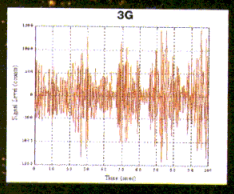

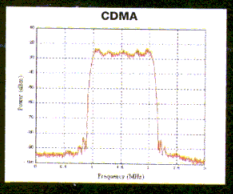

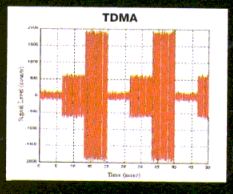

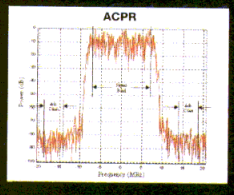

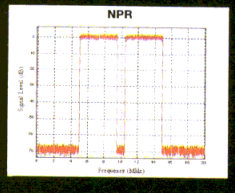

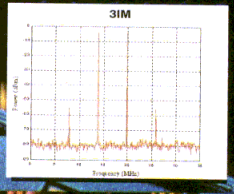

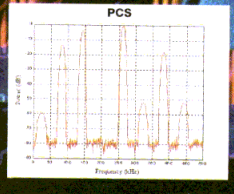

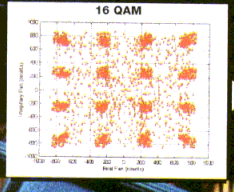

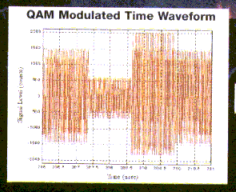

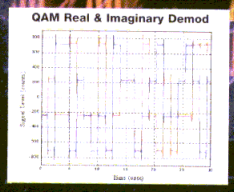

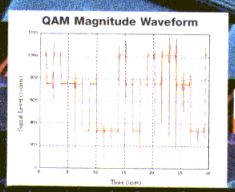

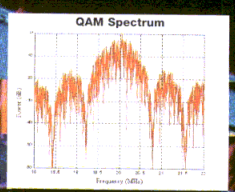

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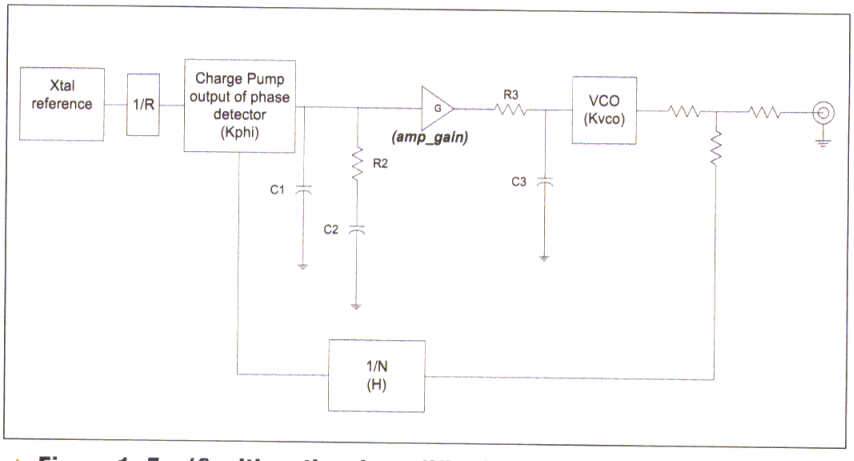
Accurate Phase Noise Prediction in PLL Synthesizers

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

By Lance Lascari
Adaptive Broadband Corporation

In modern wireless communications systems, the phase noise characteristics of the frequency synthesizer play a critical role in system performance. Higher than desired phase noise can cause degraded system performance by reducing the signal to noise ratio, increasing adjacent channel power, and reducing adjacent channel rejection.



▲ **Figure 1. $Z_{fil3}(f)$ with optional amplifier inserted.**

While many of the factors that affect phase noise in phase-locked frequency synthesizers are well understood, designers often overlook others. Neglecting these additional factors can cause frustration and overdesign, when a more complete up-front analysis may have yielded more elegant solutions.

The goal of this article will be to first review the models for standard noise sources and how these are analyzed, then to do the same for noise caused by the often forgotten resistors and amplifiers within the loop filter.

This is Part 1 of a two-part article. Part 2 will be published in the May 2000 issue of *Applied Microwave & Wireless* magazine.

Standard phase noise sources and analysis techniques

The basic equations describing the loop's frequency response will be given with a brief description of each. Plots that accompany the equations are from analysis of the test cases presented later in the article, and are typical for all PLL designs. The complete equations in context can be found in [1]. The equations presented here and in [1] have been drawn in part from [4], as well as [3], [6] and [7]. The amplifier within the loop will be ignored for all analysis presented here, as the implications of this amplifier will be discussed in the text.

Equation 1 describes the transfer function of the third-order loop filter. Equation 2 describes the transfer function of the second order loop filter and is applicable to systems that do not require the third pole for additional reference suppression.

$$Z_{fil3}(f) = \frac{Z_{fil}(f) \times \dfrac{1}{2 \times \pi \times f \times i \times C_3}}{Z_{fil}(f) + R_3 + \left(\dfrac{1}{2 \times \pi \times f \times i \times C_3} \right)} \quad (1)$$

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$$Z_{fil}(f)=\frac{(1+R_2\times 2\times\pi\times f\times i\times C_2)}{[2\times\pi\times f\times i(C_2+C_1+R_2\times 2\times\pi\times f\times i\times C_1\times C_2)]} \quad (2)$$

The total forward loop response, $G(f)$, includes everything from phase detector to VCO, and is represented by Equation 3. The equation for $G_{\_pd}(f)$ is not included, but it represents the transfer function of the discrete-sampling phase-frequency detector. Details on this function can be found in [7].

$$G(f)=\frac{K_\phi\times Z_{fil3}(f)\times K_{vco}\times \text{amp\_gain}}{2\times\pi\times \text{f}\times \text{i}}\times G_{pd}(f) \quad (3)$$

The reverse loop, or feedback gain, is defined as the reciprocal of the total frequency multiplication factor in the loop, N, as shown in Equation 4.

$$H=\frac{1}{N} \quad (4)$$

Equation 5 illustrates the open loop gain, $G_{ol}(f)$. The open loop gain is the product of equations 3 and 4, showing the response around the loop. This equation is particularly useful for stability analysis. A plot of this response is shown in Figure 2.

$$G_{ol}(f):=G(f)\times H \quad (5)$$

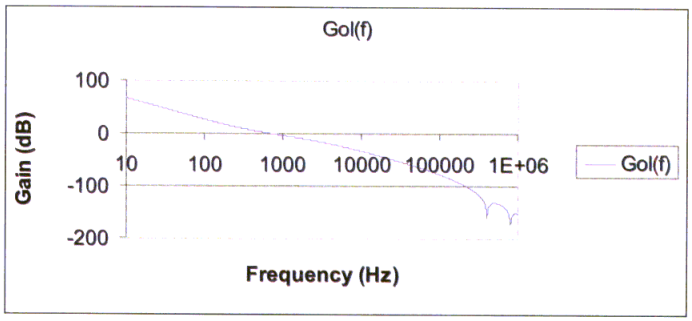
Because this is a simple negative feedback system, the closed loop response, $G_{cl}(f)$, at the VCO output is represented by the familiar feedback relationship seen in Equation 6. A plot of this response is shown in Figure 3.

$$G_{cl}(f)=\frac{G(f)}{1+G(f)\times H} \quad (6)$$

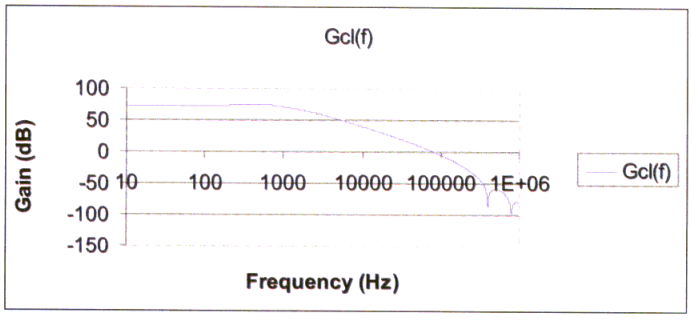
The well known noise sources (expressed in terms of equivalent noise voltage) are specifically crystal reference (TCXO) noise; phase detector noise; and VCO phase noise.

Crystal reference oscillator noise — The crystal oscillator noise is "amplified" in the loop by the gain of the closed loop transfer function. A simple approximation for this noise source due to the crystal reference itself, as with any oscillator, is that it is inversely proportional to offset frequency. Higher order approximations or actual data could be used if it were available, but the 1/f approximation is a good starting point.

Within the loop bandwidth of the synthesizer, the closed loop transfer function, $G_{cl}(f)$ is very large in magnitude, hence it increases the level of the reference oscillator noise. This gain is flat until it reaches the loop bandwidth, after which it drops off rapidly. This function represents amplification of the noise within the loop bandwidth, but attenuation of the noise above this frequency. The gain within the loop bandwidth comes largely from the ratio of the loop division ratio, N, by the reference division ratio, R. If this noise can be observed at all, it is generally seen very close to the carrier (where it is visible above the other major noise sources).



▲ **Figure 2. Open loop frequency response.**



▲ **Figure 3. Closed loop frequency response.**

If a TCXO is used, phase noise data should be obtained from the manufacturer so that reference values can be used with the models. Measuring the noise of a crystal oscillator can be quite difficult since the noise is significantly below the noise of most readily available test equipment. In fact, it may be easier to work backwards from measured PLL data to determine the TCXO noise if the data are not available from the manufacturer. Equation 7 illustrates the noise due to the reference oscillator, $N_{tcxo}(f)$, at the synthesizer output.

$$N_{tcxo}(f)=\frac{10^{\left(\frac{N_{tcxo\_ref}}{20}\right)}}{\frac{f}{f_{tcxo\_ref}}}\times\left(G_{cl}(f)\times\frac{1}{R}\right) \quad (7)$$

Phase detector noise — $N_{p\_d}(f)$, is a form of noise that represents the internal noise floor of the phase/frequency detector and frequency dividers within the PLL. This

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noise is modeled as flat versus frequency and the specific value for N_{pd_ref} can be obtained from the manufacturer of the synthesizer IC. For National Semiconductor synthesizers (the one used in this article, for example), the phase detector noise floor is given for an effective reference frequency of 1 Hz. The actual noise floor of the phase detector degrades proportional to 10*log(F_{ref}/1 Hz). This noise source is flat with respect to frequency, but it is shaped by the closed loop transfer function of the synthesizer, as shown in Equation 8.

$$N_{p\_d}(f) = 10^{\frac{N_{pd\_ref} + 10\log\left(\frac{f_{ref}}{Hz}\right)}{20}} \times G_{cl}(f) \tag{8}$$

Free-running VCO noise — This tends to have the typical noise profile. The noise is inversely proportional to offset frequency from the carrier. The synthesized output, however, is the result of the PLL "cleaning up" the close in phase noise of the VCO. This composite noise is calculated in Equation 9. The noise of the VCO is effectively high-pass filtered by the PLL, providing rejection of phase noise or phase error within the bandwidth, but leaving VCO noise well outside of the loop bandwidth unaffected. A plot of this high-pass filter function provided by the PLL is shown in Figure 4.

$$N_{vco}(f) = \frac{10^{\left(\frac{N_{vco\_ref}}{20}\right)}}{\frac{f}{f_{vco\_ref}}} \times \left(\frac{1}{1 + G_{ol}(f)}\right) \tag{9}$$

A plot of the commonly analyzed phase noise sources described above at the synthesizer output is shown in Figure 5.

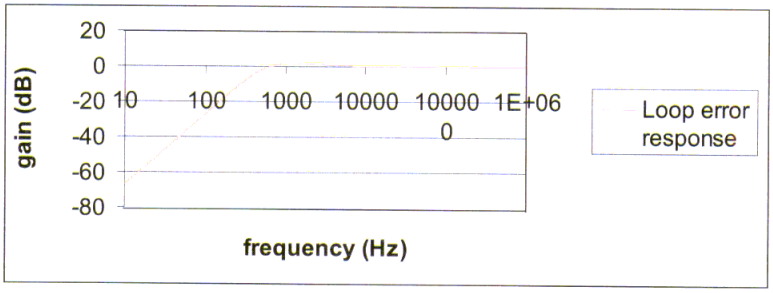
Models for noise in a typical third order loop filter

Prior to delving into the circuit equations, it is important to outline the methodology that will be employed to analyze the problem. The approach used will be to first determine the voltage at the input of the VCO due to each of the noise sources in the loop. This voltage will then be used to calculate the equivalent Frequency Modulation (FM) (i.e. phase noise) at the VCO output due to each of these sources using the VCO gain, K_{vco}.

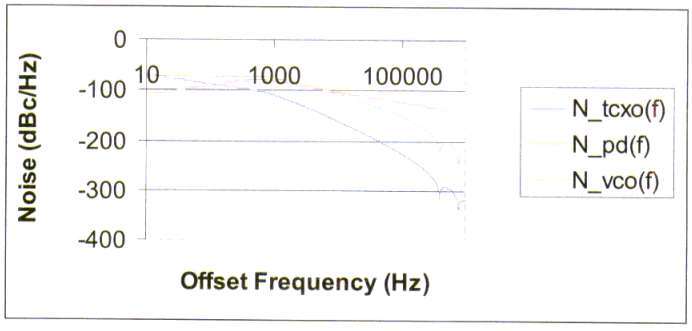
A key parameter used to analyze frequency modulation is the modulation index, m, calculated using Equation 10.

$$m = \frac{d}{f_m} \tag{10}$$

where m = modulation index=peak phase deviation in radians; d = frequency deviation; and f_m =message or modulating frequency.



▲ **Figure 4. Loop error response.**



▲ **Figure 5. TCXO, phase detector and VCO noise.**

In the case of a "direct" FM system, where the modulation/message is fed directly to the VCO in the form of voltage, the frequency deviation is simply the product of the modulation voltage and the tuning sensitivity (volts × Hz/volt = Hz).

If the peak phase deviation is well below one radian, as is the case with all that will be studied here, the higher order Bessel functions can be ignored and the relative level of the sidebands on the carrier due to the modulating frequency can be calculated using Equation 11, see reference [5] for further detail on this subject.

$$\text{sideband\_level} = 20\log\left(\frac{m}{2}\right) \tag{11}$$

These simple equations for frequency/phase modulation form the basis for the analysis of phase noise due to voltage noise sources within the loop hardware.

Calculating the noise voltages in the loop

Since the noise sources appear in different circuit nodes throughout the loop, the frequency response of the transfer function between each source and the VCO input will be different. This, in turn, results in modulation at the VCO output unique to each source in frequency and magnitude.

It is important to realize that in a system such as this, the resistor or op-amp noise modulates the VCO even if a PLL were not connected — so the "corruption" due to

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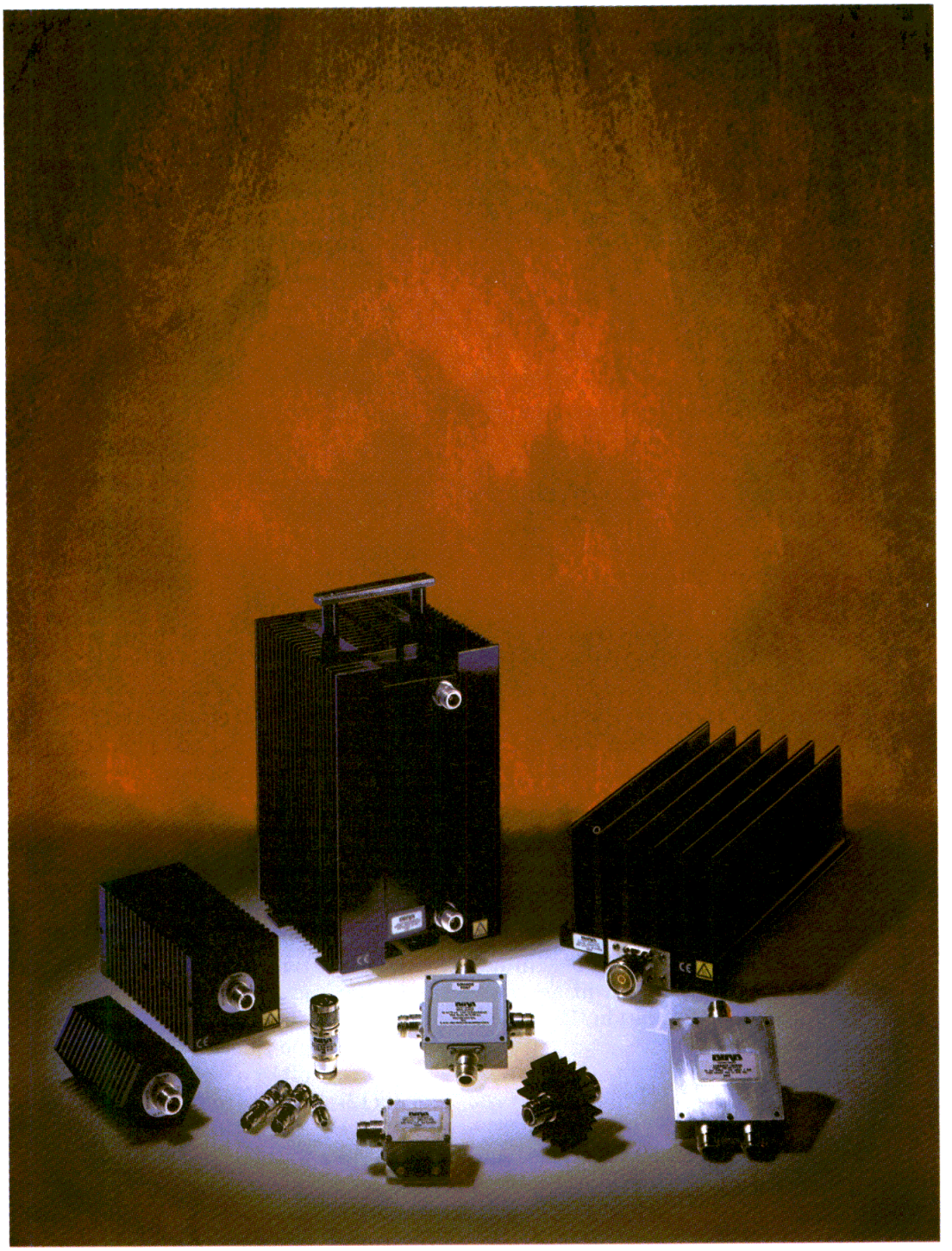

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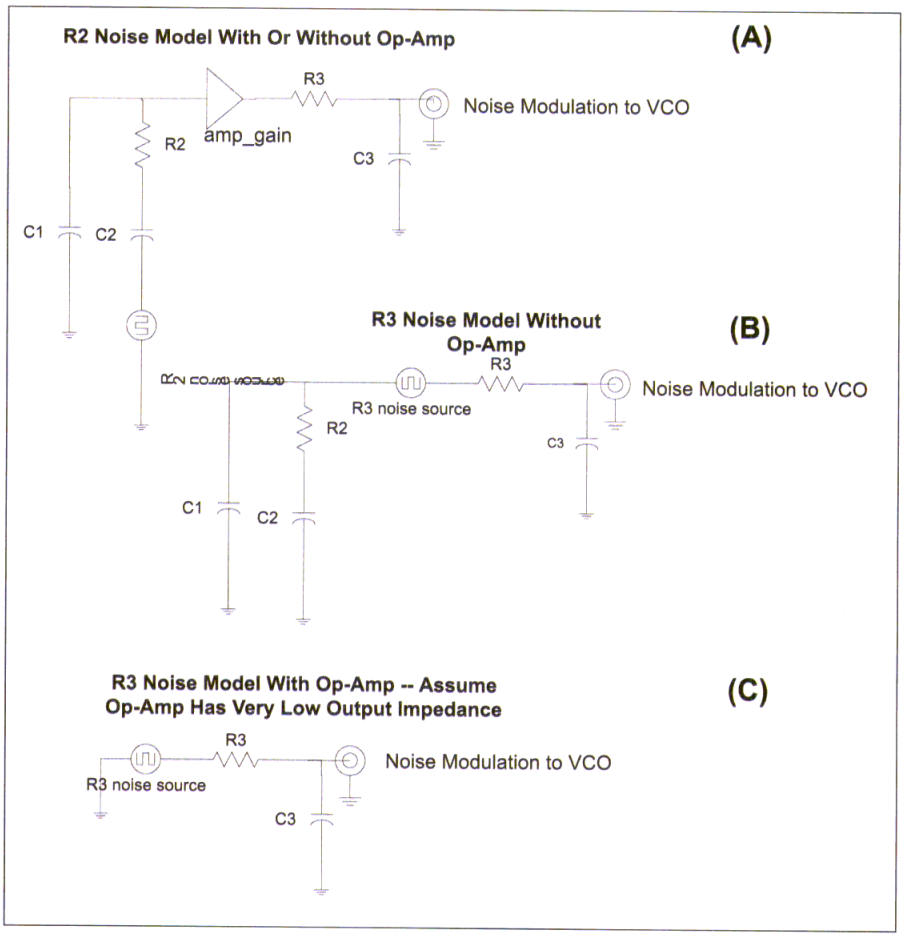
the resistors and op-amp can be considered an open-loop phenomenon. However the net result in the synthesized output requires the closed loop response, and the analysis is identical to the analysis used to show the effect of the PLL on the stand-alone VCO phase noise in Equation 9. Valuable insight can be gained by observing the open and closed loop SSB phase noise curves rather than just looking at the total output phase noise of the closed loop system. The connection between the open and closed loop responses, is the high-pass transfer function plotted in Figure 4, sometimes referred to as the error response of the loop.

The validity of the open-loop analysis technique requires the assumption that the charge pump does not load down the loop filter excessively. The following key points support this assumption. First, when in lock, the charge pump does very little but provide very minor corrections to keep the loop locked. Second, the charge pump is made up of a current source and a current sink, both of which represent a high impedance when operating in a linear region. The closed-loop action of the synthesizer fights the resistor and op-amp noise, but that is adequately described by the analysis of the closed loop system.



▲ **Figure 6. (a) R2 noise model with or without op-amp; (b) R3 noise model without op-amp; (c) R3 noise model with op-amp, assuming that the op-amp has very low output impedance.**

Noise found in resistors

Random electron motion inside of ordinary resistors makes for a "built-in" noise source in every circuit containing resistors. The noise is white in nature [8], with it's power in watts dissipated in an equivalent 1 ohm resistor is shown in Equation 12, and the units are volts^2/Hz.

$$P_{\text{resistor\_noise}}(R) = 4 \times k \times \text{Temp} \times B \times R \quad (12)$$

Thus, Equation 13 computes the equivalent RMS noise voltage generated in a known resistance

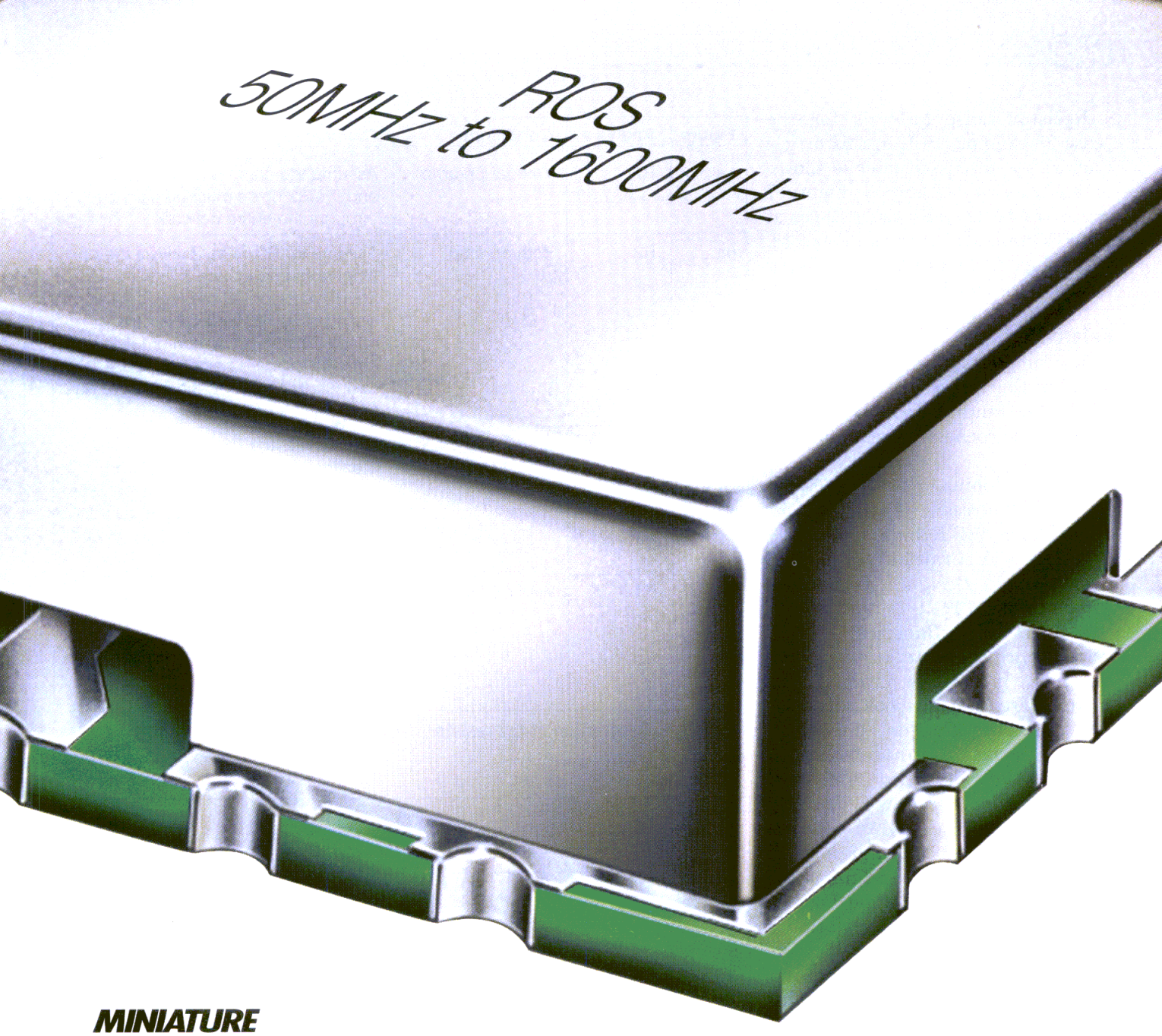
$$V_{\text{resistor\_noise}}(R) = \sqrt{4 \times k \times \text{Temp} \times R \times B} \quad (13)$$

where k = Boltzmann's constant; Temp = temperature in kelvins; B = bandwidth in Hz; and R = resistance in ohms. For most of our analysis we will use a bandwidth of 1 Hz.

These equations simply show the equivalent noise voltage source that appears in series with each resistor. Note that the noise could just as easily be modeled as a noise current source in parallel with the resistor. References [2] and [8] provide details on the noise in resistors and op-amps. When crunching the numbers for typical resistor values, one may initially dismiss the voltages as minuscule. As we will show later, even nanovolts of noise can cause several dB of degradation in the single-sideband phase noise of a synthesizer because K_{vco} is often a very large number.

Figure 6 shows the basic PLL loop filter and where the noise sources appear. The charge pump connection to the PLL has been left out for these models because it represents a very high impedance when the loop is locked. As previously stated, the initial analysis of the resistor noise will be done "open loop," and the effects of the PLL on shaping this noise further will be investigated after the basic models are developed.

Since the noise sources are uncorrelated, each resistor is analyzed separately and the effects are added at a later stage. Deriving the actual noise voltage versus frequency at the input to the VCO tuning port is a matter of basic circuit analysis using the models in Figure 6.



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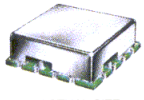

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ROS-1600PV	1520-1600	5	-100	-26	5	25	18.95
ROS-100	50-100	17	-105	-30	12	20	12.95
ROS-150	75-150	18	-103	-23	12	20	12.95
ROS-200	100-200	17	-105	-30	12	20	12.95
ROS-300	150-280	16	-102	-28	12	20	14.95
ROS-400	200-380	17	-100	-24	12	20	14.95
ROS-535	300-525	17	-98	-20	12	20	14.95
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*Phase Noise: SSB at 10kHz offset, dBc/Hz. **Specified to fourth.

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Resistor noise analysis for the "case 2" example PLL in this article that will be discussed later is shown in Figure 7 and Figure 8. Figure 7 shows the baseband noise voltages at the VCO input in the open loop case, and Figure 8 shows the noise contribution to the synthesizer output. ■

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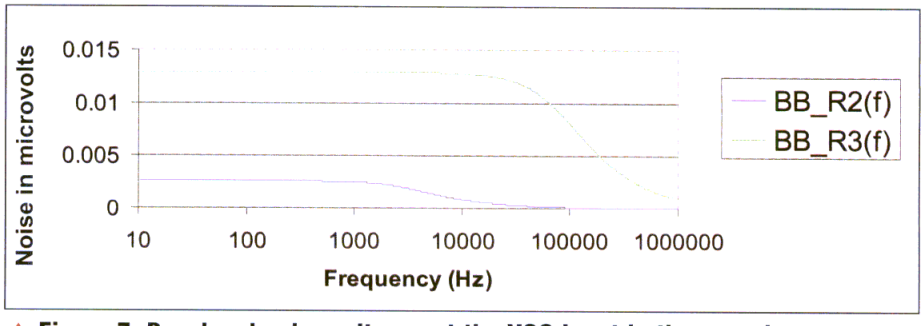
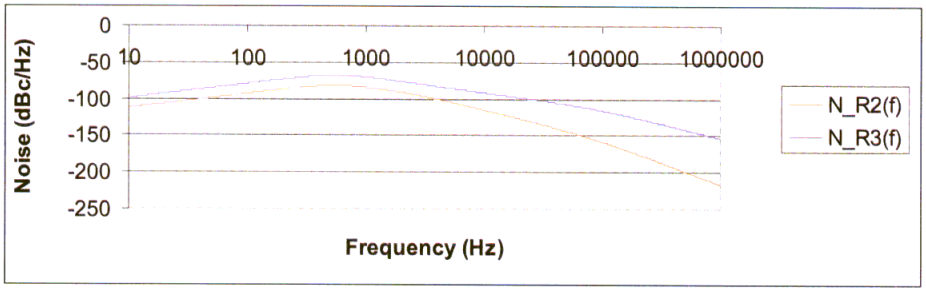
8. "Noise Specs Confusing," Application Note 104, National Semiconductor.

Figure	Analysis	Conditions	Comments
6a	R2	Without op-amp	Assume the op-amp is not present and the R2 noise must be calculated throught the entire network.
6a	R2	With op-amp	Assume for R2 noise analysis the op-amp input impedance is infinite, and the R2 noise out of the network consisting of R2, C1 and C2 is determined. This noise is then amplified by amp_gain before being passed through the network consisting of R3 and C3.
6b	R3	Without op-amp	In this case, the R3 noise source is "floating" in the loop filter network, and the transfer function between this source and the output of the network includes the impedances of all the filter components.
6c	R3	With op-amp	Since the op-amp output impedance will be assumed to be very low, we model this as a short. Hence, this is the simplest model of all, R3 shorted to ground.

▲ **Table 1. Description of the resistor noise models shown in Figure 6.**



▲ **Figure 7. Baseband noise voltages at the VCO input in the open-loop state.**



▲ **Figure 8. Resistor noise contributions at the VCO output after the PLL's high-pass error function is included.**

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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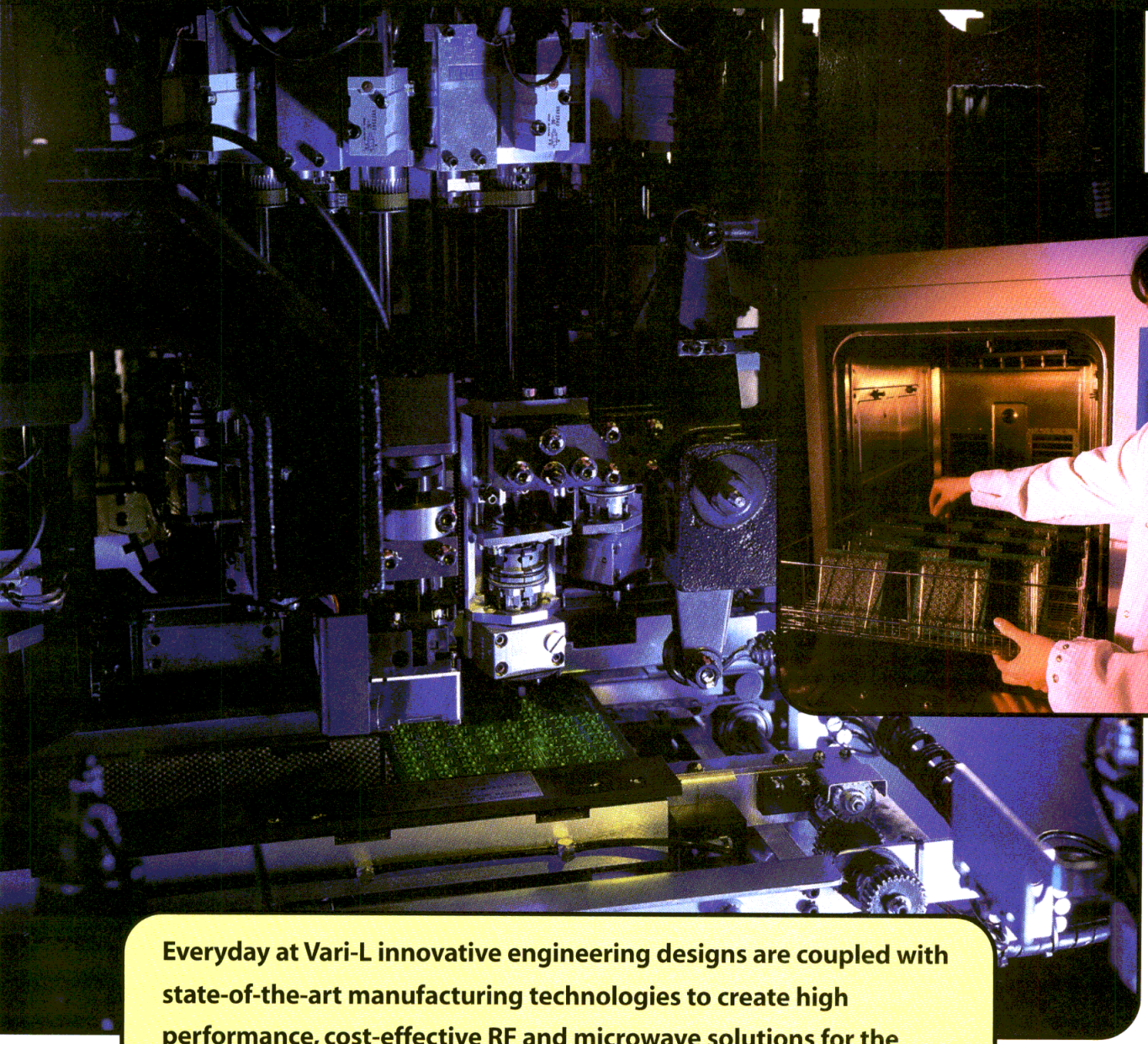

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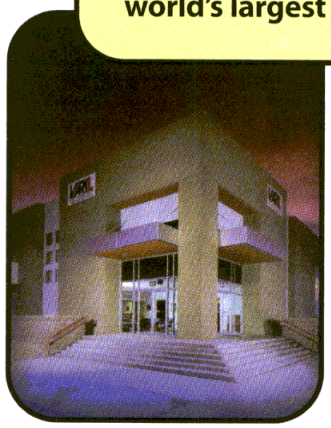

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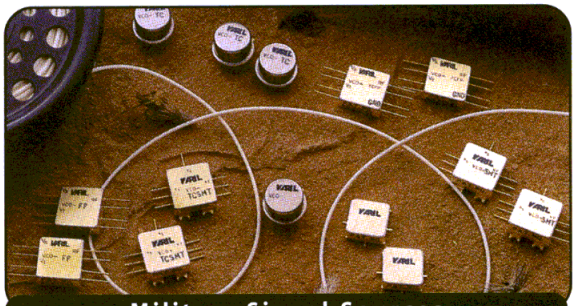

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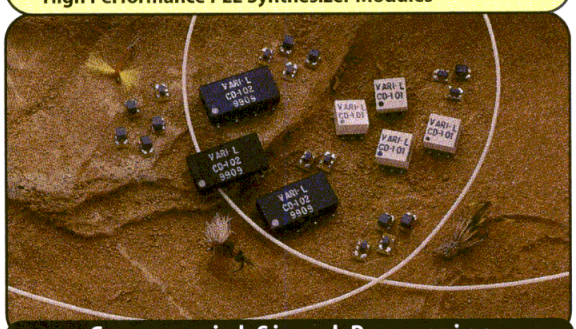

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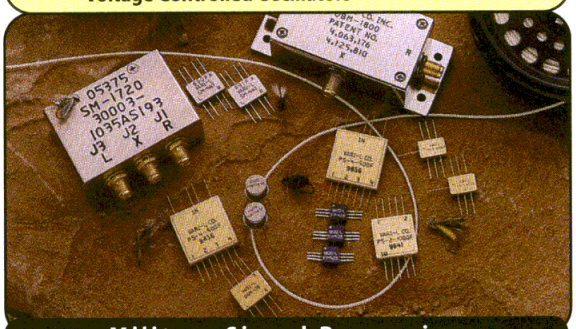

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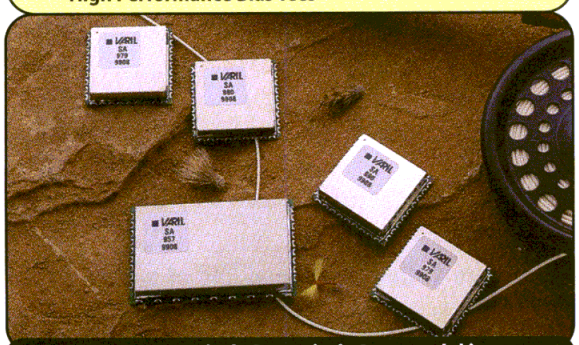

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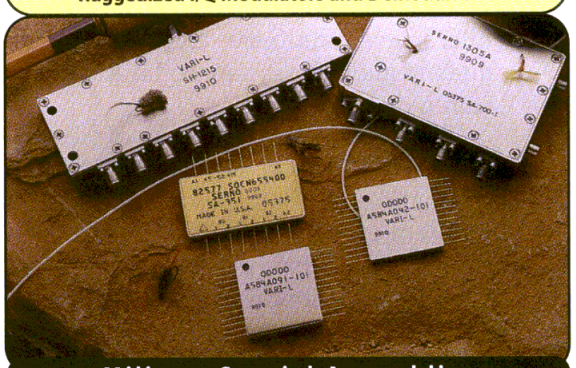

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Design of PHEMT Frequency Triplers with Conversion Gain at 6 GHz

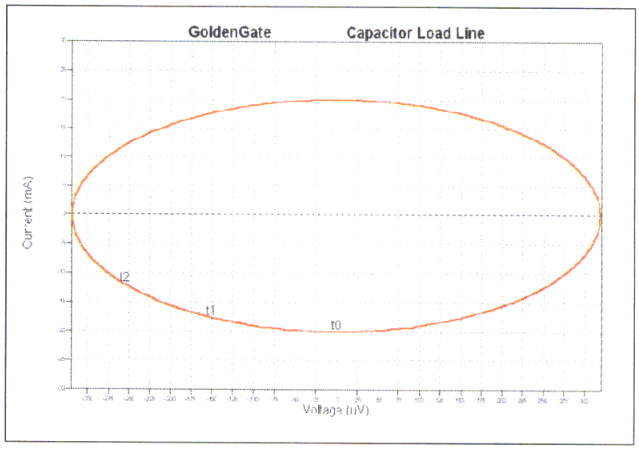
By **Francisco Madriz**, SJSU; **George D. Vendelin**, Vendelin Engineering; **Jake Goldstein**, Xpedion Design Systems, Inc.; **Masoud Mostafavi**, SJSU; and **David R. Chipman**, Filtronic Solid State

Since the early 1960s, varactor frequency multipliers have been built with nonlinear low-loss diodes using the nonlinear properties of the PN junction. These classic designs typically have a conversion loss approaching 3 dB [1]. With microwave nonlinear transistors, the frequency multipliers may be built with conversion gain.

The nonlinearity of the drain current source is the most effective element in the generation of harmonics. Because of the inherent gain of the PHEMT, frequency multipliers with gain are now possible. Computer simulation of nonlinear circuits using nonlinear PHEMTs will provide invaluable insight to the performance and reliability of the design by revealing the dynamic load line and other features of the design, which are immeasurable with normal instrumentation.

Using a new CAD package for nonlinear circuit design from Xpedion Design Systems, Inc., the design of a PHEMT tripler for 2 to 6 GHz with essentially zero dB gain and 0 dBm power will be presented. The best result was 4.1 dB gain measured with an input power of –1 dBm. Calculations predicted gains of 6 to 10 dB, but the device was biased high and operating in regions of possible burnout, which can easily be observed with the nonlinear CAD analysis. The circuit uses the LP6836-P70 packaged PHEMT from Filtronic Solid State, which is a 360 μm perimeter 0.3 μm gate transistor. The optimum bias was found both in the lab and on the computer to be in the range of:

V_{ds}= 1.2 to 2.6 V
V_{gs}= –0.70 to –2.7 V



▲ **Figure 1. Clockwise load line of a capacitor.**

I_{ds}= 20 to 40 mA

which is a rather low drain voltage and low drain current (I_{dss} = 100 mA).

The design procedures for even and odd harmonic multipliers are different [2]. For odd harmonic multipliers, the odd harmonics should see a high impedance at the drain while the even harmonics should see a short circuit (low impedance) at the drain. For even harmonic multipliers, the opposite is true. The amount of output harmonic power is based upon the size and bias of the transistor. The design procedure used here should work equally well for BJTs, HBTs, MESFETs or any other 3-terminal device.

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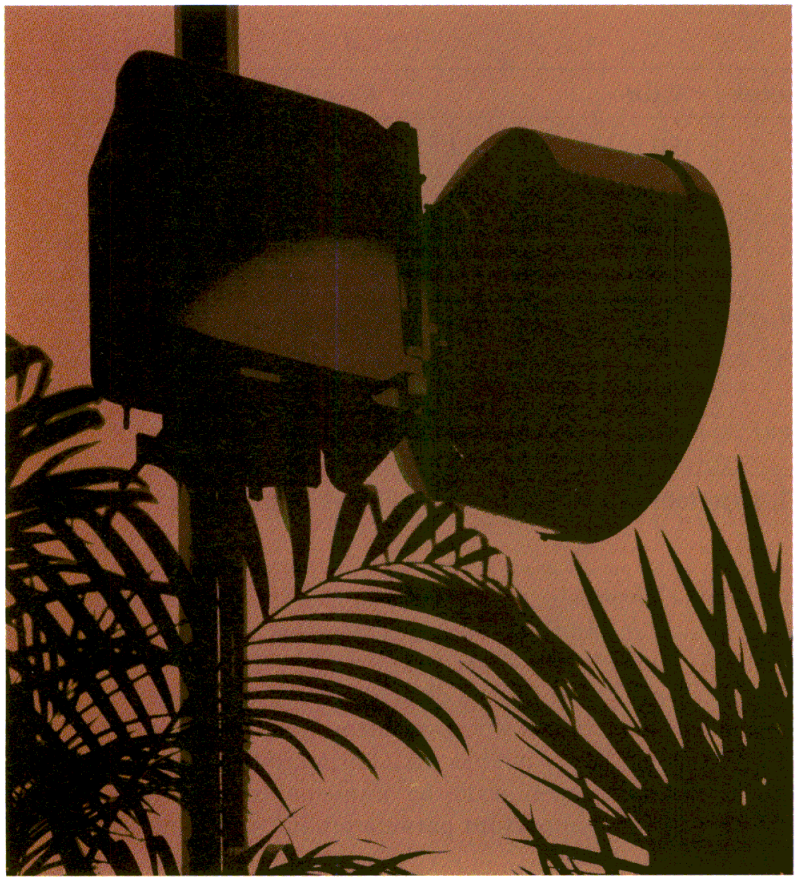

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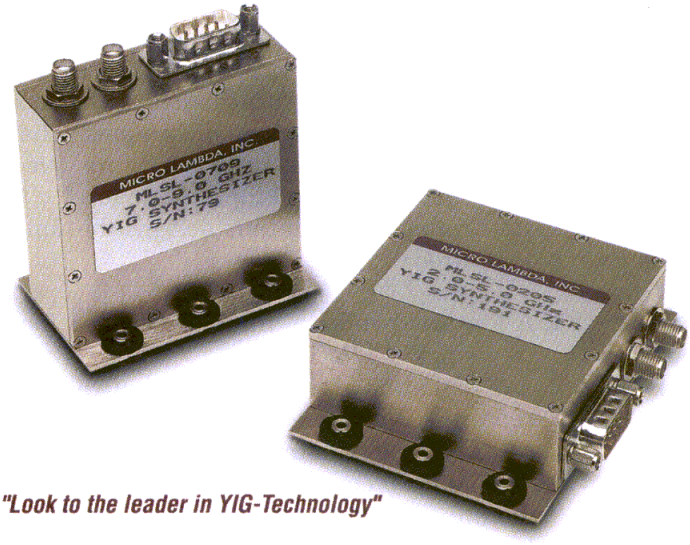

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tion [3]. The time domain transient solutions that may be obtained from both harmonic balance and envelope simulations will lead to QL and hence phase noise performance [4]. The envelope-transient technique, used in conjunction with harmonic-balance and linear-RF simulation, is the best-suited technique (and the only practical one) for all present wireless communication designs. Using envelope simulation, one can analyze circuits where inputs are simulated by RF carriers with complex, time-varying envelopes such as amplitude and phase modulations. Their spectra can represent transient signals or pseudo-random digital modulation, and can include periodic signals having discrete spectral lines, such as those from a mixer or amplifier under multi-tone excitation.

Parameter	Value	Conditions
I_{max}	190 mA	V_{ds} = 2 V V_{gs} = 1 V
G_m	95 mS	V_{ds} = 2 V V_{gs} = 0 V
V_p	–0.8 V	V_{ds} = 2 V I_{ds} = 2 mA
BV_{gd}	–16 V	I_{gd} = 2 mA
Max P_{in}	80 mW	
Max T_{ch}	150° C	
P_{1dB}	23 dBm	V_{ds} = 5 VI_{ds}= 50% I_{dss} f = 15 GHz
P_{diss}(max)	800 mW	

▲ **Table 1. Important parameters for the LP6836-P70 transistor.**

Before proceeding to the output design, the dynamic load line of any one-port (or two-port at the output port) needs to be understood in detail. It will be shown that a clock-wise rotation represents nonlinear capacitance performance (voltage leads current by 90 degrees), and the other direction represents nonlinear inductance performance. These "dynamic load lines" have been available from harmonic balance simulators since the late 1980s. In a power amplifier, the load line may be inductive over a portion of the cycle and capacitive over another portion of the cycle. This seems to imply that the load line is more resistive (a straight line) over the cycle and thus delivers more power at a higher efficiency.

The study of frequency multiplier load lines is in its infancy, but some preliminary results will be included in this article. Different CAD products seem to predict different load lines; the result included in this paper uses the Xpedion nonlinear CAD tools primarily in the harmonic balance mode.

A simple capacitive load line (CW) is shown in Figure 1, where the voltage and current of an ideal capacitor have been plotted in the time domain, and the resulting load line, a circle in the CW direction, is illustrated. By following the location of points, the dynamic load line can be better understood. This is an extremely important tool in understanding all nonlinear circuits: oscillators, mixers, amplifiers, frequency multipliers and other related circuits.

Tripler design

The PHEMT tripler was designed using Xpedion CAD for nonlinear circuits. The frequencies were f_0 = 2.125 GHz at the input and $3f_0$ = 6.375 GHz at the output, with a nominal input and output power of 0 dBm. The LP6836-P70 PHEMT was selected for its good microwave gain, 12 dB at 15 GHz. The primary nonlinearities in this transistor are the drain current generator and the nonlinear gate capacitances, which are modeled by the Statz-Pucel model. The Curtice Cubic model was used for the design and is available on the Filtronic Solid State web site, http://www.filtronicsolidstate.com, nonlinear models. In addition to this model, the Angelov model will soon be implemented for this transistor. Some important parameters for this transistor are given in Table 1.

The design procedure proceeds as follows. The S_{11} at 2.125 GHz is matched to a 50 ohm generator. Also, the stability factor, k, must be greater than unity at all frequencies in all 3-terminal transistor circuits. Thus, a 20 ohm resistor has been added in the gate bias stub to achieve this stability.

The load circuit is then designed and is the most crucial part of any generator design. All signal generators are one-ports, including this (and any other) frequency multiplier. The input port is irrelevant in the signal generator mode. Understanding the circuit performance and the role of the device is essential to improving the circuit performance. With the help of harmonic balance and envelope simulation techniques, the nonlinear device behavior may be deduced for various circuit conditions such as bias and input drive level.

Returning to the output design, the following steps are required:

1. A low-loss bandpass filter is designed for the output frequency, 6.375 GHz.
2. A 50 ohm line of $\lambda/4$ is inserted between the filter and the transistor. Since the filter is approximately a short circuit at the fundamental, the drain of the transistor sees an open circuit and therefore a maximum fundamental voltage and a maximum 3rd (and other odd harmonics) at the drain.
3. An idler stub is inserted at a voltage minimum on the drain which is a $\lambda/4$ short circuited transmission-line stub at f_0. It is therefore an open circuit at all odd frequencies and a short circuit at all even harmonics.

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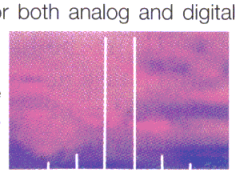

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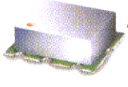
SYM-15VH	10 -1500	31	45	35	6.5	27.95
SYM-14H	100-1370	30	36	30	6.5	14.95
SYM-10DH	800 -1000	31	45	29	7.6	17.80
SYM-22H	1500 -2200	30	33	38	5.6	18.75
SYM-20DH	1700-2000	32	35	34	6.7	14.95

All models are surface mount and available in tape and reel.
LO=+17dBm except SYM-15VH LO=+23dBm



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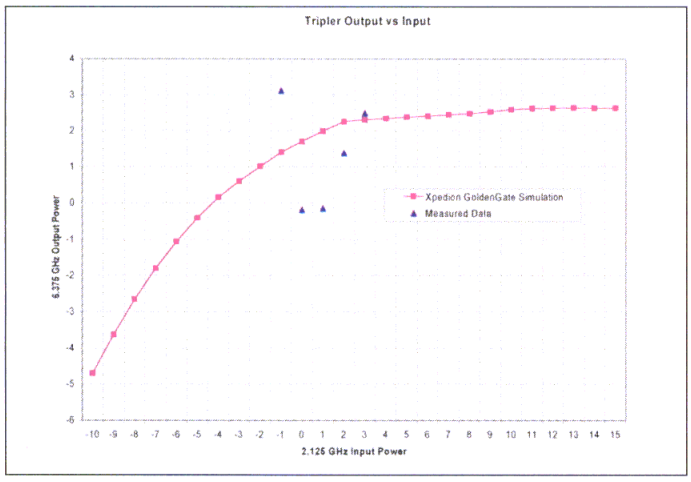
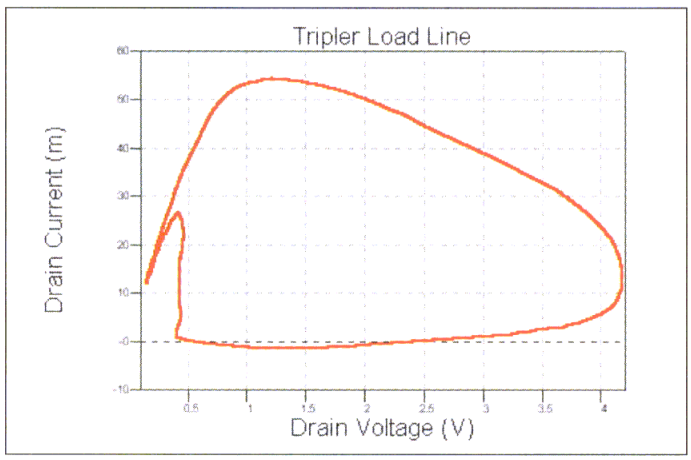
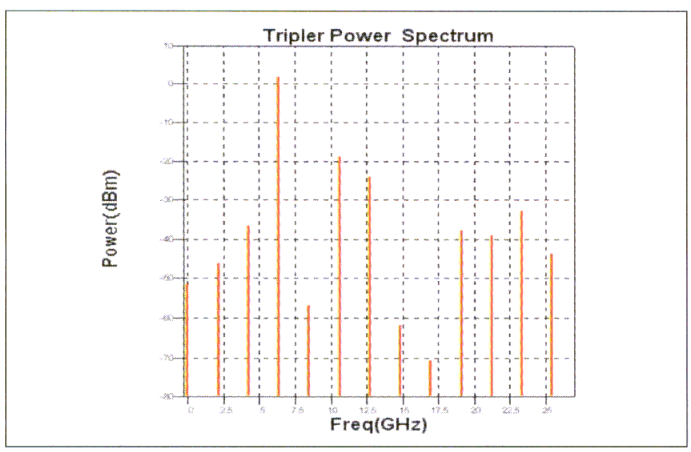


▲ **Figure 2. Simulated and measured 6 GHz levels for a swept range of 2 GHz drive levels.**



▲ **Figure 3. Tripler load line, rotating clockwise.**



▲ **Figure 4. Simulated tripler output spectrum.**

Next, the bias condition for optimum gain is found by tuning these variables for a given input power. Usually, the design is found for some optimum bias where the measurements do not agree. Then the bias for best gain is found in the lab, which can then be verified on the computer. This was the design cycle for this tripler.

Frequency (GHz)	Power (dBm)
2.125	–30
4.250	–35
6.375	0
8.500	–30
10.625	–35

▲ **Table 2. Typical data for harmonic levels.**

Measurements

In Figure 2 the third harmonic output has been plotted versus the fundamental input power for both the measurements and the design calculations. The optimum measured gain occurred for an input power of –1 dBm and an output power of 3.1 dBm at a bias of V_{ds} = 1.0 V, V_{gs} = –0.77 V and I_{ds} = 19.6 mA. The output power saturates at about 9 dBm for a bias of V_{ds} = 2.8 V, V_{gs} = –3.82 V, I_{ds} = 35.9 mA and P_{in} = 15 dBm (see Figure 2). The gain is found to be ±4 dB, or essentially 0 dB in the linear range. Several devices were tested with various values of I_{dss}, and the measurements plotted in Figure 2 include all of these transistors. We have seen CAD designs with as much as 12 dB gain, but the drain voltage is much too high for safe and reliable operation. This can only be discovered by using a nonlinear simulation and investigating the dynamic load-line.

The typical conversion gain is near 0 dB at an input power of 0 dBm. This has been verified with many devices. The most critical tuning is the idler circuit described above. The substrate material was 10 mils Rogers 6002, with ε_r = 2.94, h = 10 mils and tan δ = 0.003. Other materials could give better performance (lower loss tangent). The metal is gold with t = 5 μm. The circuits are fabricated at Filtronic Solid State using their standard low-cost process for hybrid microwave integrated circuits.

The dynamic load is plotted in Figure 3 for a bias of V_{ds} = 3.4 V, V_{gs} = –0.9 V and P_{in} = 15 dBm. The approximate slope is 200 ohms. Typical data for harmonics are shown in Table 2 and Figure 4. Using the envelope-transient technique, the startup waveform is shown in Figure 5. The circuit diagram created for simulation is shown in Figure 6.

Using the Leeson noise theory for oscillators (Ref. 4), the phase noise of this tripler may be calculated, assuming Q_L = 62, P_o = 0 dBm, F = 3 dB and f_c = 10 MHz (flicker noise corner frequency). The calculation gives

$$\mathcal{L}(f_m) = \mathcal{L}(100\ \text{kHz}) = -100\ \text{dBc}$$

For an input frequency of 2.125 GHz, this is a phase noise of –112 dBc, since the phase noise is expected to increase by 12 dB for a tripler.

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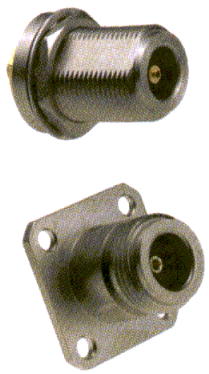

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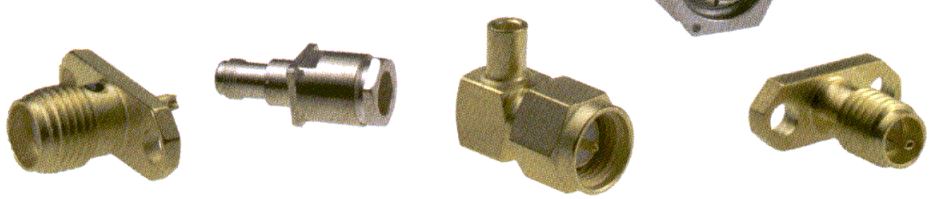

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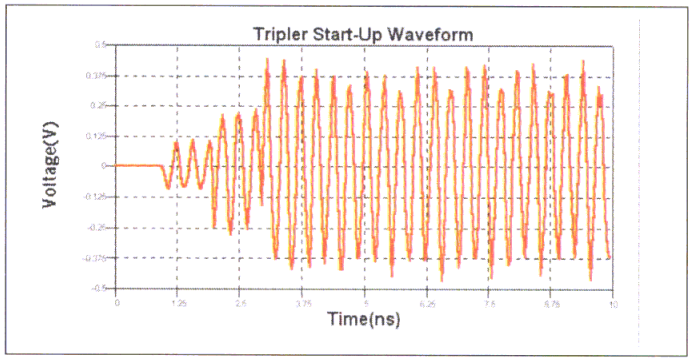
Conclusions

Using design procedures given in the literature and new PHEMTs with good microwave gain, a state-of-the-art tripler has been designed using a new nonlinear CAD package from Xpedion Design Systems, Inc., and tested for the 2-6 GHz range with 0 dB gain at an unusually low drain voltage bias point. Diode multipliers will always have loss, so this is an important bench-mark for future frequency multipliers. ■



▲ **Figure 5. Simulated tripler startup waveform.**

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3. K. S. Kundert, "Introduction to RF Simulation and Its Application," *IEEE Journal of Solid-State Circuits*, September 1999.

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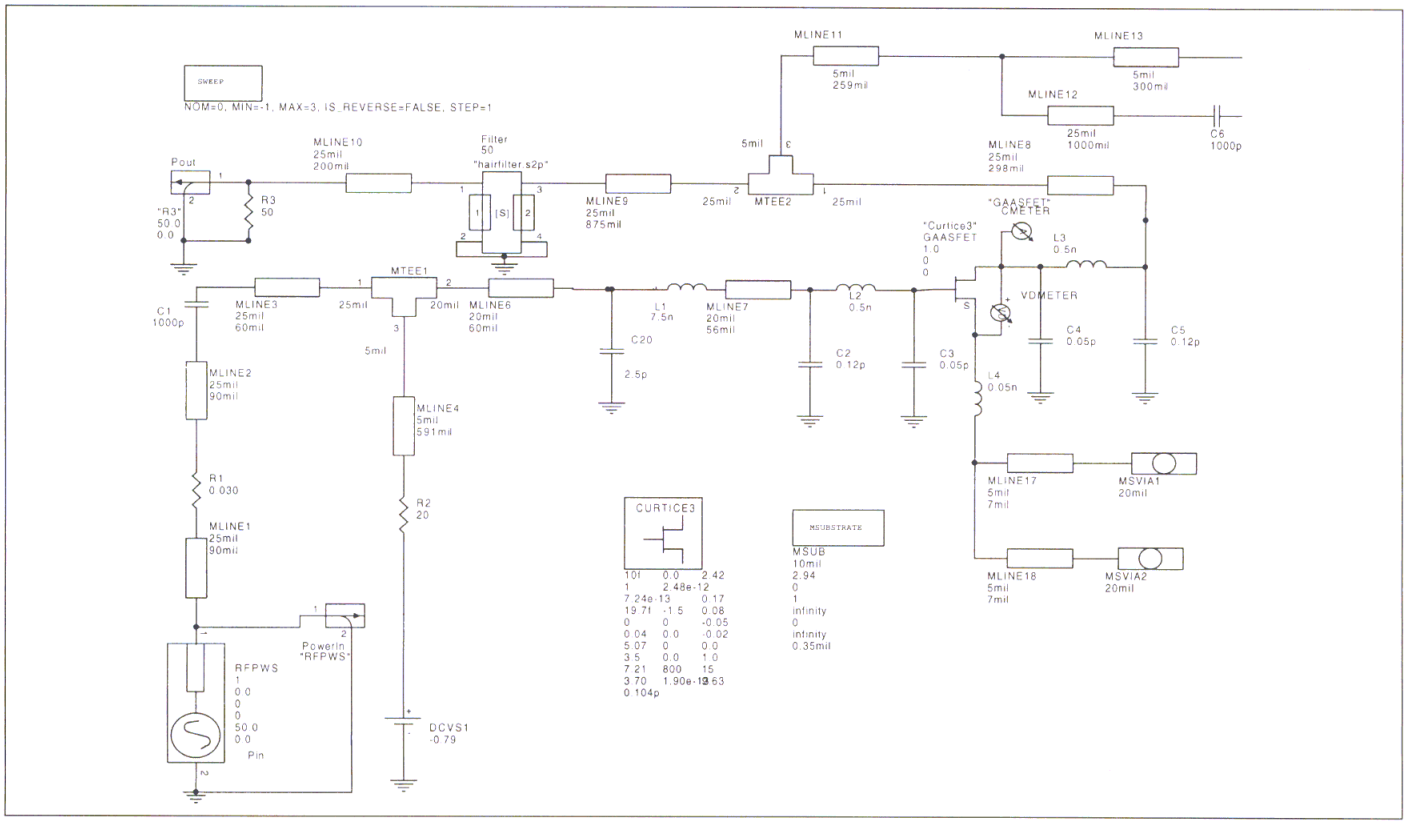
Masoud Mostafavi is a Professor of Electrical Engineering at San Jose State University, where he has taught courses in electromagnetics, wireless communications, microwaves and antennas.

Jake Goldstein is Customer Support Manager for Xpedion Design Systems, an RF simulation and modeling company based in Santa Clara, CA. He may be contacted at jakeg@xpedion.com.

David Chipman was a design engineer at Filtronic Solid State at the time this article was written. He is presently with Anritsu Company.



▲ **Figure 6. Circuit diagram of the tripler, as defined for simulation in Expedion's GoldenGate.**

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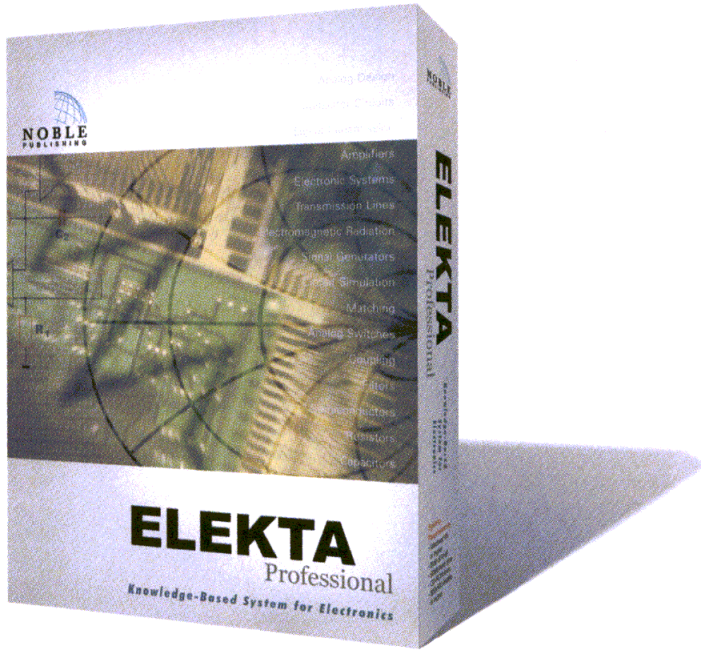

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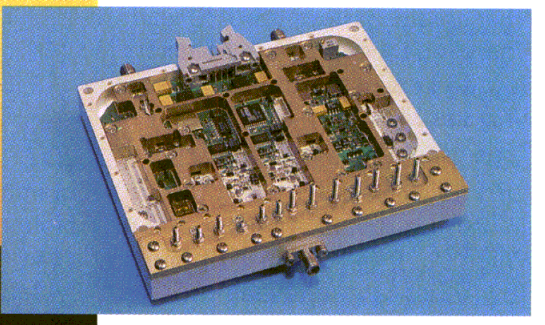

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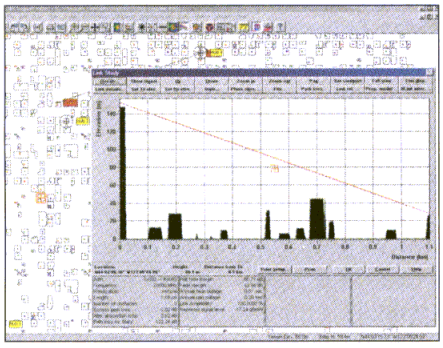


ware allows easy import and export of files in the required FCC format. Study types include power flux density, co-channel and adjacent channel interference. Interference analysis includes adjacent system hub interference (noise floor degradation) and registered ITFS sites. The Network Design Module adds engineering design of system layout and frequency planning.

EDX Engineering, Inc.
Circle #149

Vector signal analyzer hardware/software solution

Agilent Technologies has announced the Agilent 89600 series vector signal analyzer. Tightly linked hardware and software give engineers powerful signal analysis capabilities for any stage of the design and development process. The 89600 combines time- and frequency-domain analysis to handle difficult burst, hopped and modulated signals. The hardware is provided in a VXI format and offers 40 MHz bandwidth to analyze baseband or downconverted signals. Pricing starts at $37,000.

Agilent Technologies
Circle #150

Software links analysis and layout/packaging tools

AnsoftLinks™ 2.0 for Cadence® Allegro/APD converts structures into a format that can be analyzed by Ansoft's electromagnetic analysis tools. A selected layout, or a cutout section, can be converted and analyzed. Physical and electrical parameters such as layer thickness, dielectric constant and conductivity can be edited and returned to the layout. The package automatically generates and edits bond wires, solderballs and vias, and adds ports or terminations to identified pins.

Ansoft Corporation
Circle #151

Foundry models include process improvements

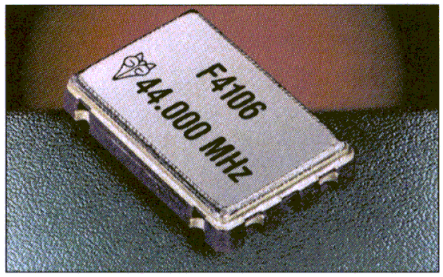
TriQuint Semiconductor has announced the availability of the TQTRx foundry process design kit, including the company's TOM3 advanced non-linear GaAs FET models. The models run on Agilent Technologies' Advanced Design System. They provide RFIC designers with seamless circuit synthesis, modeling and layout capabilities.

TriQuint Semiconductor
Circle #152

FREQUENCY CONTROL

44.00 MHz oscillator designed for WLAN chipset

Fox Electronics offers the F4106-440 CMOS oscillator designed specifically for the Intersil

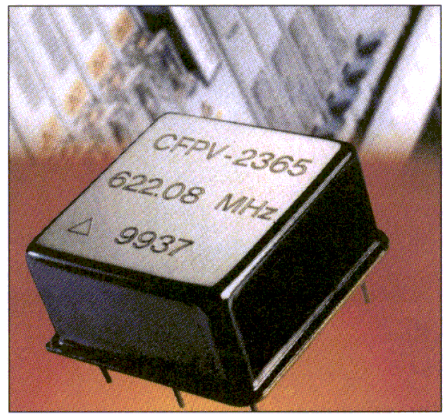


Corporation PRISM® I, II and III chipsets. The new oscillator is offered in the industry standard 5 × 7 mm ceramic SMD package. It operates at a frequency of 44.000 MHz with ±25 ppm stability. Operation is from a 3.3 VDC supply. Typical pricing is $5 each in quantities of 1,000.

Fox Electronics
Circle #153

622 MHz BAW VCXO

C-MAC Frequency Products offers a high frequency voltage controlled crystal oscillator (VCXO)



designed for time multiplexing applications in SDH STM-4 and SONET STS-12 synchronous digital trunk lines. The CFPV-2365 is a 622.08 MHz unit using bulk acoustic wave (BAW) crystal technology for frequency stability and voltage control that is superior to surface acoustic wave (SAW) devices. Stability is ±20 ppm from 0° to 70° C with pullability of between ±80 and ±120 ppm. The oscillator runs at 155.52 MHz with the fourth harmonic selected and amplified to provide the final output frequency. The CFPV-2365 is priced from $48 each, depending on specification, in quantities of 10,000.

C-MAC Frequency Products
Circle #154

SAW resonator and front-end filter set

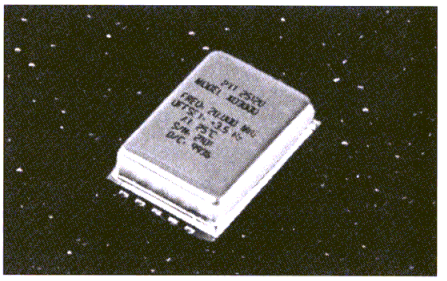
RF Monolithics has introduced surface-mount and TO-39 SAW resonators and front-end filters with an accompanying 10.7 MHz IF LO resonator for use in North American 390 MHz remote control

applications. These applications are primarily garage door openers but also include automotive, utility, industrial and other consumer applications. The set includes the RO2188A resonator and the RO1355 front-end filter. The devices are suited for design upgrades from older technology.

RF Monolithics
Circle #155

Surface mount TCXO/VCXO

Piezo Technology now offers



Model XO3080, a surface mount TCXO/VCXO for wireless applications. Available for frequencies from 10 to 100 MHz, the oscillator provides ±0.75 ppm over a temperature range of –30° to +70° C. Extended temperature range operation may be specified, with modified stability performance. The oscillator package is 0.98 × 0.69 × 0.22 inches. The XO3080 operates from a 5 VDC supply.

Piezo Technology, Inc. (PTI)
Circle #156

Low cost OCXOs can replace TCXOs

Raltron Electronics announces a line of oven controlled crystal oscillators OCXOs) that outperform typical temperature compensated crystal oscillators (TCXOs) at a lower price. Model OX-2000 series

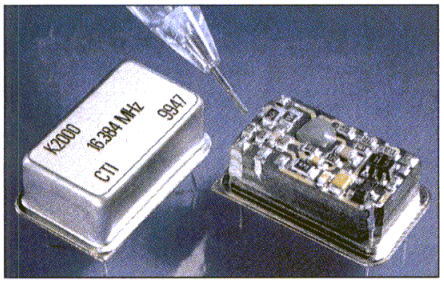
units are available from 1 MHz to 160 MHz in the popular 14-pin DIP package. Frequency stability is specified at ±0.1 ppm over 0° to +50° C. The OX-2000 meets ANSI Stratum-3 requirements, including ±4.6 ppm total stability over lifetime and ±0.37 ppm over a holdover period of temperature, voltage and load variations. Prices start at $50 each in OEM quantities of 10,000.

Raltron Electronics Corporation
Circle #157

VCOCXOs for Stratum-3

Champion Technologies offers the K2000 series, a line of voltage controlled ovenized crystal oscillators (VCOCXOs). Housed in a DIL14 package, the K2000 series

operates from +5 or +12 volt supplies. With the 12 volt supply, frequency stability is less than ±1 × 10^{-7} (±100 ppb) over the temperature range of 0° to +70° C. Phase



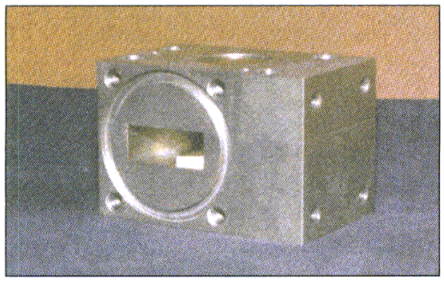
noise is specified at less than –95 dBc/Hz at 10 Hz offset. Standard frequencies are available immediately to 20 MHz, with optional frequencies up to 38.88 MHz. Pricing starts at $75.00 each in quantities of 1,000.

Champion Technologies
Circle #158

SIGNAL PROCESSING

9 GHz isolator meets military specifications

Pathwave announces delivery of the IX2E Isolator in compliance with MIL-I-45208A. The unit operates in the frequency range of 9.0 to 9.2 GHz with isolation of 30 dB

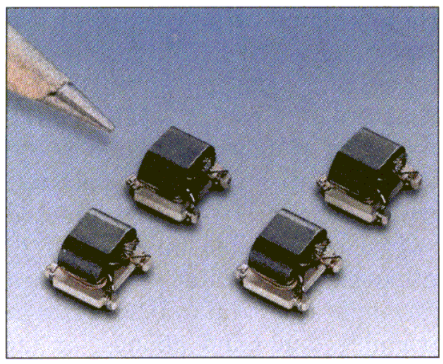


(min.), insertion loss of 0.1 dB (max.) and VSWR of 1.6:1 (max.). Operation is specified over a temperature range of –50° to +85° C. Similar units can be provided over a wide range of frequencies.

Pathwave
Circle #159

SMT directional couplers

Sprague-Goodman Electronics has introduced a new line of surface mount directional couplers designated the GLSN series. These couplers provide coupling values from 6 to 16 dB in a compact 5.7 × 5.7 × 4.0 mm design. An example is the GGLSN16D152, a 16 dB coupler with a maximum loss at 20 MHz of 0.6 dB and 3 dB band limits of 0.5 and 1500 MHz. Production pricing for this model is $0.99 each.



Sprague-Goodman Electronics
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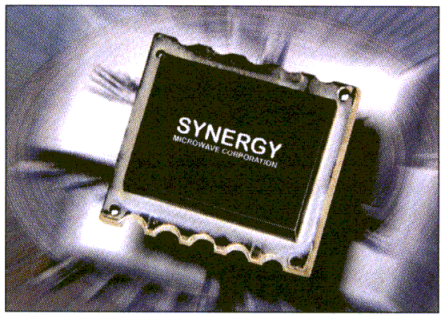
Double-balanced mixers cover C-band

Synergy Microwave now offers C-band double-balanced mixers using multilayer microstrip technology. The new mixers cover the

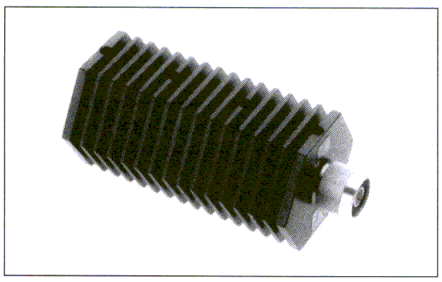


frequency range of 3.6 to 4.8 GHz with typical conversion loss of 8 dB, LO to RF isolation of 25 dB and LO to IF isolation of 17 dB. They are available at various LO drive levels and are housed in a 0.3 × 0.2 × 0.1 surface mount leadless package.

Synergy Microwave Corp.
Circle #161

50 watt loads feature low intermod performance

BCP presents Model 50-T-FN, a 5-watt load with low intermodulation distortion performance for cellular and PCS applications. Typical IMD in the cellular band is –116 dBc when tested at +43 dBm, –121



dBm in the PCS band. The loads have a frequency range of DC to 4 GHz with VSWR 1.10:1 from DC to 1 GHz and 1.25:1 over the entire range. Connector options are BNC, IEC 7/16, type N and TNC.

BCP (Bird Component Products)
Circle #162

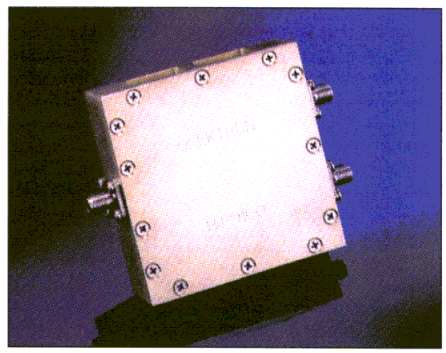
GaAs SPDT switches

M/A-COM announces the availability of two new SPDT switches. these switches are provided in low cost, very small SOT plastic packages and cover the DC to 3.0 GHz range. The SW-437 MMIC SPDT reflective switch is available in the ultra-miniature SOT-363 package, while the model SW-442 terminated switch is available in the SOT-26 package. Both switches are suited for applications up to 0.25 watts in portable dual-band phones, or for general purpose switching needs.

M/A-COM
Circle #163

2-way power divider covers 800-1000 MHz

Model HJ-9100 is a high power 2-way 0-degree power divider

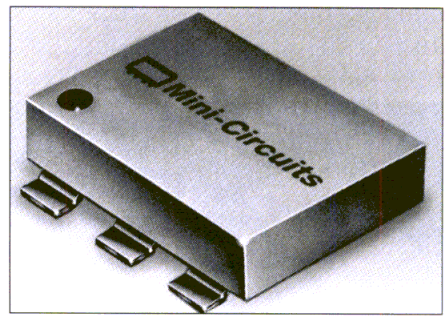


designed to handle 150 watts power over the 800 to 1000 MHz frequency range. The unit features isolation of 20 dB minimum, VSWR of 1.3:1, phase balance of ±3 degrees and amplitude balance of ±0.1 dB. Insertion loss is 0.25 dB (beyond normal power division). The power divider is housed in a 2.5 × 2.5 × 0.75 inch aluminum case with SMA connectors. The price is $150 each in quantities of 500 to 999.

Signal Technology, Olektron Operation
Circle #164

4:1 ratio transformers feature low cost

Mini-Circuits' ultra-low-profile ADT4-1WT surface mount RF transformers feature a height of just 0.108 inch. Covering the 2 to 775 MHz range, the transformers typical specifications include 20 dB return loss, 0.1 dB amplitude balance and 1 degree phase unbalance with the 1 dB bandwidth. referenced to midband, insertion loss is

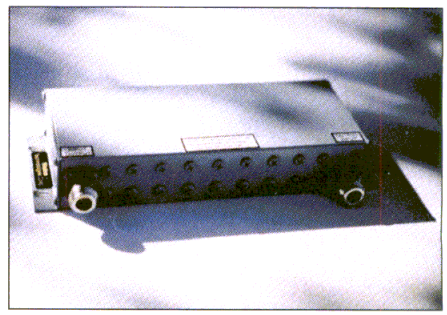


3 dB maximum over the entire band. In quantities of 10 to 49, they are priced at $2.95 each.

Mini-Circuits
Circle #165

Cavity filter screens paging interference

Model W915F from Wireless Technologies Corporation offers sharp attenuation to nearby signals emanating from pager and cellular stations. The standard rejection bandwidth is 25 MHz, centered on 915 MHz. AMPS cellular band and



pager isolation is >30 dB. Insertion loss outside the rejection bandwidth is less than 1.5 dB. Designed for the receive signal path, the filter will withstand 200 watts of power.

Wireless Technologies Corp.
Circle #166

UHF cavity filter

The Pennywhistle equal element bandpass filter from Moorestown Microwave is available at frequencies from 750 to 4000 MHz with 1 percent bandwidth and 1 dB loss. Pricing is $95 each for 1 to 5 units.

Moorestown Microwave Company
Circle #167

NEW PRODUCTS

NO.69

RF/IF MICROWAVE COMPONENTS

FROM $4.45

RF TRANSFORMERS HAVE 4:1 IMPEDANCE 200 TO 1400MHz

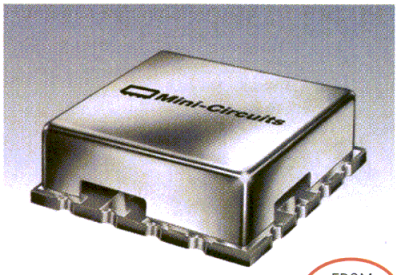
Broad band TCM4-14 surface mount RF transformers from Mini-Circuits operate in the 200 to 1400MHz band with 4:1 impedance ratio. Referenced to midband loss (0.8dB typ), insertion loss is 1dB from 800MHz to 1000MHz, 2dB in the 300 to 1300MHz range, and 3dB band wide when operated within -20°C to +85°C (max.). Open case design has plastic base with solder plated leads, and applications include impedance matching and baluns. RF power is 250mW (max.).

FEATURED PRODUCT

FROM $7.95

3000 TO 4000MHz MIXER IS TEMPERATURE STABLE

Higher frequency designs will benefit from Mini-Circuits patented family of MBA model Blue Cell™ mixers, which deliver a unique combination of low conversion loss, superb temperature stability, thin 0.07" profile, and low cost. This level 13 (LO) MBA-35MH model spans 3000MHz to 4000MHz with 22dB L-R, 14dB L-I isolation and low 5.1dB midband conversion loss (all typ). Operating temperature is -40°C to +85°C (max.) and applications include satellite and PCMCIA.



FROM $19.95

1550 TO 1720MHz VCO HAS LINEAR TUNING

The ROS-1720 voltage controlled oscillator from Mini-Circuits operates within the 1550MHz to 1720MHz band targeting PCS and DCS applications with low -141dBc/Hz SSB phase noise typical at 1MHz offset, wide 3dB modulation bandwidth typical at 18000kHz, and 28-34MHz/V (typ) linear tuning sensitivity. Housed in a miniature 0.5"x0.5"x0.18" industry standard package, typical power output is 7dBm.

FROM $12.95

50 TO 200MHz MAGIC-TEE OPERATES WITH LOW LOSS

Mini-Circuits has introduced a versatile 2way-0°/180° power splitter and combiner for the 50 to 200MHz band. Model AMT-2 typically has low insertion loss (0.25dB S-1 and S-2, 0.8dB J-1 and J-2), very good 1.10:1 input/1.12:1 output VSWR, plus excellent 0.1dB amplitude and 1 degree phase unbalance. Designed for 50 ohm systems, this 4 port hybrid covers IF receiver and satellite applications. Maximum power input as a splitter is 0.5W.

824 TO 849MHz COAXIAL AMPLIFIER FEATURES LOW NOISE

This 824 to 849MHz cellular band ZQL-900LN low noise amplifier from Mini-Circuits typically provides high 16.5dB gain (±0.2db flatness), ultra-low 1.0dB noise figure, and 22.5dBm maximum power output at 1dB compression. High +35dBm IP3 helps suppress noisy intermodulation products, and operating temperatures range from -40°C to +70°C maximum. Equipped with 50 ohm SMA-Female connectors.

FROM $229

6 pc. KIT $150

2W SMA ATTENUATORS AVAILABLE IN DESIGNER'S KIT

Six different DC to 18GHz fixed attenuators from Mini-Circuits "BW" series are now available at a special evaluation price in designer's kit form. Kit number K-BW2 contains units that display nominal attenuation values of 3dB, 6dB, 10dB, 20dB, 30dB, and 40dB. Built tough to handle 2W average, 125W peak power, these miniature stainless steel precision attenuators are ideal for matching, test set-ups, and instrumentation applications. Available from stock.

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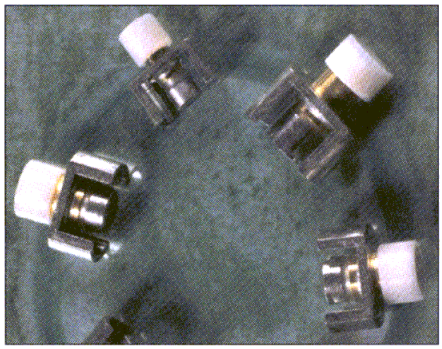
COMPONENTS

Trimmer capacitors

ER Gigahertz trimmers from Temex Microwave are available for tuning of microwave circuits for fil-



ters, impedance matching, resonator tuning and amplifier adjustment. The extended range versions pictured above are rated at 500 VDC and are offered in two series. The AT 2ER70 series has a Q factor >3000 at 100 MHz and is available with 0.8 to 8.0 pF capacitance. The AT 2ER80 series has a Q factor of >3000 at 250 MHz and is offered in values of 0.6 to 4.5 pF. Non-magnetic versions are also available.

Temex Microwave
Circle #168

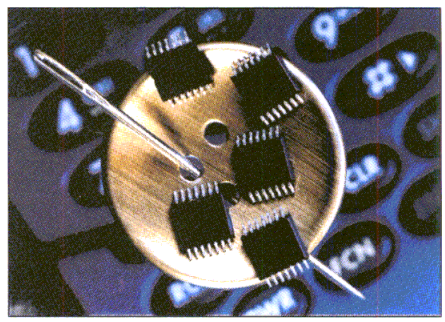
Quad MOSFET mixer offers high linearity

Peregrine Semiconductor announces the PE4120 high-linearity quad MOSFET mixer, a passive broadband device for conversion or phase detection applications up to 2.5 GHz. Conversion loss is 6 dB over its operating range with 20 dBm LO drive. Third order intercept (IP_3) performance is 28 dBm, LO to IF isolation is 36 dB and LO to RF isolation is 34 dB. The mixer is fabricated using the company's UTSi which uses a synthetic sapphire substrate, which improves power dissipation and reduces noise and stray capacitance. The PE4120 is offered in 8-pin TSSOP and SOT-23 packages at a price of $1 each in quantities of 10,000.

Peregrine Semiconductor
Circle #169

Voltage converter includes on-chip regulator

Toko America offers a new switched-capacitor DC-DC convert-



er for use in wireless and portable battery powered systems. The TK75018 can crate a negative sup-

ply voltage which can track the positive supply or be regulated via its own feedback pin. With no external timing elements, the converter will self-oscillate at 25 kHz. This frequency can be adjusted with a small capacitor or synchronized with an external source. Pricing begins at $1.75 each in 1,000 piece tape and reel quantities.

Toko America
Circle #170

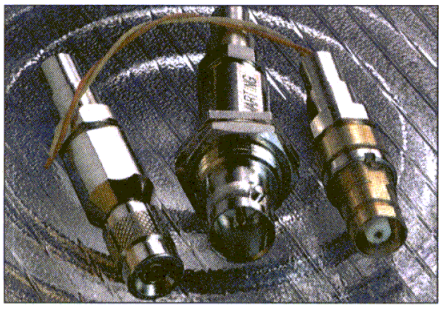
Traveling wave tube for 28 GHz applications

ISTOK Microwave offers the ITW-28GC-150WA, a 28 GHz, 150 watt traveling wave tube. This broadband device is a high performance single-beam tube for applications in LMDS, wireless communications or satellite uplink service. The TWT features a coupled cavity circuit for increased reliability over traditional helix designs. EIA WR 28 waveguide and a UG 599/U flange transition provide RF output and input access. VSWR does not exceed 1.3:1 with integral ferrite isolators. An integral vac ion pump ensures best vacuum conditions.

ISTOK Microwave
Circle #171

Baluns convert twisted pair to coaxial cable

Harting announces the Mini-Baluns, a new series of telecommunications baluns. The baluns con-



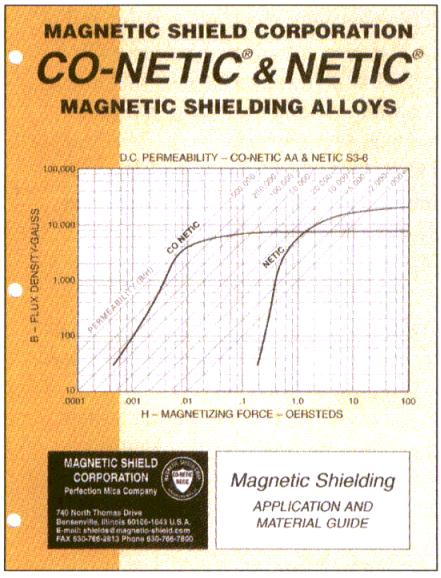
vert the 120 ohm impedance of a balanced twisted pair to 75 ohm unbalanced for commonly-used coaxial cable. The baluns perform the conversion as a cable adapter, eliminating the need to include conversion on the equipment p.c. board. They are offered in 2 to 34 Mbps and 34 to 155 MBps versions. The adapter is fully shielded with low insertion loss and minimal crosstalk. Pricing for the BNC model begins at $25 each.

Harting, Inc.
Circle #172

LITERATURE

Guide to magnetic shielding alloys

A new MG-7 magnetic shielding alloy catalog from Magnetic Shield Corporation provides complete specification, application and fabrication information for EMI engineering solutions. It contains com-



prehensive tables of alloy properties, instructions for use, shield construction methods and part number listings. It also includes full details on the company's NETIC S3-6 and CO-NETIC AA Alloys for stopping magnetic interference. These alloys are available in both sheet and foil. Magnetic Shield Corporation offers its CO-NETIC AA Perfection Annealed Alloy that already has received the final magnetic stop under controlled factory conditions. This alloy can save time and expense for fabricators and users when applied correctly. The company also offers a brochure that

provides details vital to proper alloy selection.

Magnetic Shield Corporation
Circle #173

2000 data book features crystal products

C-MAC Frequency Products has released its new Crystal Product Data Book 2000. The book allows customers to specify and order components off the page using the specifications and controlled issue numbers provided. The 284-page Crystal Product Data Book provides detailed specifications of hundreds of standard and custom frequency control devices. New quartz crystal products included in the 2000 edition include the CFPT-9100, an "all causes" Stratum III surface-mount TCXO (temperature compensated crystal oscillator) based on mass-market mobile phone technology, the CFPV-2365,

a low-voltage 622.0 MHz VCXO (voltage controlled crystal oscillator) for time multiplying in SDH/SONET trunk lines, and a number of ultra-stability OCXOs (oven controlled crystal oscillators). The book also includes C-MAC's first rubidium oscillators.

C-MAC
Circle #174

RF Micro Devices offers designer's handbook

RF Micro Devices has announced the availability of its 2000

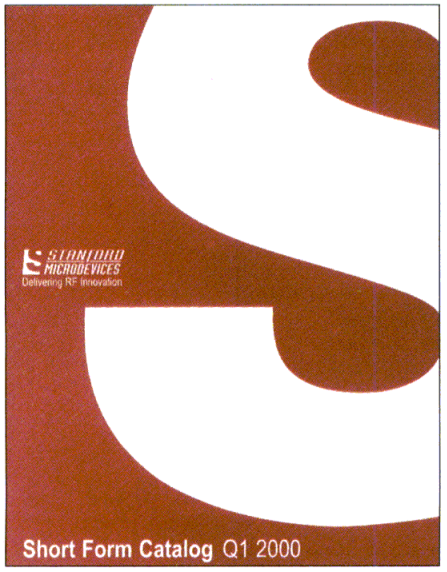
Designer's Handbook. Featuring more than 150 products from the RF Micro Devices power amplifier,

digital cellular, silicon systems and broadband product lines, the 2000 Designer's Handbook is available free of charge in standard print version and on CD-ROM. New this year, RFMD is also offering a short-form catalog, which includes the CD-ROM version. Applications engineers will find extensive technical information, performance test data, comprehensive product specs, schematics, application notes and in-depth articles about specific components.

RF Micro Devices
Circle #175

Short form catalog highlights semiconductors

Stanford Microdevices has released a new short form catalog, introducing the company's MMIC



amplifiers, power amplifiers, power transistors, low noise amplifiers, medium/high power amplifiers and high isolation switches. The catalog provides a selection guide for each product category and highlights the possible applications. Outline drawings are also included.

Stanford Microdevices
Circle #176

Telecom catalog

Jensen Tools, a division of Stanley Works, has released a new catalog designed for the telecom,

electrical and global communications industries. This 116-page, full color catalog offers a wide range of tool kits, hand and specialty tools, cable, telephone and electrical test equipment and service aids. Many new products are featured, including Jensen's new line of JTS Telecom Test Sets.

Jensen Tools
Circle #177

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Circle 16

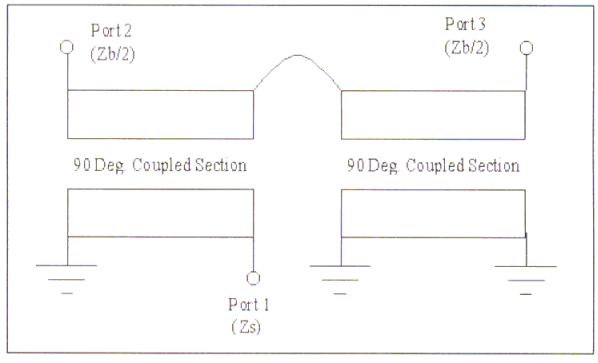
Design of Baluns Using Backward Wave Couplers

This balun design allows impedance transformation in addition to providing the balanced-to-unbalanced function

By Jeff Merrill
Anaren Microwave, Inc.

This article introduces a technique for designing balanced to unbalanced transmission line transformers (baluns), which offer the flexibility to transform impedance from the balanced to unbalanced ports. This device has applications in the RF/microwave industry for antennas, push-pull amplifiers, mixers and modulators, as well as other circuits. Two backward wave couplers with a specific interconnect and port termination scheme are used to achieve this balun function.

The discussion that follows assumes the reader is familiar with the concepts of characteristic impedance and even and odd mode impedances as they relate to backward wave couplers [1, 2]. The schematic shown in Figure 1 illustrates the interconnect scheme for the balun. To help simplify the analysis, this illustration intentionally omits parasitic elements that are due to interconnection or packaging. These issues must be given serious consideration when implementing this design into a packaged product. However, because the parasitics associated with physical implementation will vary depending on the type of structure that is used, these issues will not be addressed here and are left for the reader to consider in his or her specific design.



▲ **Figure 1. Interconnection scheme for the balun.**

Circuit analysis

As can be seen in the schematic representation of Figure 1, the circuit is composed of two equivalent couplers that both have a characteristic impedance of Z_0. After shorting three of the ports and making the coupler interconnection, we are left with three ports. Note that the coupler on the right, with two ports grounded, could be replaced by its equivalent circuit, which is a quarter wave piece of transmission line with an impedance as defined in reference [3]. We chose to use a coupler to maintain symmetry in the circuit as well as to minimize the layout space required.

This three-port device (with all three ports referenced to ground) has the following S-parameter matrix at center frequency when Z_0 is such that port one is matched [4]:

$$S^t = \begin{bmatrix} S^t_{11} & S^t_{12} & S^t_{13} \\ S^t_{21} & S^t_{22} & S^t_{23} \\ S^t_{31} & S^t_{32} & S^t_{33} \end{bmatrix} = \begin{bmatrix} 0 & j/\sqrt{2} & -j\sqrt{2} \\ j/\sqrt{2} & -1/2 & -1/2 \\ -j/\sqrt{2} & -1/2 & -1/2 \end{bmatrix} \quad (1)$$

(Note that the "t" in S^t stands for three port.)

The following equalities are valid at all frequencies. The proof of these statements is obtained using flow graph theory and applying Mason's rule [5]:

The Marketing Guy Said No. The Test People Said No. The Applications Engineer Said No. The Designers Said Maybe.

But Shep Said Yes.

It doesn't always make sense to give customers more than they think they need. After all, if testing for PCS and wireless happens right now at 0.8 to 1.9 GHz, it makes sense to do an amp that tests there. No unwanted extras. No stress on anyone's budget. At least that's what the experts say.

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Circle 42

$$S^t_{22} = S^t_{33} \quad (1)$$

$$S^t_{23} = S^t_{32} \quad \text{(Reciprocity)} \quad (2)$$

$$S^t_{21} = -S^t_{31} \quad \text{(equal amplitude and 180 degree phase difference)} \quad (3)$$

$$|S^t_{22} + S^t_{32}| = 1 \quad (4)$$

Equations 1 and 2 seem intuitively obvious; however, equations 3 and 4 may not and have been simulated for confirmation. The S^t-parameters are plotted over a 3:1 bandwidth in Figures 2 and 3. In Figure 2, port 1 is set to 50 ohms, ports 2 and 3 are set to 12.5 ohms (25 ohm balanced termination), the coupler normalized even mode impedance is set to 3.5 and coupler characteristic impedance is calculated (with formula to be presented later) to be 28.41 ohms. These conditions yield perfect match at port 1 at center frequency. Note that the normalized even mode impedance $Z_{0en} = Z_{0e}/Z_0 = Z_0/Z_{0o}$ where Z_{0e} and Z_{0o} are even and odd mode impedances.

These equations are also valid when the ports are not perfectly matched. To illustrate this fact, Z_0 will be changed from 28.41 ohms to 25 ohms. Port impedances and normalized even mode impedance will remain the same. The S^t-parameters of equations 3 and 4 are again plotted in Figure 3 for this new condition. Notice that S^t_{22} and S^t_{32} have both changed, but equation 4 is still valid. Changes in S^t_{21} and S^t_{31} are difficult to see but have occurred, and equation 3 is still valid.

Network conversion from three-port to two-port

Given the above equalities, the circuit can now be reduced from a three-port network to a two-port network, with port 1 remaining the single-ended port and ports 2 and 3 being combined to be the balanced port (Figure 4). The combining of ports 2 and 3 to yield a single balanced port is mathematically illustrated below. Because this is a balanced port, there will be a differential and a common mode solution. Both are solved below, although only the differential solution will exist in our analysis of this balun circuit. This is driven by the above equality $S^t_{21} = -S^t_{31}$.

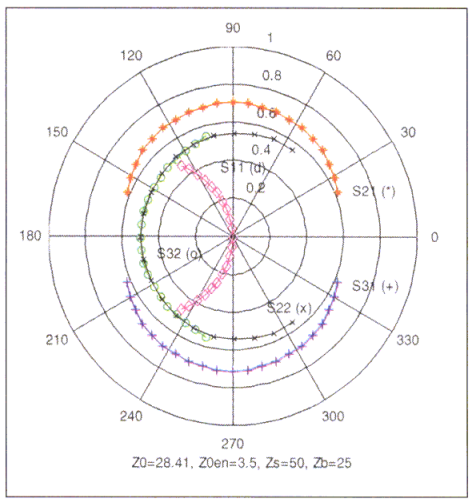
$$b_2 = a_2 \times S^t_{22} + a_3 \times S^t_{23} \quad (5)$$

$$b_3 = a_3 \times S^t_{33} + a_2 \times S^t_{32} \quad (6)$$

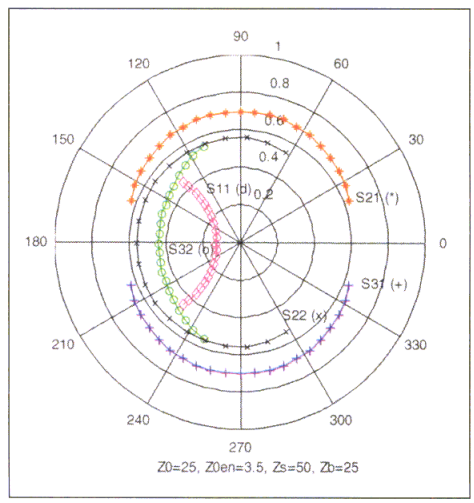
For differential mode: $a_2 = \frac{1}{2}$ and $a_3 = (-\frac{1}{2})$

$$S^d_{22} = \Gamma_{\text{diff}} = \frac{b_2 - b_3}{a_2 - a_3} = \frac{\left(\frac{1}{2}\times S^t_{22} + \frac{1}{2}\times S^t_{23}\right) + \left(\frac{1}{2}\times S^t_{33} + \frac{1}{2}\times S^t_{32}\right)}{\frac{1}{2} - (-\frac{1}{2})} = \frac{1}{2}\left(S^t_{22} + S^t_{33}\right) + \frac{1}{2}\left(S^t_{23} + S^t_{32}\right) \quad (7)$$

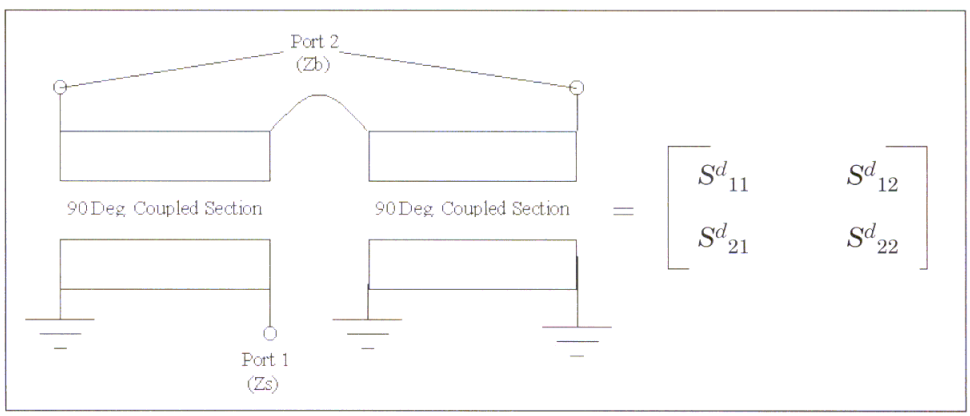
For common mode: $a_2 = \frac{1}{2}$ and $a_3 = \frac{1}{2}$



▲ **Figure 2. S_t-parameters with port 1 set to 50 ohms and ports 2 and 3 set to 12.5 ohms (25 ohms balanced termination). Z_0 is 28.41 ohms.**



▲ **Figure 3. S_t-parameters from equations (3) and (4) with the same conditions as Figure 2, but with Z_0 of 25 ohms (not perfectly matched).**



▲ **Figure 4. Reduction of the three-port representation of the balun to two ports, with port 2 being a balanced port.**

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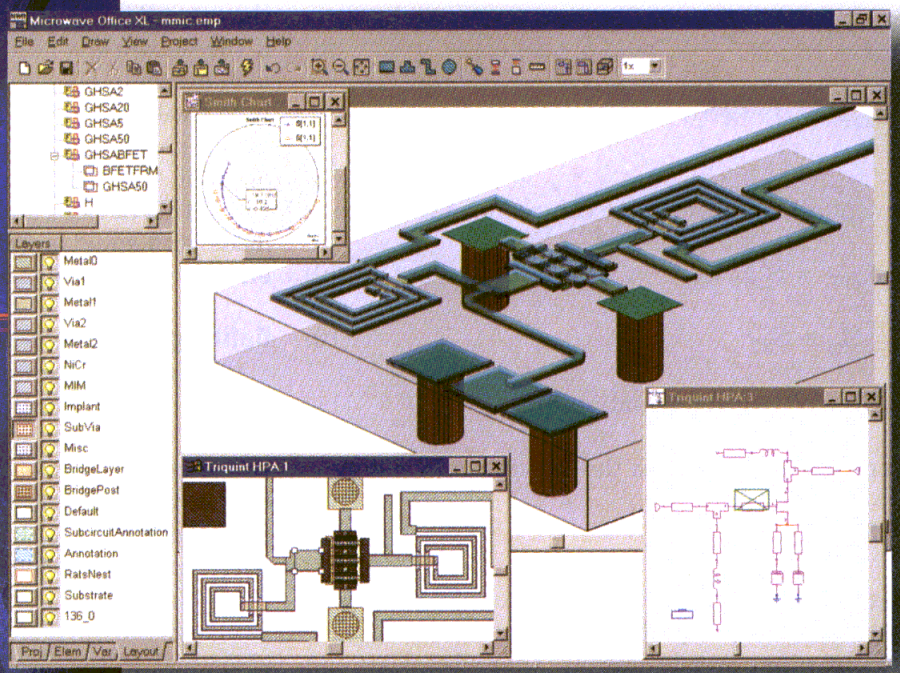

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Circle 66

$$\Gamma_{com} = \frac{b_2 + b_3}{a_2 + a_3}$$
$$= \frac{\left(\frac{1}{2} \times S_{22}^t + \frac{1}{2} \times S_{23}^t\right) + \left(\frac{1}{2} \times S_{33}^t + \frac{1}{2} \times S_{32}^t\right)}{\frac{1}{2} + \frac{1}{2}} \quad (8)$$
$$= \frac{1}{2}\left(S_{22}^t + S_{33}^t\right) + \frac{1}{2}\left(S_{23}^t + S_{32}^t\right)$$

Based on equations 1 and 2, we can reduce further to:

$$S_{22}^d = \Gamma_{diff} = S_{22}^t - S_{32}^t \quad (9)$$

$$\Gamma_{com} = S_{22}^t + S_{32}^t \quad (10)$$

$$S_{21}^d = S_{21}^t \times 2^{1/2} \text{ (given equation 3)} \quad (11)$$

Port 1 remains unchanged in the conversion, yielding:

$$S_{11}^d = S_{11}^t \quad (12)$$

Taking the absolute value of both sides of equation 10 and substituting from equation 4, we see that $|\Gamma_{com}|$ is always 1. In other words, ideally, there is maximum reflection for the common mode component. If we analyze this as a lossless two-port device, the S^d-parameter matrix is unitary by definition [6]. This is a reciprocal device so we can state that $S_{21}^d = S_{12}^d$. This leads to $|S_{11}^d| = |S_{22}^d|$. Plots of S_{11}^d, S_{22}^d and S_{21}^d can be seen in Figures 5 and 6 for the same conditions that were used in Figures 2 and 3.

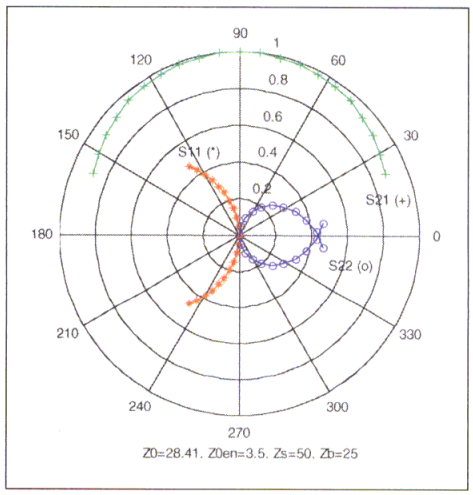
Again, these illustrations show that the equalities hold with Z_0 selected for matched conditions at the center frequency as well as when Z_0 is selected to provide mismatched conditions. In summary, a special property of this device is its ability to produce signals at ports 2 and 3 (from Figure 1) that are equal in amplitude and 180 degrees out of phase. This property allows for the device to be reduced to a two-port network for further analysis.

Also noteworthy at this point is the balanced port termination technique. As illustrated in Figure 4, a termination is placed between the two output terminals. This is where a balanced load would be placed. An equivalent balanced port termination can be achieved by using two single-ended terminations. Each of these terminations would have a value of $Z_b/2$ ohms; one would be placed from port 2 to ground and the other from port 3 to ground (Figure 1). For example, if the network is designed so that the single-ended port is matched to 50 ohms when the balanced port is terminated with 25 ohms, the single ended port will also be matched when 12.5 ohm terminations are placed from each of the two balanced port terminals to ground. Thus, this device can be used to drive two single-ended loads with equal amplitude and 180 degree phase difference as well as balanced loads.

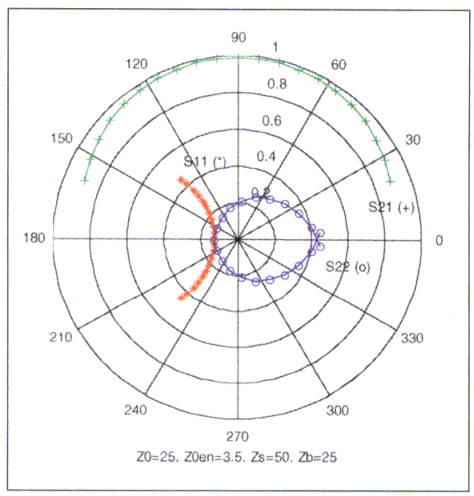
Defining the couplers

The analysis throughout the remainder of this paper will be based upon the balun as a two port device. The validity of this is supported in the above text. First is the single ended (referenced to ground) port labeled port 1 in Figures 1 and 4. The impedance of this port will be assigned the variable name Z_s. Second is the balanced port which is the combination of ports 2 and 3 as illustrated in Figure 4. The impedance of this port will be assigned the variable name Z_b. These and other variables that will be used are outlined in Table 1.

As mentioned earlier, the purpose of this device is to



▲ **Figure 5. Plot of S_{11}^d, S_{22}^d and S_{21}^d under the same conditions as Figure 2.**



▲ **Figure 6. Plot of S_{11}^d, S_{22}^d and S_{21}^d under the same conditions as Figure 3.**

Variable Name	Description
Z_s	Single-ended port impedance.
Z_b	Balanced port impedance.
Z_0	Coupler characteristic impedance.
Z_{0m}	The value of Z_0 that provides perfect port match at center frequency.
Z_{0en}	The normalized (to Z_0) even mode impedance.

▲ **Table 1. Definition of variables used to describe the coupler.**

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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

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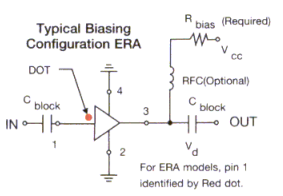
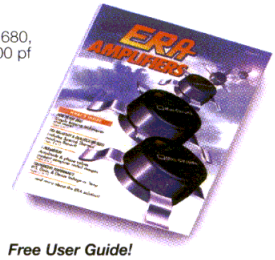
120x60	.002, .047, .068, .1 µf

ERA-1 ERA-1SM
ACTUAL SIZE





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provide a transformation from balanced to unbalanced (single-ended) transmission line. It may also be desirable to achieve an impedance transformation at the same time. Impedance transformation means that the two ports will have different impedances. For example, a single-ended port impedance of 50 ohms can be transformed down to a very low balanced port impedance for use in push-pull amplifiers or transformed to a higher impedance to match certain antenna types. This configuration of couplers allows for both transformations as well as a degree of bandwidth adjustment.

As with any design, certain parameters must be defined and then others will be calculated. For this balun circuit, both port impedances must be defined as well as the Z_{0en} that can be achieved. Bandwidth is a function of the port impedances and Z_{0en}. The higher the value of Z_{0en} that can be achieved, the greater the bandwidth.

The designer usually knows the port impedances and the bandwidths that are required. In this case, a graph (shown later) can be used to determine the value of Z_{0en} required. Once these values are known, the characteristic impedance (Z_0) of the couplers can be calculated.

In the early research on this circuit, the value of Z_{0en} was held at 2.414 (3 dB coupler). With this value held constant, the exact expression for Z_0 as a function of Z_b was found to be:

$$Z_0 = \frac{Z_b}{2\times\sqrt{\frac{Z_b}{Z_s}}} = \frac{\sqrt{Z_b^{\,2}}}{2\times\sqrt{\frac{Z_b}{Z_s}}} = \frac{\sqrt{Z_b}\times\sqrt{Z_s}}{2} \qquad (13)$$

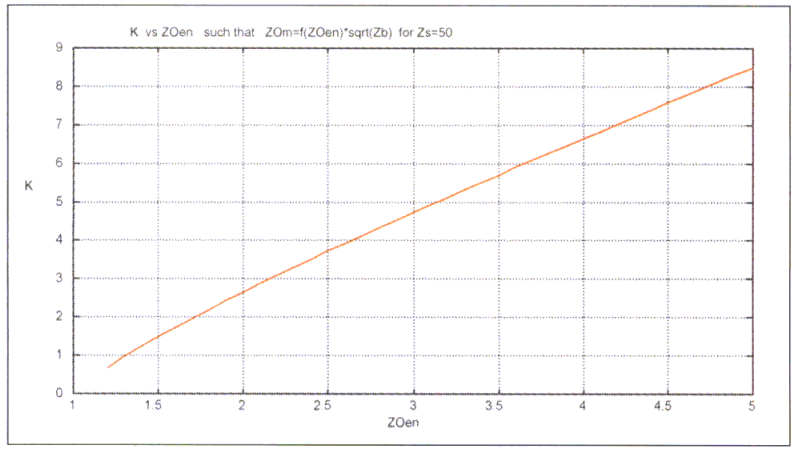
Insert $Z_s = 50$ Ohms

$$\Rightarrow Z_0 = \frac{\sqrt{Z_b}\times\sqrt{50}}{2} = \frac{\sqrt{Z_b}\times\sqrt{50}}{\sqrt{2^2}}$$

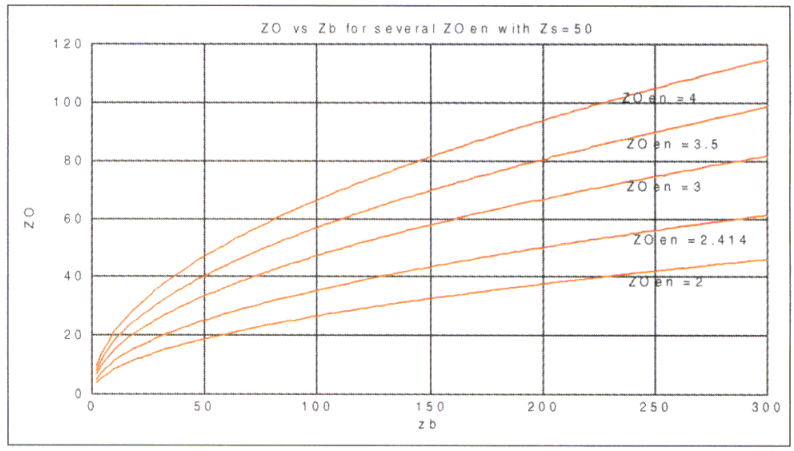
$$= \sqrt{Z_b}\times\sqrt{\frac{50}{2^2}} = \sqrt{Z_b}\times\sqrt{12.5}$$

Simulating this circuit for a range o values for Z_b showed that bandwidth was also a function of Z_b. After some investigation it was determined that Z_{0en} also had a significant impact on bandwidth. It was noted that bandwidth peaked at a value of Z_b that is slightly higher than the value of Z_s and rolled off on both sides of this symmetrically relative to percentage of Z_b. The difference between Z_b and Z_s at the bandwidth peaks varies with Z_{0en}. The higher Z_{0en} the closer Z_b is to Z_s at these bandwidth peaks.

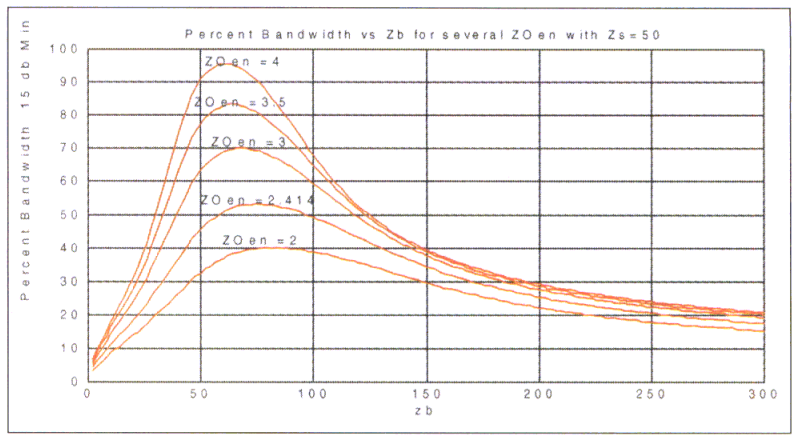
Each time Z_{0en} is changed, a new Z_0 is required to maintain impedance match at the ports. So, a relationship between Z_0, Z_b and Z_{0en} was found using the procedure outlined next:



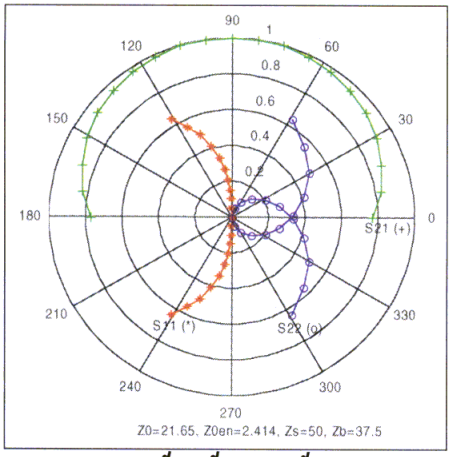
▲ **Figure 7. Polynomial fit of *k* vs. Z_{0en}.**



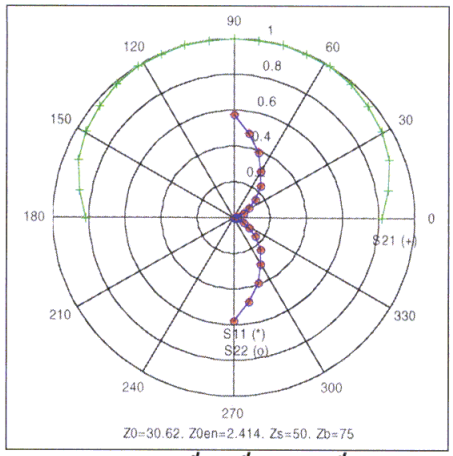
▲ **Figure 8. Plot of equation (14) for several values of Z_{0en}.**



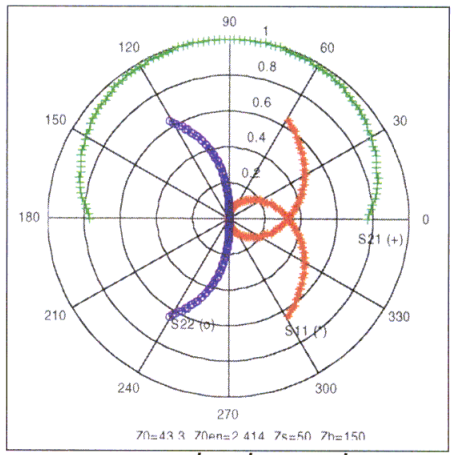
▲ **Figure 9. Plot of bandwidth for the same values of Z_{0en}.**



s Figure 10. S_{11}^d, S_{21}^d and S_{22}^d with Z_b set to 37.5 ohms.



▲ Figure 11. S_{11}^d, S_{21}^d and S_{22}^d with Z_b set to 75 ohms (peak bandwidth).



▲ Figure 12. S_{11}^d, S_{21}^d and S_{22}^d with Z_b set to 150 ohms.

1. Set port 1 impedance (Z_s) to 50 ohms.
2. Set port 2 impedance (Z_b) to a fixed value.
3. Simulate the circuit, setting $Z_0 = k \times Z_b^{1/2}$ and step through values of Z_{0en} and adjust k at each step so that the ports are impedance matched. Record the values of k for each Z_{0en}.
4. Calculate the polynomial line fit for k vs. Z_{0en}. This is defined as $f(Z_{0en})$. A plot of this function can be seen in Figure 7.

The value of Z_0 that provides impedance match at band center is a function of Z_b and k as described in step 3 above. Replacing k with $f(Z_{0en})$, the polynomial line approximation from step 4, leads to the following:

$$Z_{0m} = f(Z_{0en}) \times Z_b^{1/2} \quad \text{(with } Z_s = 50 \text{ ohms)} \tag{14}$$

$$f(Z_{0en}) = 0.03128 \times Z_{0en}^{\,3} - 0.35590 \times Z_{0en}^{\,2} + 3.2509 \times Z_{0en} - 2.6787 \tag{15}$$

where $f(Z_{0en})$ is a 3rd order polynomial line approximation with an error of less than 0.1 percent for $2 \le Z_{0en} \le 4$. Note that $f(Z_{0en})$ can be reduced to the first order polynomial $(2 \times Z_{0en} - 4/3)$ for an error of less than 1.0 percent over the same range.

Notice that Z_{0m} varies with the square root of Z_b. Another way of stating this is that Z_b varies as the square of Z_0, which means small changes in Z_0 produce larger changes in Z_b. So, this circuit offers a sort of "leverage" between coupler impedance (Z_0) and the ratio of impedance transformation. Figure 8 is a plot of Equation (14) for several values of Z_{0en}. Figure 9 is a plot of bandwidth (defined as 15 dB return loss) for the same conditions. These plots were generated with ideal circuit simulation results. As mentioned earlier, the bandwidth does peak at a certain value of Z_b; and more bandwidth is available when greater values of Z_{0en} can be achieved.

An interesting effect of this circuit can be observed when S_{11}^d and S_{22}^d are compared for different values of Z_b. This effect can be illustrated by selecting Z_b at the bandwidth peak and two other values that are an equal percentage above and below. Data plotted in Figures 10 through 12 show that there is a "flip" in the S_{11}^d and S_{22}^d response as Z_b transitions through the bandwidth peak. Z_b was selected to be 75 ohms, which is where the peak bandwidth occurs when Z_s is 50 ohms and Z_{0en} is 2.414 (Figure 11). Then, Z_b was set to 37.5 and 150 ohms, and Z_0 was adjusted. Plots for these two conditions can be seen in Figures 10 and 12. Notice that the S_{11}^d data in Figure 10 is the same as the S_{22}^d data in Figure 12. Also, the S_{22}^d data in Figure 10 is the same as the S_{11}^d data in Figure 12.

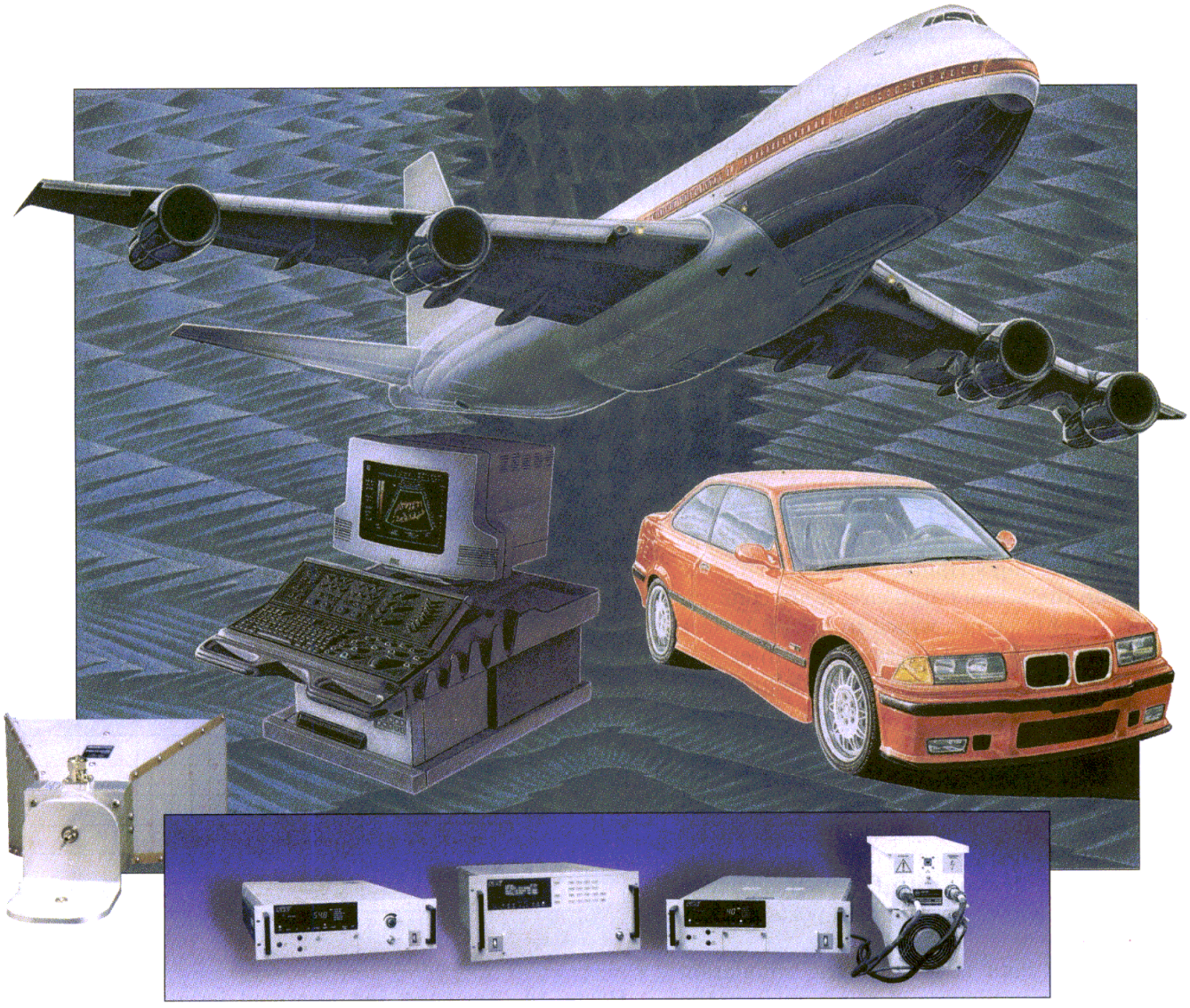
Equation (14) can also be normalized to any single-ended port impedance (port 1) by the following rational: In equation (14), $f(Z_{0en})$ replaced the $\sqrt{Z_s}$ term in line two of equation (13). But when the polynomial $f(Z_{0en})$ was found, Z_s was set to 50 ohms. Dividing the $f(Z_{0en})$ term of equation (14) by $\sqrt{50}$ and multiplying by $\sqrt{Z_s}$ will generalize the expression for Z_0 (equation (16)). Finally, a normalized expression can be obtained by dividing both sides by Z_s (equation (17)).

$$\text{Generalized: } Z_{0m} = \sqrt{Z_s} \times \sqrt{Z_b} \times \frac{f(Z_{0en})}{\sqrt{50}} \tag{16}$$

$$\text{Normalized: } \frac{Z_{0m}}{Z_s} = \frac{\sqrt{Z_s} \times \sqrt{Z_b} \times \dfrac{f(Z_{0en})}{\sqrt{50}}}{Z_s} = \sqrt{\frac{Z_b}{Z_s}} \times \frac{f(Z_{0en})}{\sqrt{50}} \tag{17}$$

Design example

An entire series of circuits with different port impedances and different frequencies of operation have been



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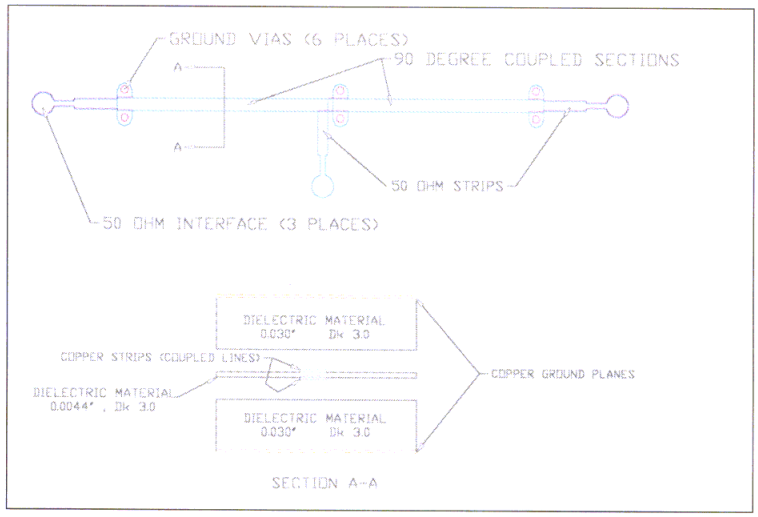
Center frequency design	2.1 GHz
Frequency range tested	1.5 to 2.5 GHz
Single ended port impedance	50 ohms
Balanced port impedance	25 ohms
(12.5 ohms to ground at each terminal)	
Z_{0en} selected	3.17
(based on the stripline geometry used)	
Calculated Z_0	25.23 ohms

▲ **Table 2. Parameters selected for the circuit used as a design example.**

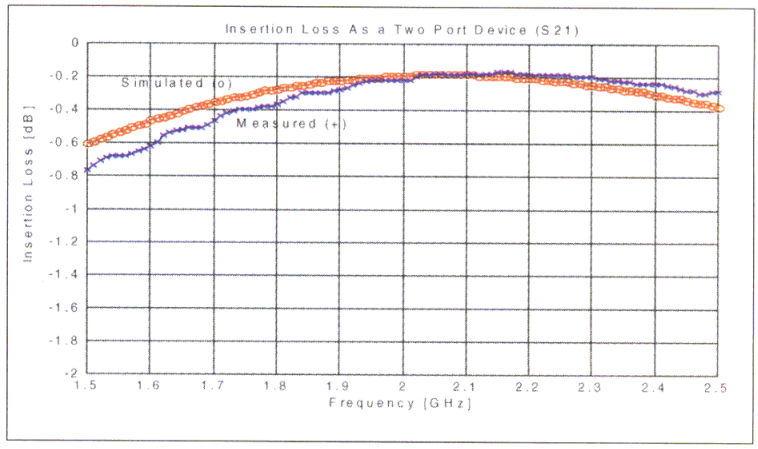
built, tested and compared with simulation results. The outcome of these experiments has supported the theory and the simulation techniques. One circuit has been selected for presentation here. The details of this circuit are stated in Table 2. A circuit was constructed using stripline (Figure 13).

All ports on the actual balun circuit are connected to short 50-ohm strips, which in turn interface with an SMA connector. This connector-interface-strip combination has been very well defined and de-embedded from the measured data. The data was taken using an *S*-parameter test set, manufactured by atnmicrowave, which is designed for measuring balanced port devices. This test equipment provides data on the balun as a two-port device (with one single-ended port and one balanced port) or as a three-port device (with three single-ended ports) and also allows setting the ports to any impedance.

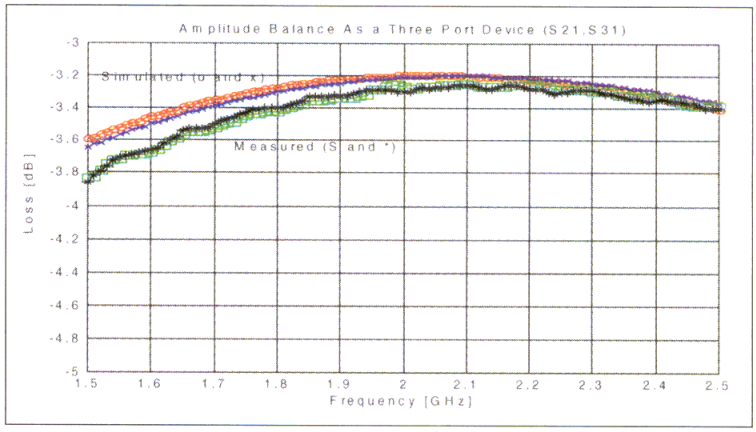
The measured data as well as the simulation results can be seen in Figures 14 - 19. Note from the S_{11} return loss data that the 15 dB bandwidth is 30 percent as predicted from the graph of Figure 9. The polar plot of reflection coefficient (Figure 19) is normalized to 50 ohms for the single ended data and to 12.5 ohms for the differential and common mode data. Differences between simulated and measured reflection coefficient/return loss data are most likely due to a small common mode component that occurs in the measured data. This is probably due to imperfect grounding of the couplers in the actual circuit and/or differences in even and odd mode electrical lengths of the coupler. These deviations from ideal are being explored at the time of this writing. However, the performance of the circuit is very close to what was predicted and supports the theory stated here.



▲ **Figure 13. Construction details of the balun/coupler circuit.**



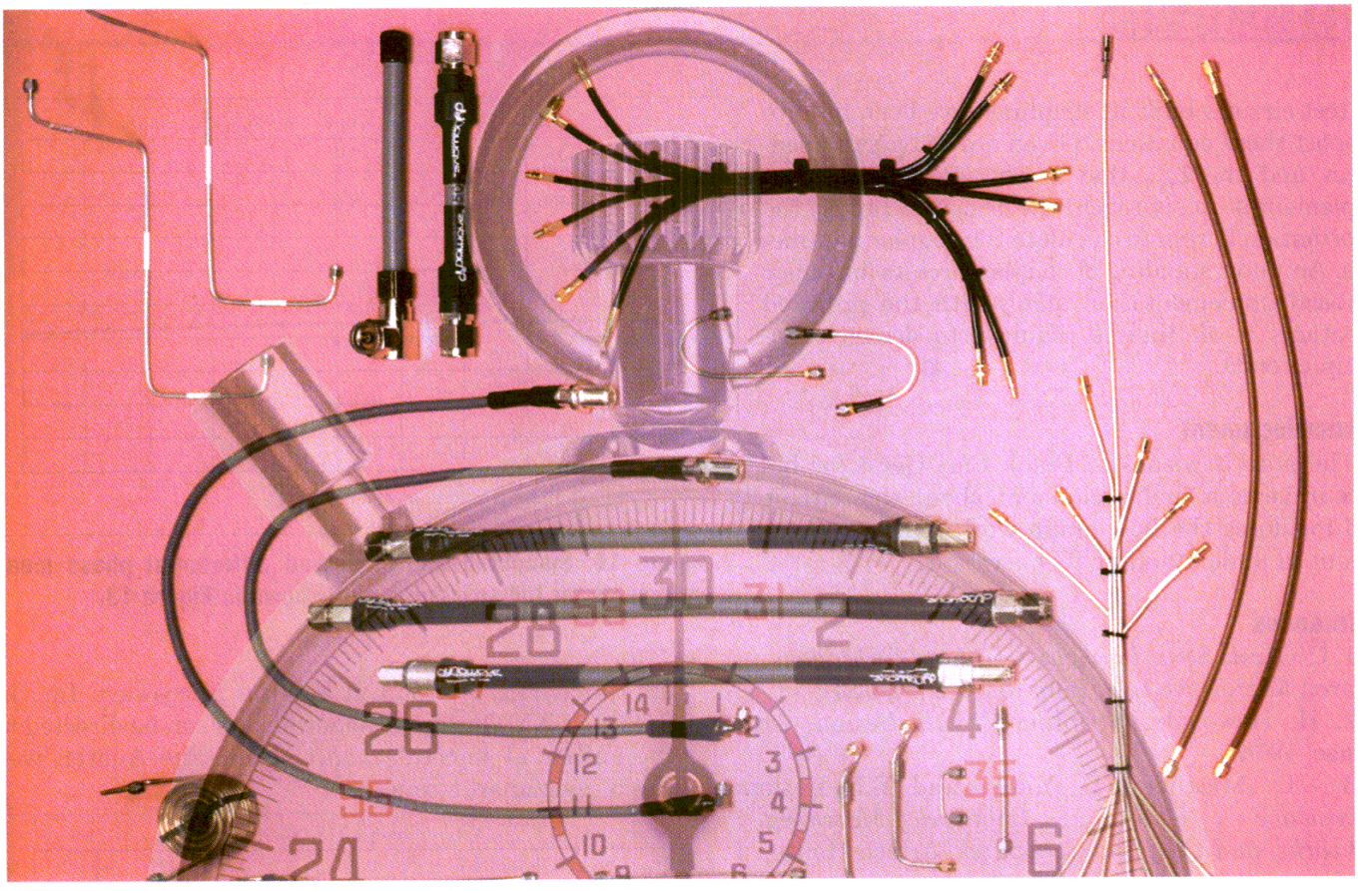
▲ **Figure 14. Simulated and measured insertion loss for the stripline circuit shown in Figure 13.**



▲ **Figure 15. Simulated and measured amplitude balance for the stripline circuit shown in Figure 13.**

Conclusion

This material has presented a method for achieving a balanced to unbalanced transmission line transformer using couplers. This balun also offers impedance transformation between the two ports. Circuit analysis information and design equations have been provided. Simulation results and actual data taken



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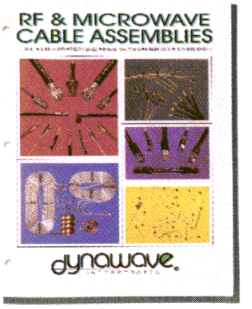

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on test circuits built in stripline have been used to support these equations. Given desired port impedances and the Z_{0en} that is obtainable (based on implementation approach) the designer can use the information herein to calculate the coupler parameters. An understanding of coupler circuits and their physical implementation along with the provided equations is all that is required to design these balun circuits. ■

Acknowledgment

The author wishes to thank Carl Gerst for his encouragement and excitement about this circuit and for doing the flow graph work that was paramount in understanding its operation.

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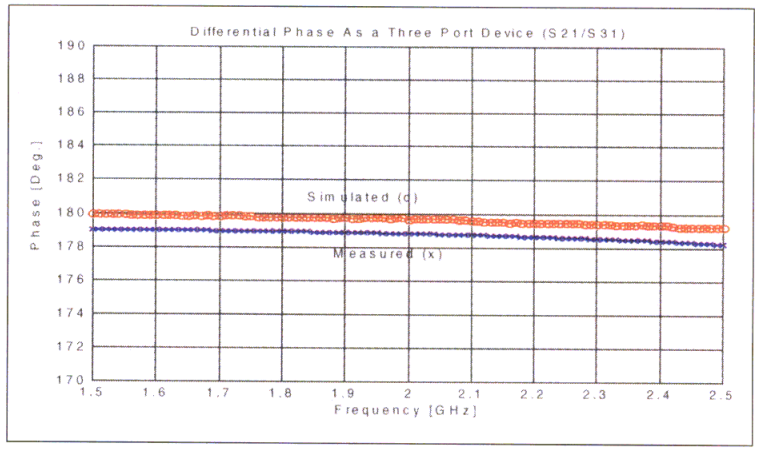
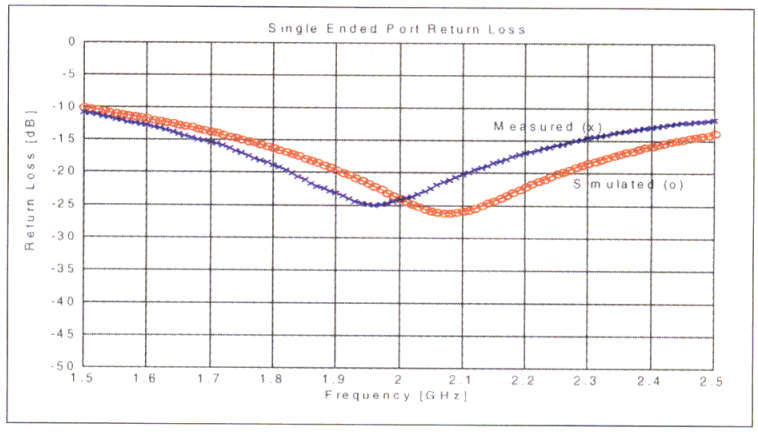
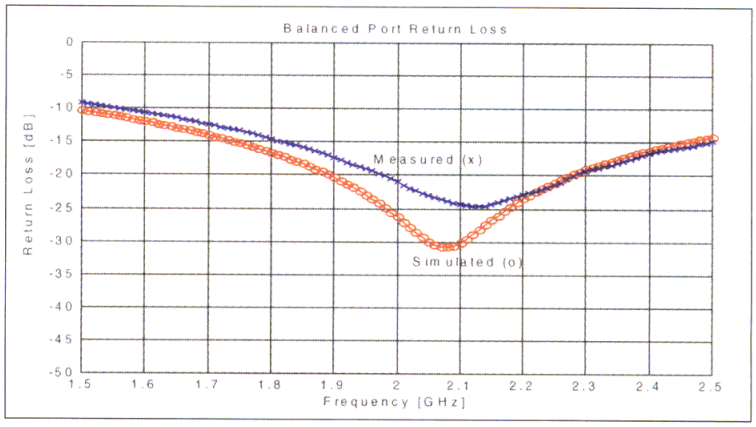


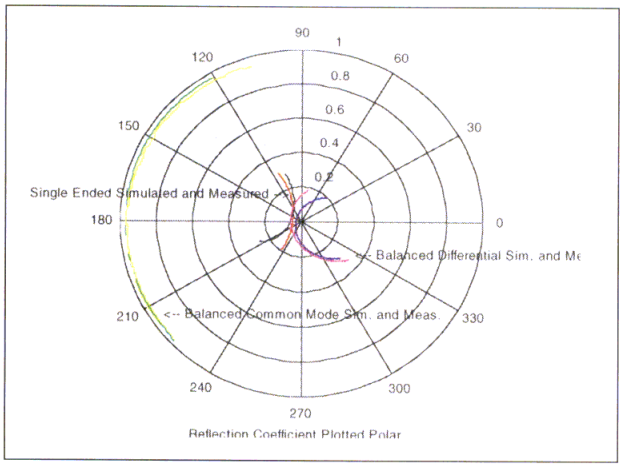
▲ **Figure 16. Simulated and measured differential phase measurements for the stripline circuit shown in Figure 13.**



▲ **Figure 17. Simulated and measured single-ended port return loss for the stripline circuit shown in Figure 13.**



▲ **Figure 18. Simulated and measured balanced port return loss for the stripline circuit shown in Figure 13.**



▲ **Figure 19. Polar plot of reflection coefficients, normalized to 50 ohms for the single-ended port and 12.5 ohms for differential- and commmon-mode data.**

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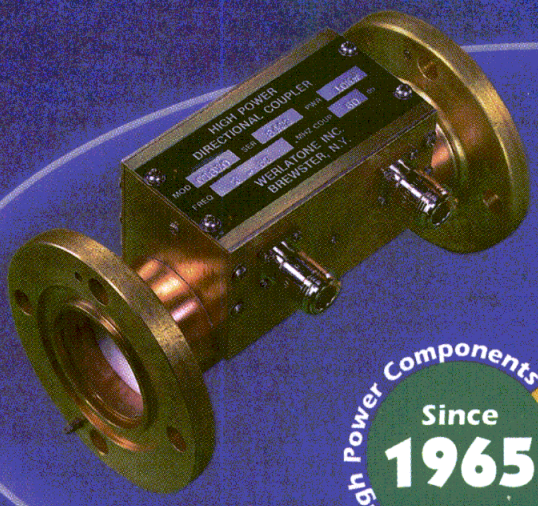

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Circle 41

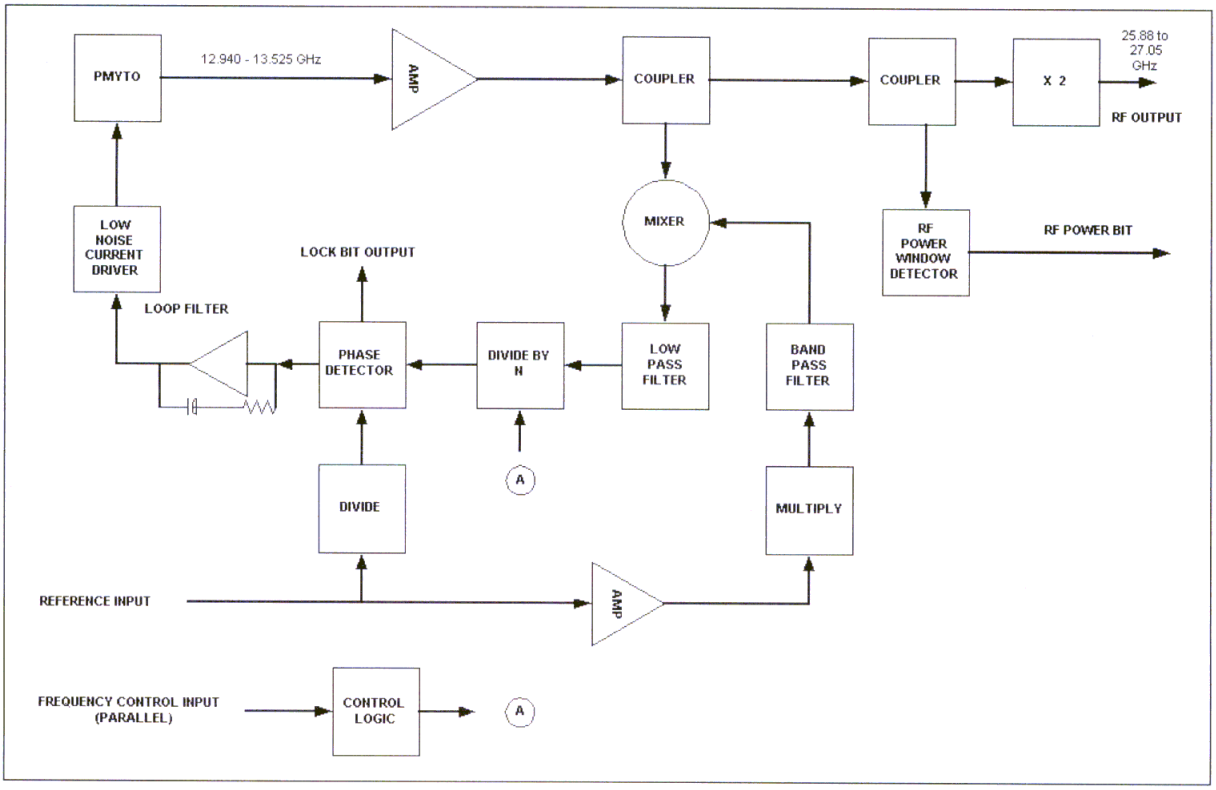
New Technology Improves LMDS Synthesizer Phase-Hit Performance

By Dave Castetter
Microsource, Inc.

Permanent Magnet YIG Tuned Oscillator (PMYTO) based synthesizers from Microsource Inc. (MSI) have overcome the mechanical problem of external shock sensitivity that has been associated with YIG technology in the past. This breakthrough in technology allows the synthesizers to be actively deployed in outdoor-mounted distribution sites as node local oscillators for Local Multipoint Distribution Service (LMDS) systems.

Operating at 25.88 to 27.05 GHz, these synthesizers were designed to improve the receiver's phase-hit performance when subjected to large temperature gradients and external mechanical shocks. As Node Local Oscillators, this product has undergone extensive field trials and is now in production at Microsource.

Operating from ±15 VDC and +5 VDC supplies, the synthesizer produces a nominal output power of +7 dBm across the operating frequency band. In customer tests, MSI's synthesizer design has proven capable of standing up to the environmental punishments of wind, rain, hail and large temperature changes with-



▲ **Figure 1. A simplified block diagram of the synthesizer.**

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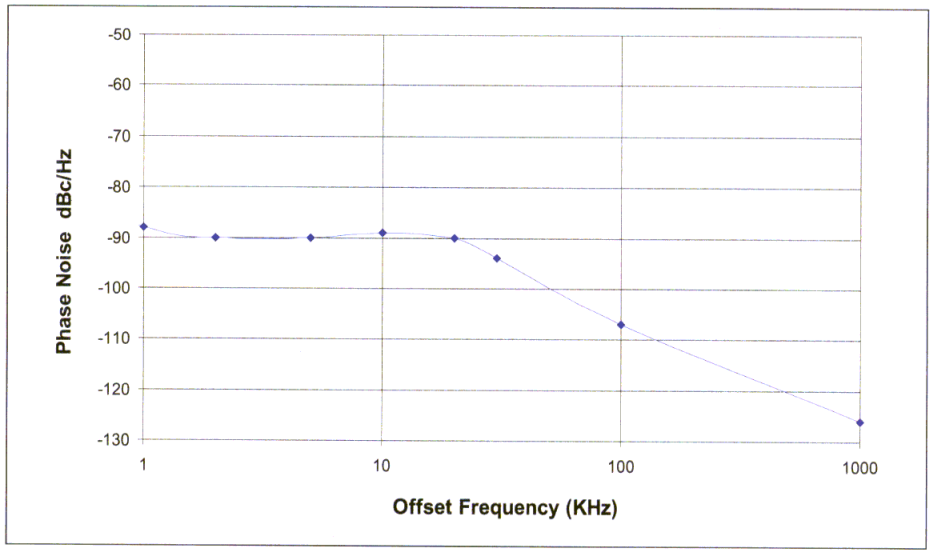
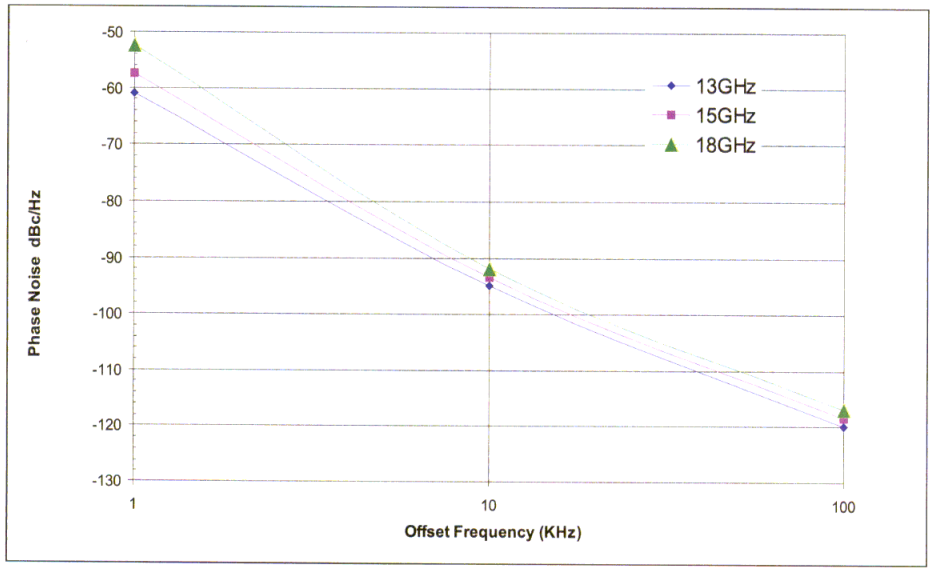


▲ **Figure 2. LMDS synthesizer noise data at 26.5 GHz.**



▲ **Figure 3. FET PMYTO phase noise data at 12, 15 and 18 GHz.**

out causing the LMDS system to lose frame or bit information.

A simplified block diagram of the synthesizer is shown in Figure 1. The synthesizer is a single loop design having an external reference input of 960 MHz. The synthesizer loop locks a PMYTO operating at half the output frequency; a ×2 multiplier on the output of the loop establishes the final frequency. The operational temperature range is –40° C to +80° C, the frequency step size for the synthesizer is 10 MHz and the spurious are –65 dBc.

The plot shown in Figure 2 details the synthesizer's typical production phase noise capability over the operational frequency range. Measurement has shown that the phase noise of the unit is typically better than –88 dBc at 10 kHz offset from the carrier.

The heart of the synthesizer is the PMYTO. MSI has developed a ruggedized FET oscillator design that has a typical phase noise of –95 dBc/Hz at 10 kHz offset from the carrier over its frequency range of operation. This FET PMYTO design is used to cover 2 GHz bandwidths through 18 GHz where it provides similar phase noise performance. Figure 3 shows data from the PMYTO family.

One of the advantages of the FET-based oscillator is its performance over temperature. When used in an enclosed distribution site environment, case temperatures of the PMYTO can reach 100° C for extended periods of time. Each production PMYTO is actively tested at 105° C to ensure performance over harsh environmental conditions.

This synthesizer provides a ruggedized architecture, which also supports option changes in step size, operating frequency and reference frequency. ■

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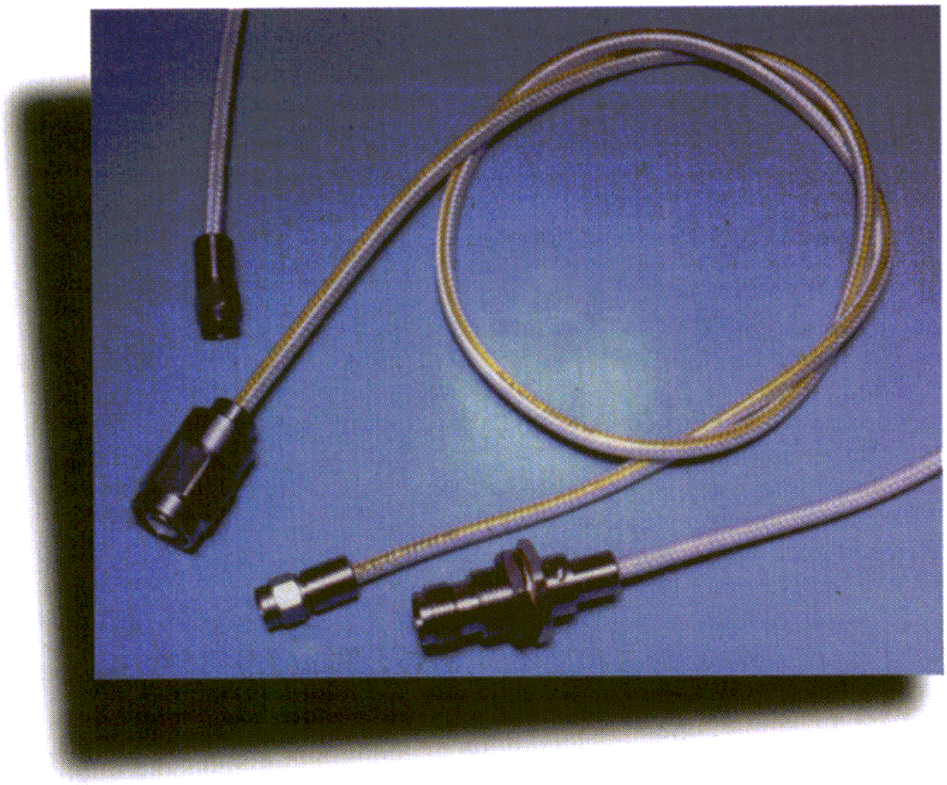

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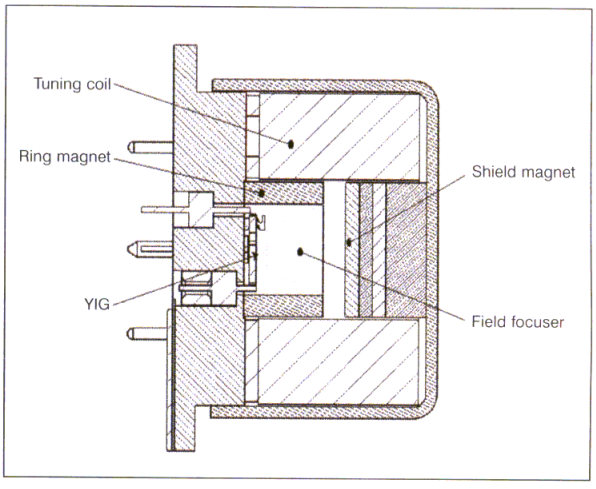
Circle 32

Oscillators are Designed for Digital Microwave Communications

By Ron Perrot
Verticom, Inc.

Verticom, Inc. has developed and is producing a patented line of digital-ready oscillators for Satcom, LMDS and point-to-point communications. The VIDA microwave oscillators are currently in use in the company's MTS1500 synthesizer product line.

This oscillator was designed from the start to satisfy the rigorous requirements of high data bandwidth and digital outdoor links. Verticom's experience in digital satellite communication was systematically applied and defined as the Value Intrinsic Design Axiom (VIDA), simply stated as "reduce parts and improve function." The goals for the intended application were to optimize phase noise to DRO equivalence, tuning and microphonics to VCO equivalence and producibility to disk drive equivalence.



▲ **Figure 1. The VIDA YIG oscillator structure.**

Results

A significant amount of research has been conducted to vibration harden YIG devices for military missile and aircraft applications. An accepted method is to stabilize the air gap by clamping a non-magnetic incompressible structure between the pole pieces. Over temperature, deferential stresses are incurred because of mismatched temperature expansion coefficients, specific heats, thermal conductivity and clamping mechanisms. These problems are greatly magnified in permanent magnet designs, due to magnet non-linear behavior and the brittle nature of permanent magnets. The VIDA solves the vibration problem by defining the air gap with the ring magnet and a re-entrant field focuser, as shown in Figure 1.

A shield magnet is above the field focuser to keep magnetic flux from flowing through the shell. The shell can then be made thinner and lighter. The entire magnetic structure can then be clamped with the shell — the shell deforming within elastic limits. This assures that no air gap develops in the magnetic circuit over temperature and that the magnet clamping force does not exceed the compressive limits of the magnets. Compared to other vibration-resistant YIG devices, nonlinear temperature effects in the VIDA have been minimized by the compliance of the structure, enabling an excellent resistance to phase hits that is not usually associated with YIG oscillators in temperature excursions. Figure 2 illustrates vibration-induced FM as a result of excitation frequency.

Vibration responses are normalized to 2 G peak-to-peak, but responses are linear and tested to 10 G peak-to-peak. The two traces show the differences in a gasket and hard mounting the device to a brass fixture. The hard mount is generally better but the damping factor is lower,

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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

resulting in a resonance response at 880 Hz due to the small diameter mounting screws.

The magnetic YIG bias in the VIDA is derived from two types of MMF sources — the permanent magnet material and the electromagnet coils. MMF from two permanent magnets, a ring magnet and a shield magnet, perform the two functions supplying the magnetic flux for the YIG bias and shielding the drive magnet to prevent losing flux through leakage. This method provides improved tuning efficiency for the electromagnet (EM) MMF because the drive flux generated by the ring magnet is not in series with the EM-MMF. However, the shield magnet, in series with (EM) MMF, with an external field scaled to the smaller leakage field, is much shorter. The advantage is apparent since the external field of a magnet is dependent on the intrinsic flux density ($4 \times \pi \times I_d$) and the length of the magnet.

B in the gap (B_g):

$$B_g = ((4\pi I_d) \times L_m) / (\zeta \cdot (L_g / L_m) + f \cdot (A_g / A_m))$$

ξ = reluctance factor
f = leakage factor
L_m = length of magnet
A_g = area of gap
A_m = area of magnet
L_g = length of gap
I_d = induction of the permanent magnet

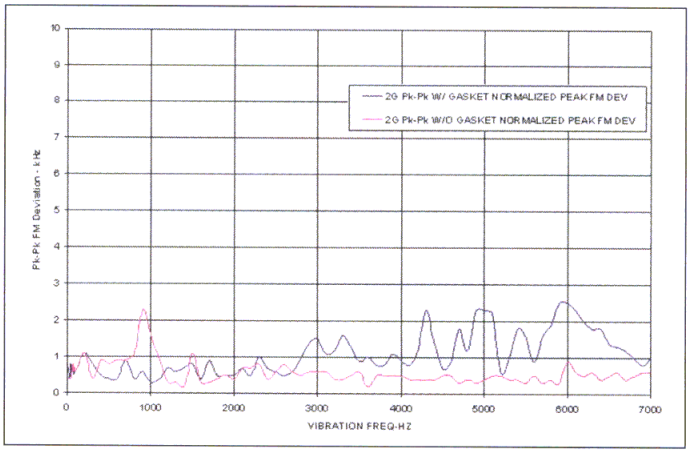
The demonstrated electromagnet air gap of the VIDA oscillator tuned to 12 GHz is 100 mils. If the leakage factor is neglected, then all the flux generated by the electromagnet goes through the gap and the tuning sensitivity is:

$$TS = .0139 * N$$

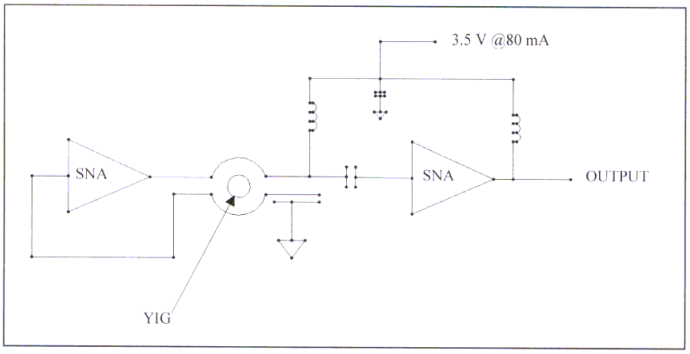
where N is the number of turns.

Balancing voltage with package size, and minimizing the power required, puts the number of turns for the VIDA size coil at 2200, yielding a tuning sensitivity of 30.5 MHz/mA. The resistance of this coil would be 90 ohms and the power required to tune 1 GHz would be less then 100 mW. The voltage for this case is less than 3 volts. Data on production runs demonstrate an average tuning sensitivity of 31.8 MHz with a standard deviation of 1.3.

Oscillator topology uses a three-port YIG resonator with an SNA-100 chip as an amplifier with non-reciprocal positive feedback (NRPF) to produce oscillations up to 1 octave continuous tuning bandwidth and another SNA-100 chip as a buffer amplifier. The circuits in use are optimized for phase noise, and produce good results at up to a 30 percent tuning band. The range of frequencies covered is from 5.8 to 12.1 GHz in ±1 GHz steps, with output power characteristically at 10 dBm due to the saturated output of the SNA-100. Phase noise is typically –100 dBc at 10 kHz offset and 125 dBc at 100 kHz offset. A simplified schematic is shown in Figure 3.



▲ **Figure 2. FM vs. excitation for the VIDA oscillators.**



▲ **Figure 3. IC-based oscillator circuit.**

The use of ICs simplifies bias considerations for wide temperature operation and minimizes circuit elements. Coplanar microcircuit format minimizes performance variation and assures that RF parasitic currents do not couple to the YIG resonator.

Going forward, the use of NRPF will facilitate application of SiGe bipolar devices due to the stability of the grounded emitter amplifier model and the 50 ohm impedance feedback circuit. With the new devices, we expect both the phase noise and frequency coverage to be greatly improved. ■

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Circle 35

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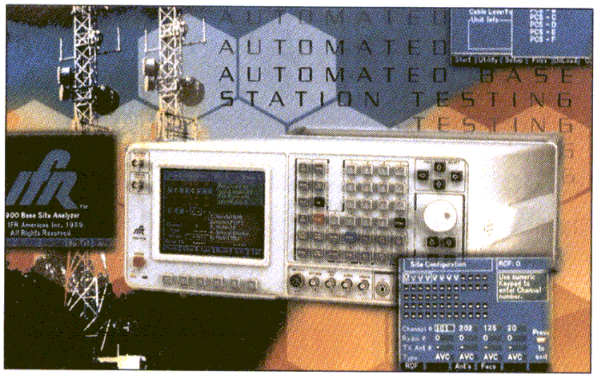

TIA/EIA-136 specifications in the 400/800 MHz and 1900 MHz bands, and provides full service monitor functionality from 10 MHz to 2 GHz. Its advanced test capabilities include low-level power measurements to –40 dBm (usable to –60 dBm), allowing field engineers to test a base station without taking it offline. The 1900 uses a dual digital signal processor design. It offers full crossband duplex test and automated bit error rate test capabilities. Test functions include a full-function spectrum analyzer, line fault analysis, cable sweep and off-air monitoring. In addition to TIA/EAI-136 testing, the 1900 has the capability required to fully test AMPS base stations. The 1900 Base Station Analyzer is priced at $43,995, with optional accessories for testing specific systems.

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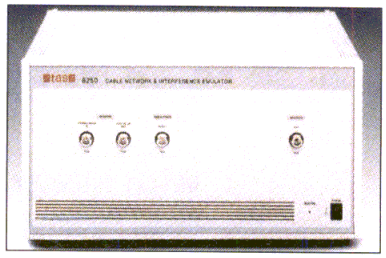
Circle #178

Cable network emulator evaluates cable modems and set-top boxes

Telecom Analysis Systems (TAS) offers the TAS 8250 Cable Network & Interference Emulator. The 8250 emulates critical hybrid fiber/coax (HFC) cable network impairments in a controllable laboratory environment. The instrument can evaluate cable modems, Cable Modem Termination Systems (CMTS), set-top boxes, HDTV equipment and Internet Protocol (IP) telephony products. The unit emulates both upstream (4 to 42 MHz) and downstream (50 to 860 MHz) HFC channel characteristics. Impairments include amplitude tilt, intermodulation distortion, group delay distortion, noise and interference. They can be emulated individually or simultaneously. TASKIT 8250 software provides a graphical interface for controlling the 8250 test operations and measurement results.



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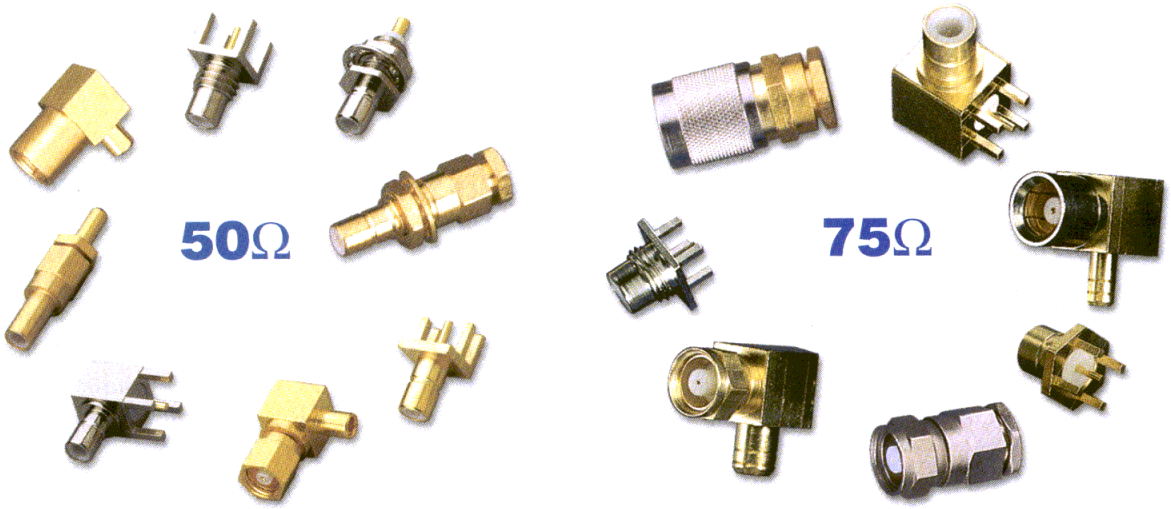

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Circle 26

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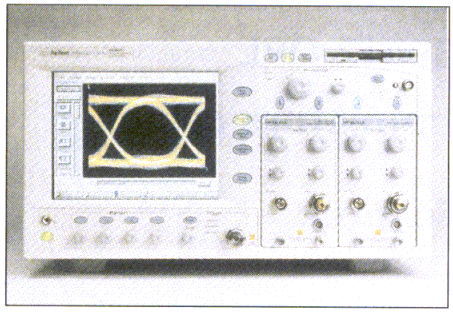
Racal Instruments offers two new test systems for advanced wireless communications. The 1X-AIME protocol test system for cdma2000 phase 1 mobile equipment offers engineers a controllable and repeatable environment for platform testing. The system can speed development of software, regression and conformance testing for cdma2000 and cdmaOne mobiles. The user interface is provided with a suite of prepared and tested "test cases" based on the CDG stage 2 interoperability tests. The system also included detailed testing and logging of forward and reverse link layer 2 and 3 messaging as well as handoff and power control testing. For CDMA testing, Racal offers the C-AIME, designed for cdmaOne radio communication manufacturers and network operators, this test system ensure full compliance for the supplementary services. Included are capabilities for regression, conformance and CDG-22 stage 2 interoperability testing. In addition, layer 2 and 3 logging and IS95B protocol testing, including handoff and power control, are included.

Racal Instruments Inc.
Circle #181

Instrument combines oscilloscope with communications analyzer

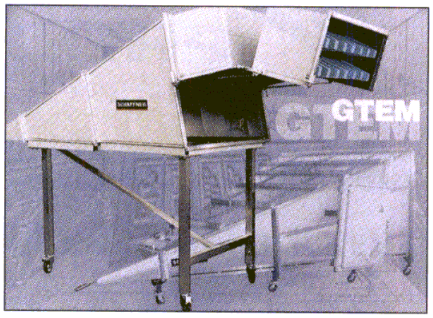
Agilent Technologies has introduced a high-speed 50 GHz oscilloscope that also functions as a digital communications analyzer. Both optical and electrical communications systems can be tested quickly, including compliance eye analysis. The Agilent 86100A Infiniium uses receivers that cover the standard rates for SONET/SDH, Gigabit Ethernet and Fibre channel up to 10 Gb/s. The 86100A mainframe is priced at $16,500 plus the cost of modules. Optical and electrical receiver modules range from $9,000 to $24,500 depending on bandwidth, wavelength range and data rate.



Agilent Technologies, Inc.
Circle #182

GTEM cells provide affordable EMC testing

A new range of GTEM test cells from Schaffner-MEB offers a low-cost alternative to open-site and anechoic chamber testing for compliance with radiated electromagnetic compatibility standards. GTEM "Lite" is a self-contained test chamber for test to 5 GHz (immunity) and 2 GHz (emissions). The new cells are combined with test software to create a complete laboratory-based radiated EMC test system. The smaller cells in the family are suitable for testing small battery-powered devices such as cell phones and pagers. Three new models have septum heights of 350, 550 and 950 mm. GTEM techniques can be used for immunity compliance testing to IEC 61000-4-3 and for emission pre-compliance (in some cases, compliance) to FCC and ANSI C63.4.



Schaffner-MEB
Circle #183

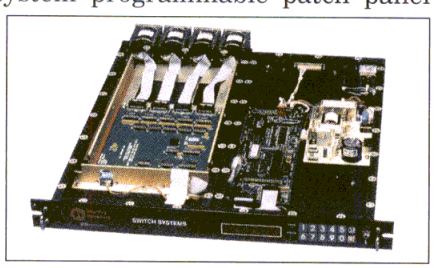
Dual-band noise generator is available for VME and VXI based test systems

Noise Com has announced the new dual-band VXI9000 Series Programmable Noise Generator. This VXIbus programmable instrument is able to switch between two noise bands within one instrument over the range of 10 Hz to 40 GHz. Available options include C/N, E_b/N_0 generation for BER testing, VME based test systems and compact shipboard test systems. A recent system delivered to a military contractor incorporates both C-band and S-band noise generators into one unit.

Noise Com
Circle #184

Coaxial switch matrix routes DC to 18 GHz signals

Dow-Key Microwave announces the Model 2104 Coaxial Switch Matrix. This electromechanical assembly is directed at test system programmable patch panel applications, and is configured with up to four SP10T switch assemblies. Each unit is provided with a solid state controller with LCD front panel display and keypad for manual or remote control. Two remote interfaces (RS-232 and IEEE-488/GPIB) are provided.



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MBA-25L	+4	2.0-3.0	6.95
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MBA-9	+7	0.8-1.0	5.95
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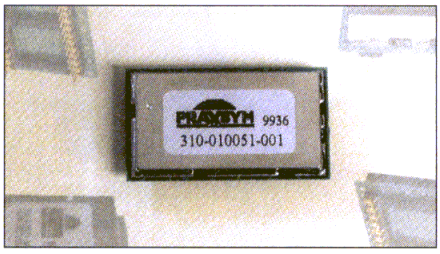
Power detector module handles signals from 100 kHz to 400 MHz

Praxsym, Inc. now offers a power detector module with a broad bandwidth and linear mV/dB power detection. The modular power detector can be used to monitor the operation of any HF/VHF/UHF transmission system. The 28-pin DIP form factor permits easy integration into systems requiring built-in-test (BIT) capabilities. The module can be part of a leveling loop or VSWR monitoring subsystem. It features 35 dB dynamic range, maximum input power of +10 dBm and ±0.5 dB measurement error. In quantities of 1,000, the price is $105 each. An evaluation board is available.



Praxsym, Inc.
Circle #186

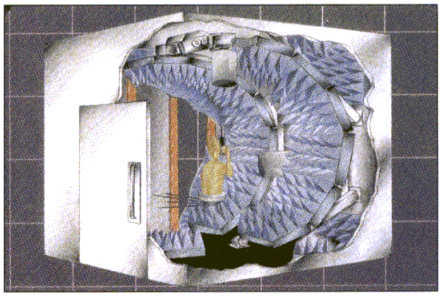
Firmware enhancements test TIA/EIA-95-B CDMA

Agilent Technologies has introduced firmware enhancements to its mobile manufacturing test sets that test the latest generation of CDMA mobile phones. Using the Agilent E8285A, 8924C or 8924E test sets, CDMA mobile phone designers and manufacturers now have the capability to support the TIA/EIA-95-B protocol. The test sets now support the new dynamic pilot thresholds, smaller closed-loop power control step sizes, access channel procedures and interband handoff support between PCS and cellular in CDMA mode.

Agilent Technologies, Inc.
Circle #187

Turnkey measurement system for cellular, GPS and other antennas

Orbit/FR offers the ASCENT measurement chamber for analysis of cellular handset antennas, base station antennas and other antennas operating from 400 MHz to 6 GHz. The chambers include absorber materials, a



low reflection turntable, single or twin orthogonal polarized probes and operating software. The AL-2000 software provides data acquisition and analysis algorithms, as well as user-friendly GUI. Measurement speed is <90 seconds per frequency at 2 GHz. The chamber is a compact 4 × 3 × 4 meters in size.

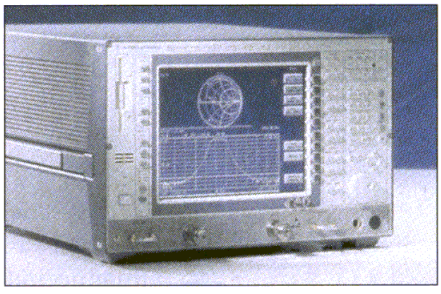
Orbit/FR
Circle #188

New portable cable/antenna analyzer has improved dynamic range and more data storage

Anritsu Company's newest Site Master™ B Series boasts improved dynamic range over previous models and storage of 517 data points. Other features include a 640 × 480 VGA display, field-replaceable NiMH battery, >42 dB directivity and immunity to interference from on-channel signals up to +13 dBm. Trace math and trace overlay capabilities are available in the instrument, or may be accomplished with an external personal computer.

Anritsu Company
Circle #189

20 GHz vector network analyzer offers fast, high dynamic range measurements



Tektronix announces the ZVM, a 20 GHz vector network analyzer offering fast measurement and fundamental mixing that achieves dynamic range greater than 110 dB. Developed by Rohde & Schwarz, the ZVM also offers independent frequency settings for the receiver and generator for harmonic or offset testing.

Tektronix Inc.
Circle #190

New Product Highlights from the *Wireless Symposium* and *Wireless 2000*

Two recent wireless industry trade shows provided excellent forums for the announcement of new products. Here is a selection of new products that were introduced at those events.

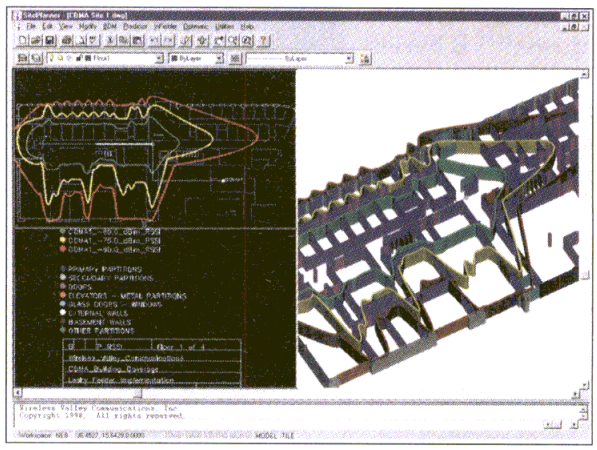
Mobile Internet access products

Microsoft has introduced the MSN™ Mobile 2.0 Internet service and Mobile Explorer™ platforms for portable and mobile Internet access using small computing devices and wireless handsets. MSN Mobile 2.0 provides access to Internet-based services such as travel information, financial services, e-mail and online shopping, using mobile phones and palm- or pocket-size handheld computers. The Mobile Explorer operating system can access both HTML and WAP-based Web sites. It is available in two versions, one for independent operation in phones, and the other using computing power available in more powerful smart phones or wireless-enabled handheld computers.

Microsoft Corp.
Circle #191

Software for wireless coverage analysis

Wireless Valley Communications has released SitePlanner™ 4.0, which can analyze coverage of indoor or outdoor wireless systems in 3D, using advanced propagation modeling techniques combined with a diagram of the facility. SitePlanner is a valuable tool for selecting an optimum location for a microcell or WLAN terminal, establishing the required power level, and locating difficult-to-reach area within the coverage area. Real-time computation allows the user to select antenna characteristics and location, with immediate visualization of the

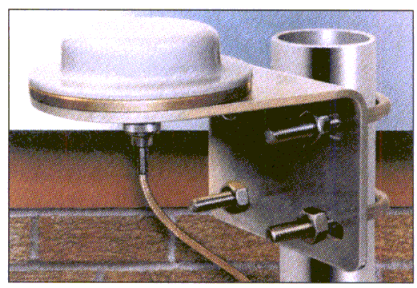


coverage signal strength contours. Also available are channel simulation tools, plus receivers and measurement equipment to provide the most accurate data for analysis.

Wireless Valley Communications, Inc.
Circle #192

GPS antenna for timing applications

Hirschmann Antennas announces the model GPS-FM antenna for GPS-based timing systems. An internal 26 dB LNA with a noise figure of 1.6 dB overcomes feedline losses. A hemispherical radiation pattern assures reception of available satellites and rugged construction assures survival in an outdoor environment.



Hirschmann Antennas
Circle #193

Telecom Solutions with UMS

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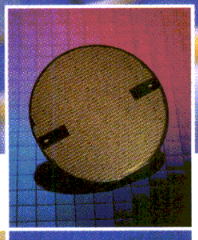
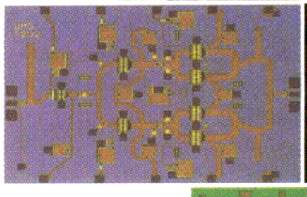
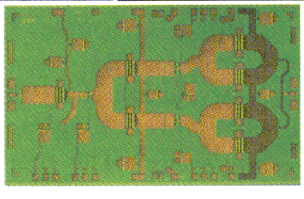
Oscillators
Multifunctions
Mixers from 18 to 60GHz





- 24 to 26GHz
- 20dB small signal Gain
- 1W Output Power



- 36 to 40GHz
- 13dB small signal Gain
- 1W Output Power

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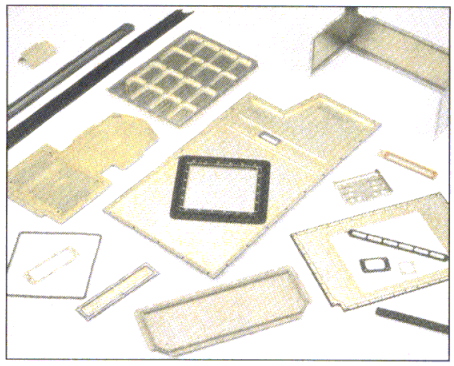
Circle 73

Low cost sealed enclosures

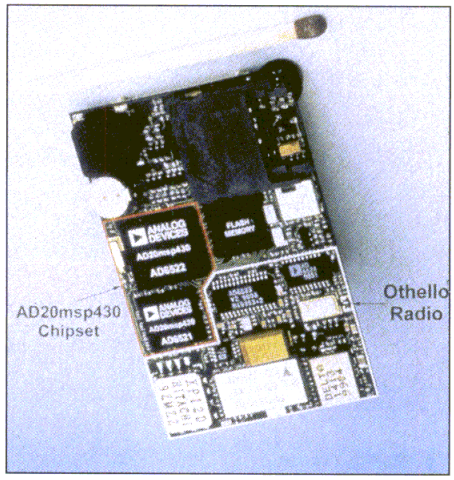
Alloy Die Casting offers a line of standard and custom aluminum die cast and sheet metal enclosures with integral environmental, EMI, RFI and ESD seals and gaskets. Designed for telecommunications applications, these enclosures will protect equipment in harsh outdoor environments with high ambient RF levels. The company has a full complement of engineering expertise and machining capabilities to create prototype enclosures quickly.



Alloy Die Casting Co.
Circle #194

RAM-based GSM phone chip set

Analog Devices has introduced a RAM-based baseband chipset for wireless handsets. The new chipset allows customizable features that can even be changed over the air. Accommodating 2.5G services such as GPRS and HSCSD, the new chip set is also forward-compatible with future 3G standards. The AD6522 digital baseband processor and AD6521 baseband converter provide the interface to the radio, all audio functions and required auxiliary monitoring and control functions. In quantities of 100,000, the devices are priced at less than $15 each.



Analog Devices Inc.
Circle #195

Ultra-low-power prescaler

Peregrine Semiconductor has introduced the PE3501, a high frequency CMOS divide-by-two prescaler. The new device operates from 1.5 to 4.0 GHz while consuming a total of 7.85 mA from a 3 volt supply. With an input power of 0 dBm, the output level is –9.5 dBm. The PE3501 uses Peregrine's Ultra-Thin Silicon (UTSi) process to achieve its performance. Pricing is $2.32 each in quantities of 10,000.

Peregrine Semiconductor, Inc.
Circle #196

Dual band downconverter IC

Motorola has combined 900 MHz and 1800 MHz donwnconverters, LNAs and buffer circuitry into a single IC, the MC13740A. The device can simplify the design and manufacture of cellular, PCS and ISM band wireless handsets and related products. The input RF bandwidth is 100 to 2000 MHz with mixer linearity specified at IP_3 of 10 dBm at 850 MHz and 8.0 dBm at 1900 MHz. An external linearity adjustment can increase mixer IP_3 up to 15 dBm. In 10,000 unit quantity, the MC13740A is priced at $3 each.

Motorola Inc.
Semiconductor Products Sector
Circle #197

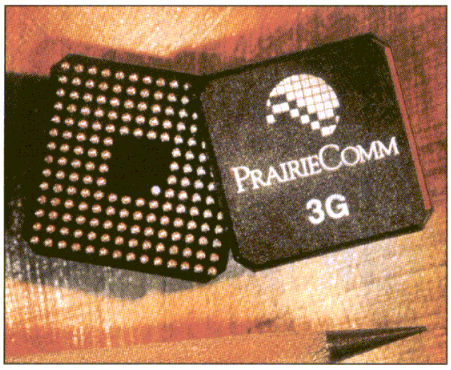
1.1 GHz DSP is announced

Texas Instruments has developed a new member of its DSP family, the TMS320C64x, operating at a record-breaking clock speed of 1.1 GHz. With 9 billion instructions per second, the new DSP will support powerful wireless multimedia applications, enhanced base station technology, ADSL and cable modem transmission systems and other ultra-high performance signal processing applications.

Texas Instruments
Circle #198

CDMA baseband processor IC

PrairieComm has announced development of its next-generation IC supporting CDMA standards for wireless telephony. The new device complies with the 1X specification for cdma2000 and is backward compatible with IS-95A, B and analog modes of operation. With data rates up to 153 kbps in 3G systems, Web-based services will be a large part of its value. The company is targeting customer who want a fast time-to-market solution for handset development and manufacturing. The new 3G chip will have samples available in the second quarter of 2000.



PrairieComm, Inc.
Circle #199

Ultraminiature Package Shrinks Small Signal Bipolar Transistors

With an overall footprint of just 1.0 × 0.6 × 0.55 mm, the new M23 transistor package from NEC can reduce the size of RF/microwave circuits while retaining the performance and design flexibility advantages of discrete transistor designs. California Eastern Laboratories (CEL) now offers a variety of NEC's popular NPN silicon bipolar transistors in the M23 package. These devices are commonly used in VCOs, LNAs and buffer amplifiers in pagers and other handheld wireless devices. The following transistors are now available in the new package:

NE681M23 — This NPN bipolar has typical specifications of 12.0 dB gain and 1.4 dB noise figure (NF) at 1 GHz, 65 mA maximum I_C and f_T of 7.0 GHz.

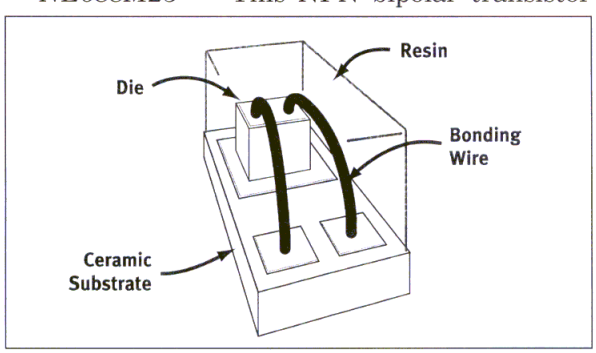
NE685M23 — This device offers a typical gain of 10.0 dB and NF of 1.5 dB at 2 GHz with 30 mA maximum I_C and f_T of 12.0 GHz.

NE687M23 — Typical specifications are 4.5 dB gain and 1.5 dB NF at 2 GHz, 30 mA maximum I_C and f_T of 5.5 GHz.

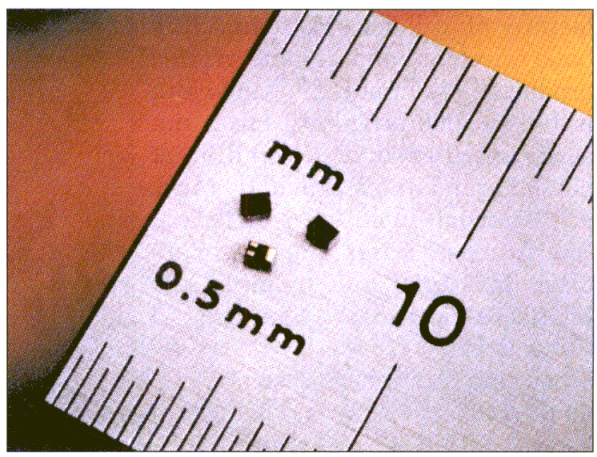
NE688M23 — This NPN bipolar transistor offers 4.0 dB and 1.9 dB NF at 2 GHz, with 100 mA maximum I_C and f_T of 5.0 GHz.

NE856M23 — This transistor provides 10.0 dB gain and 1.4 dB NF at 1 GHz, with 100 mA maximum I_C and f_T of 4.5 GHz.

The transistors are offered on tape and reel, with prices starting at $0.34 each in 100,000 quantities. ■



▲ **Outline drawing of the M23 package, which features a "leadless" design using a low cost ceramic substrate.**



▲ **The new M23 package from NEC is only 1.0 × 0.6 × 0.55 mm, allowing further miniaturization of wireless circuits.**

For more information, contact:

California Eastern Laboratories
4590 Patrick Henry Drive
Santa Clara, CA 95054
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Internet: www.cel.com

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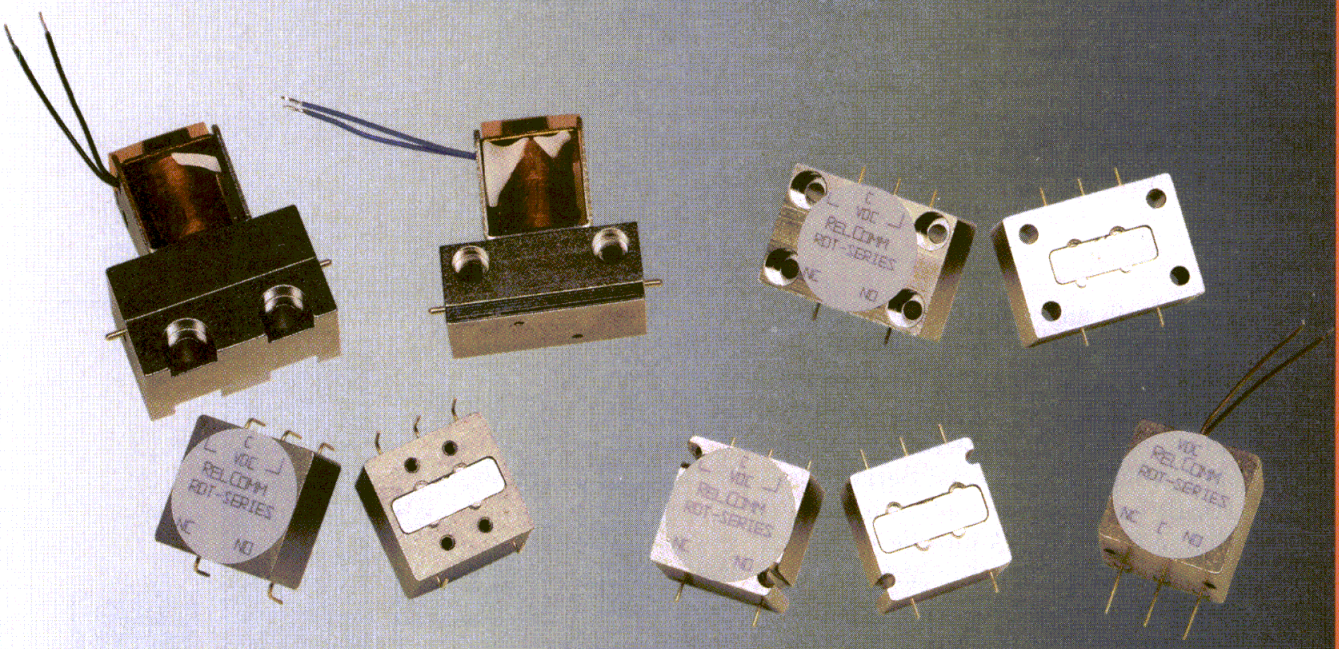

Typical Insertion Loss is 0.07dB at 900MHz, 0.12dB at 1900 MHz
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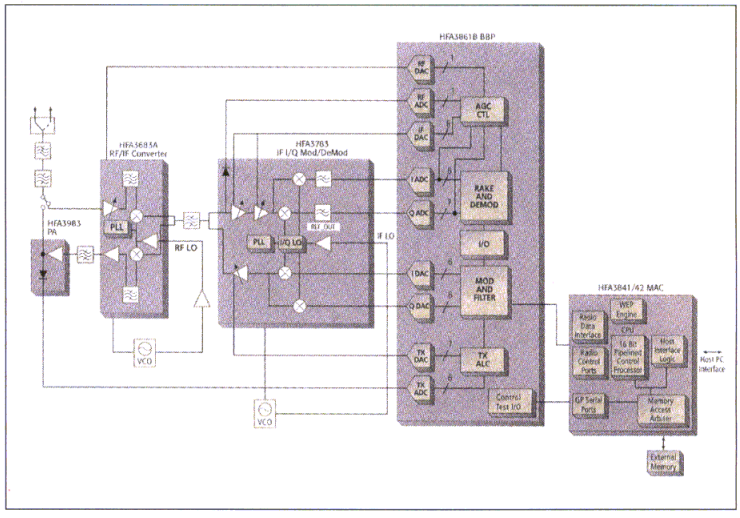
EXCELLENCE BY DESIGN

New Devices Allow WLAN Chipset to Achieve a Higher Integration Level

Intersil has announced new IC additions to its PRISM® II WLAN chip family that further reduce board space, cut WLAN adapter card manufacturing costs and provide a Universal Serial Bus (USB) host interface option in addition to the PCMCIA interface.

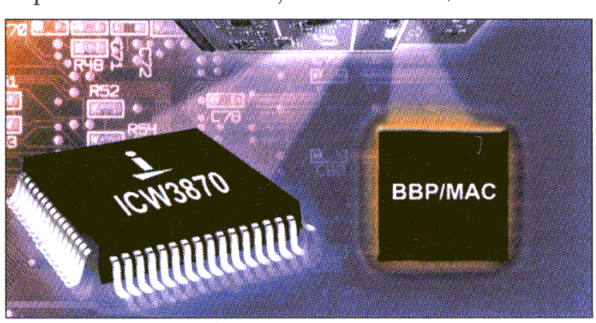
Dubbed PRISM 2.5, the redesigned chip set demonstrates the company's commitment to combine functions into more highly integrated devices. The block diagram of a PRISM II WLAN adapter is shown at the left. PRISM 2.5 makes a major step forward by integrating the baseband processor (BBP) and medium access controller (MAC) onto a single IC. The ICW3870 BBP/MAC combines the functions of the HFA3861 BBP and the HFA3842 USB MAC. The combined device maintains the same performance of the two separate ICs, and reduces the need for external Flash memory.



▲ **Intersil's PRISM 2.5 ICs reduce WLAN designs to four chips from the five chips shown here for PRISM II.**

Also included in the PRISM 2.5 family are the ICW3984 and a low cost power amplifier that replaces the HFA3983, a smaller RF/IF converter (HFA3683IR). The RF devices are fabricated using SiGe technology, while the BBP/MAC chip is a sub-micron CMOS circuit.

The PRISM family of products from Intersil is designed to provide a complete data radio using the IEEE 802.11 global WLAN standard for the 2.4 GHz unlicensed band at data rates up to 11 Mbps. ■



▲ **The ICW3870 combines functions on one IC.**

For more information, contact:

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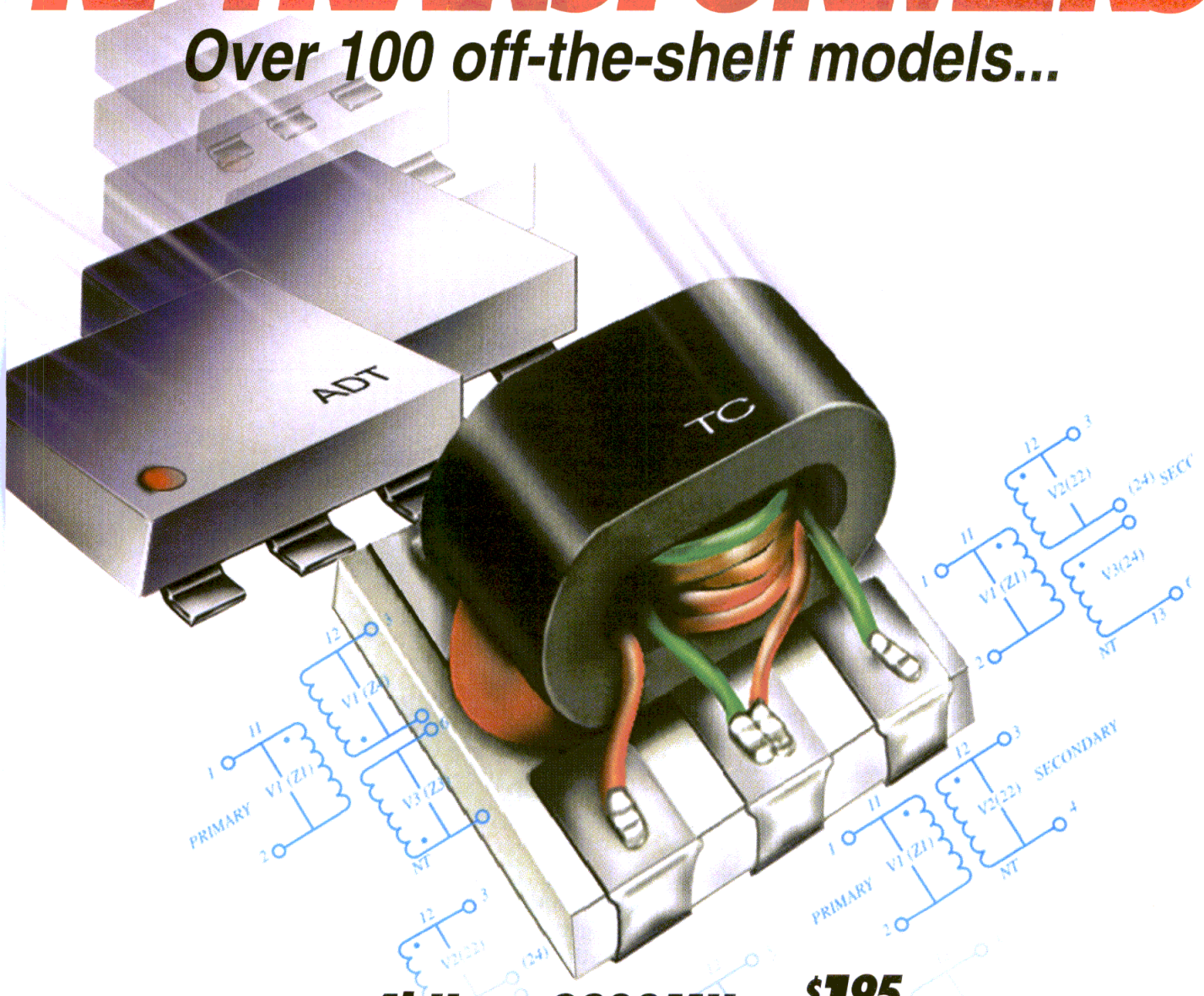

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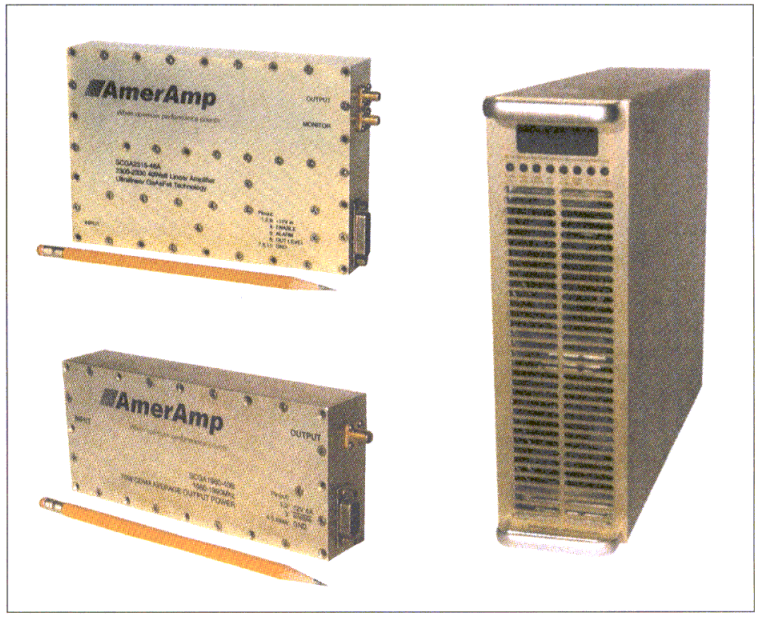
Single- and Multi-Channel Amplifiers Target PCS and WLL Applications

New amplifiers available from AmerAmp are offered for single-channel PCS systems, multi-channel PCS systems and wireless local loop (WLL) applications. The amplifiers are designed for low intermodulation distortion or adjacent channel power ratio (ACPR) specifications required for high performance wireless transmission.

The SCGA 1960-40B is a 10 watt amplifier (average power per IS-97 test procedure) covering 1860 to 1990 MHz. Gain is typically 40 to 60 dB, as specified by the customer. Spurious signals are –70 dBc and gain flatness is ±0.5 dB across the band. The amplifier features operation from a 12 VDC power source, GaAs FET technology plus built-in notch filter and output circulator.

The MCGA 1960-45A is a multi-channel feedforward amplifier providing 25 watts in the 1930 to 1990 MHz band. An internal DC-DC converter allows operation from 18 to 34 VDC power sources. Over any single 1.25 MHz bandwidth, gain flatness is ±0.01 dB and phase linearity is ±0.125°. Microprocessor control and remote control and monitoring via RS-485 interface are included.

For the wireless local loop (WLL) applications in the 2300-2330 MHz band, the SCGA 2315-46A provides 46 dBm power (P_{1dB}) and an IP_3 of 56 dBm. This amplifier is designed for use in 8 MHz chip rate WLL subscriber hub applications. Spurious signals are –70 dBc and gain flatness is ±0.5 dB across the 30 MHz band.



▲ **AmerAmp offers the SCGA 1960-40B (upper left), MCGA 1960-45A (right) and SCGA2315-46A (lower left) for PCS and WLL applications requiring low distortion and low ACPR.**

All amplifiers are fully VSWR protected and specified for operation over either 0° to +50° C or –40° to 50° C. ■

For more information, contact:

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Carlsbad, CA 92008
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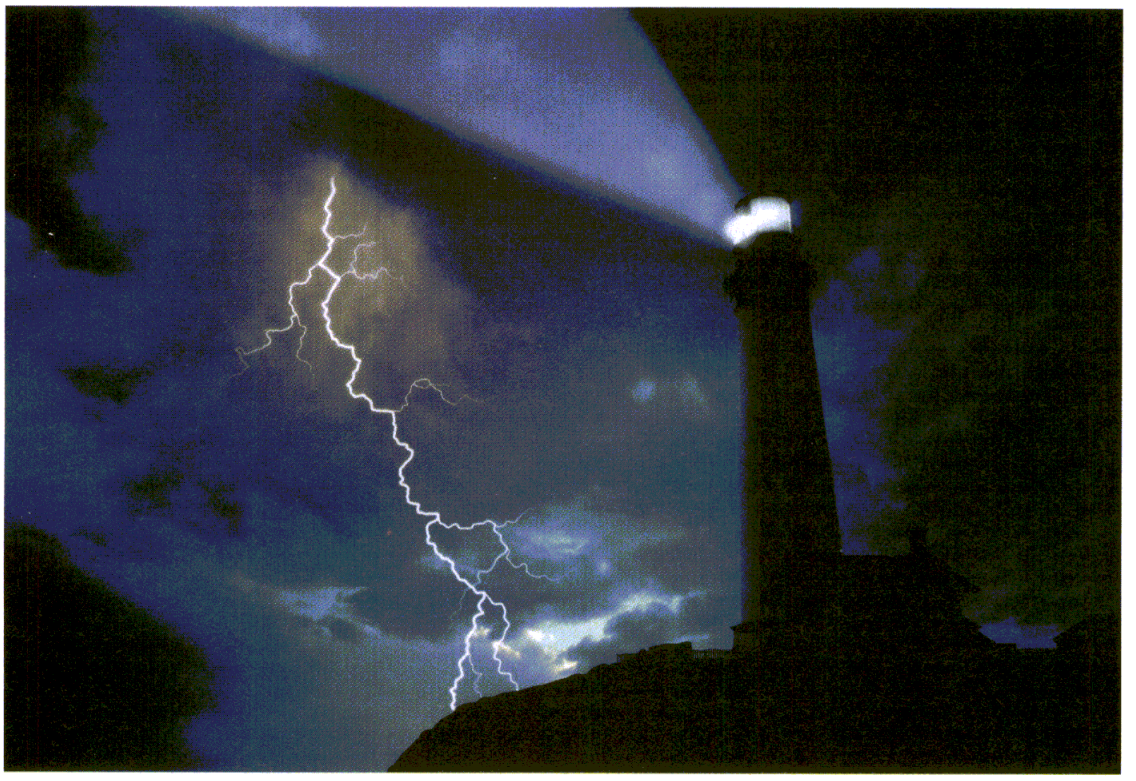

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Our SGA 6000 series of silicon germanium MMIC amplifiers offers the high intercept point, high efficiency and high integration level at high output power desired, while providing the low noise figure and low power consumption needed for all wireless applications.

SGA-6386 has 1dB compressed output power of +20dBm, output third-order intercept point of +36dBm and 15.5dB of gain at 900MHz. Pricing on the SGA-6386 is $1.21 in quantities of 10,000 pieces with availability from stock to eight weeks.

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SPECIFICATION MATRIX

	SGA-6286 SGA-6289	SGA-6386 SGA-6389	SGA-6486 SGA-6489
Frequency (GHz)	DC-3.5	DC -3.0	DC-1.8
Gain (dB)	13.8	15.4	19.7
TOIP (dBm)	34.0	36.0	34.0
P1dB (dBm)	20.0	20.0	20.0
N.F. (dB)	3.9	3.8	2.9
Supply Voltage (Vdc)	4.2	5.0	5.2
Supply Current (mA)	75	80	75

All data measured at 1GHz and is typical. MTTF @ 150C T_j = 1 million hrs. (R_{TH} = 97C/W typ)

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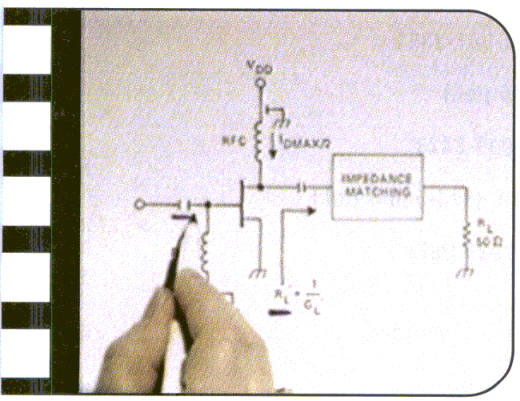

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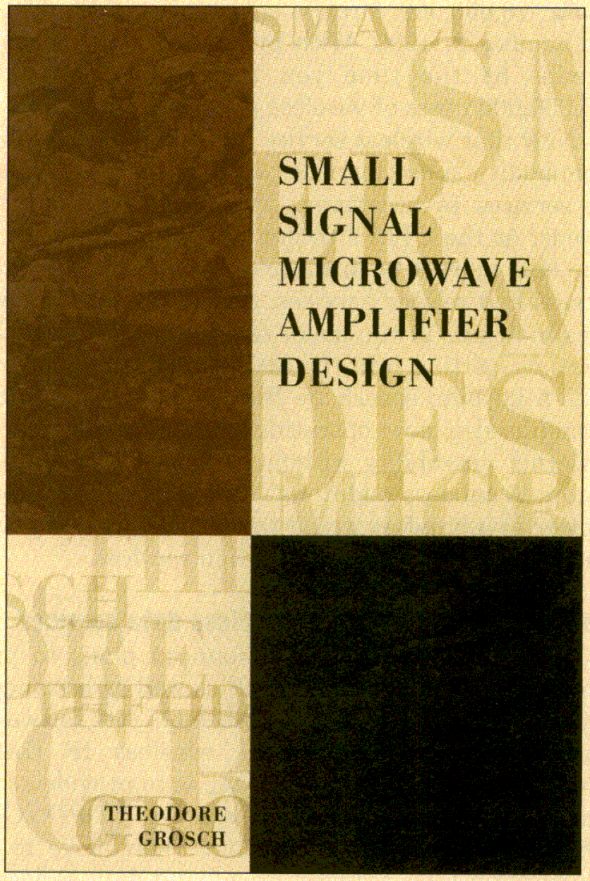

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Wireless Internet Access is the Next Big Market Push

The Cellular Telecommunications Industry Association (CTIA) estimates that there were 78,650,000 wireless subscribers in the U.S. as of September 9, 1999. With present growth trends, that means by the time you read this, there will be 86,000,000 users of wireless phones in the U.S.

Now that wireless service has become an established commodity, subscribers are a prime target for additional services to accompany their voice communication needs. At the CTIA's recent Wireless 2000 trade show, the next market push was clearly identified as Internet access and related services. As the following news stories indicate, all the major telecommunications companies are getting into the act. Highlighting this subject was a keynote speech by Bill Gates of Microsoft, who announced a new operating system that would allow Internet operability without the need for a host computer. A modest additional amount of microprocessor power in a handset would permit the phone to support many Internet-based information services.

IBM and AT&T to provide wireless data services

IBM and AT&T have announced plans to provide wireless access to the Internet, as well as intranets and corporate databases. IBM will combine its software and data services with AT&T's wireless IP (Internet Protocol) network. The first step is to provide access to corporate applications using existing CDPD (Cellular Digital Packet Data) technology, then move to Third Generation (3G) wireless broadband data services and global roaming capabilities. The 3G network being developed by AT&T will be based on the combined TDMA/GSM standard known as EDGE (Enhanced Data rates for Global Evolution).

IBM's transcoding technology will be used to enable data to be translated into the appropriate formats for a wide variety of devices, including wireless phones, PDAs and laptop computers. The partnership will include participation in joint development of new technologies.

Lucent and TeleCommunication Systems offer wireless data and Internet services

Lucent Technologies and TeleCommunication Systems (TCS) announced the launch of a new software application for providing wireless data and Internet services such as e-mail origination, Web search engines, stock quote delivery, news items and prepaid account access to mobile users. The enhanced Short Message Service Center (SMSC) software provides reliable wireless data transport for two-way messaging services as well as for Wireless Application Protocol (WAP) services. SMSC with WAP software will enable network operators to provide a host of browser-based wireless data and mobile Internet services.

The software supports roaming, which allows users to obtain reliable service across both TDMA and CDMA systems in areas outside their home network. Initially, SMSC supports TDMA, with CDMA support to follow the anticipated adoption by the WAP Forum of a specification for data delivery over SMSC.

SignalSoft demonstrates location-based WAP service

SignalSoft Corp., a developer of wireless location-based services, has demonstrated its local.info™ application, allowing WAP phones to access a broad range of Internet content based on calling location. Using Sprint PCS WAP-enabled phones, the company demonstrated simulated calls that delivered information requested on traffic, weather, nightclubs, restaurants, attractions and shopping.

SkyTel and Wireless Online announce wireless Internet infrastructure solutions

SkyTel Communications and Wireless OnLine Inc. announced a contract under which SkyTel will use Wireless OnLine's narrowband smart antenna platform in its nationwide two-way wireless messaging network. The WOL-2000R antenna technology has the potential to reduce the number of receive antenna sites by a factor of seven without reducing the overall coverage area. SkyTel provides both traditional paging and text messaging, as well as interactive two-way messaging and telemetry services. Reduced cost and complexity of receive site acquisition and construction will permit more rapid development of a complete two-way network that can support all types of data traffic, including Internet-based services.

Internet delivery is a common application for wireline services, and it is a logical extension of wireless services as well. With efforts to provide support for simpler terminals such as wireless phone handsets, the convenience of a phone will be enhanced with an equally convenient access to Internet and other data services. ■

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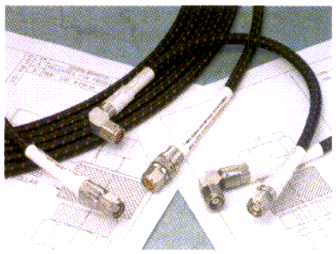

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