

Applied

MICROWAVE & WIRELESS

www.amwireless.com

The central image is a composite graphic. At the top center, the words "modulator" and "demodulator" are stacked vertically in a white, sans-serif font. To the right of this text is a blue, rounded rectangular box with a white border. Inside this box, the words "Miniature", "Passive", "Excellent Dynamic Range", and "Low Cost" are listed vertically in a white, serif font. Below the text box is a 3D rendering of a microwave chip. The chip is a small, square, metallic component with a gold-colored base. It has the text "SYNERGY", "Microwave Corporation", "VMS", and "Pat. Pend." printed on its top surface. The chip is surrounded by several glowing, blue, ethereal light trails that suggest motion or signal flow. In the bottom left corner of the image is a yellow spectrum analyzer graph. The graph shows a series of peaks and valleys, with a prominent peak in the center. The x-axis is labeled "Center 1.47 GHz" and "300 KHz". The y-axis is labeled "D1 -40.2 dBm". In the bottom right corner of the image is a circuit diagram. It shows a square loop with a yellow sine wave inside, and a small circular component at the bottom right. The entire image has a blue, textured background that resembles a fine, woven fabric.

Circuit Design

Phase Lock Loop Stability Analysis

Wireless Systems

Unfiltered FQPSK: Interpretation and Enhancements

Product Focus

Components for mm-Wave Systems

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!

If you checked "C" call us today to receive your free SRI Connector Gage *High Frequency Connectors* catalog.

We are proud to offer the full line of products from SRI Connector Gage Company, which specializes in the design and manufacturing of custom and standard connectors, adapters and interface gages.

C.W. Swift & Associates is the original RF and microwave stocking distributor, providing delivery and personalized sales and service for over 40 years.



Call 1-800-CW SWIFT (1-800-297-9438)

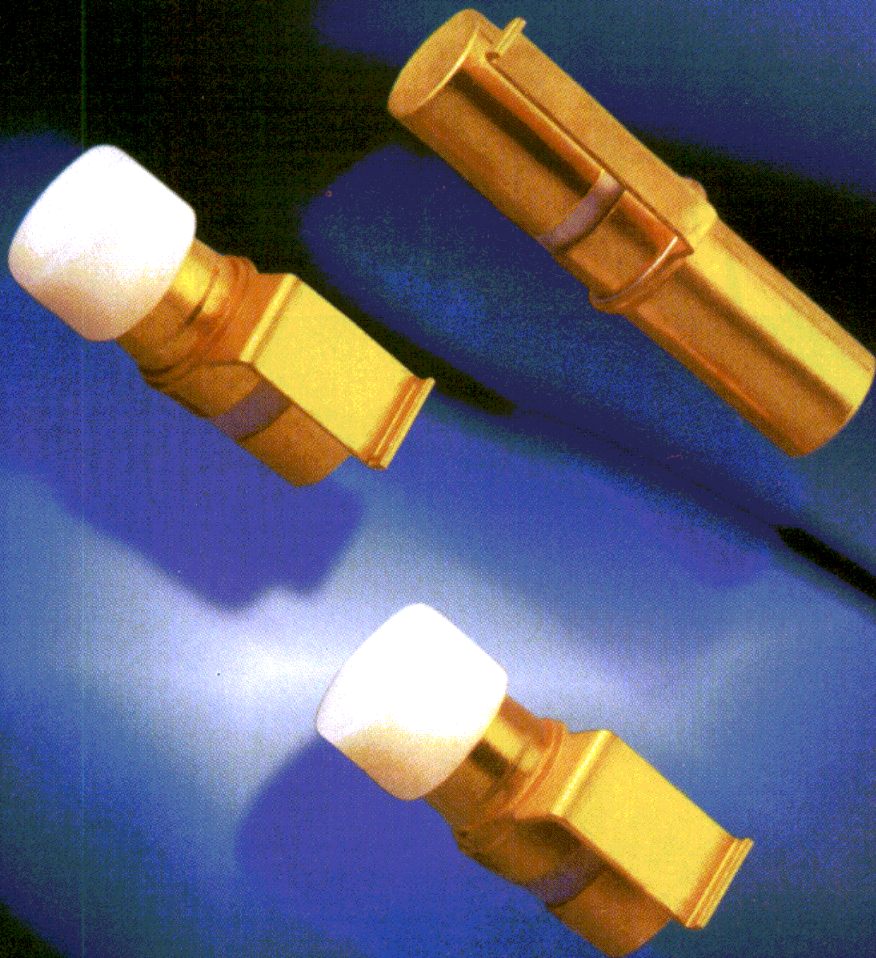
In-stock orders received before 4:00 p.m. PST are shipped the same day!

C.W. SWIFT & Associates, Inc.

15216 Burbank Blvd., Suite 300, Van Nuys, CA 91411
800-CW SWIFT • 818-989-1133 • 818-989-4784 (fax)

ADVANCED "C2K" TECHNOLOGY...

**TRIMMERS 30% - 40% SMALLER WITH
HIGH Q & MINIMUM ESL FOR
POWER AMPLIFIER APPLICATIONS**



- Model 57283
Capacitance Range: 0.8 to 4.5 pF
Height: 0.23"
- Model 57273
Capacitance Range: 0.8 to 8.0 pF
Height: 0.33"

- Tape and reel available
- High Resonant Frequency
- Delivery: Stock to 6 weeks

Tuned To Your Needs

Johanson

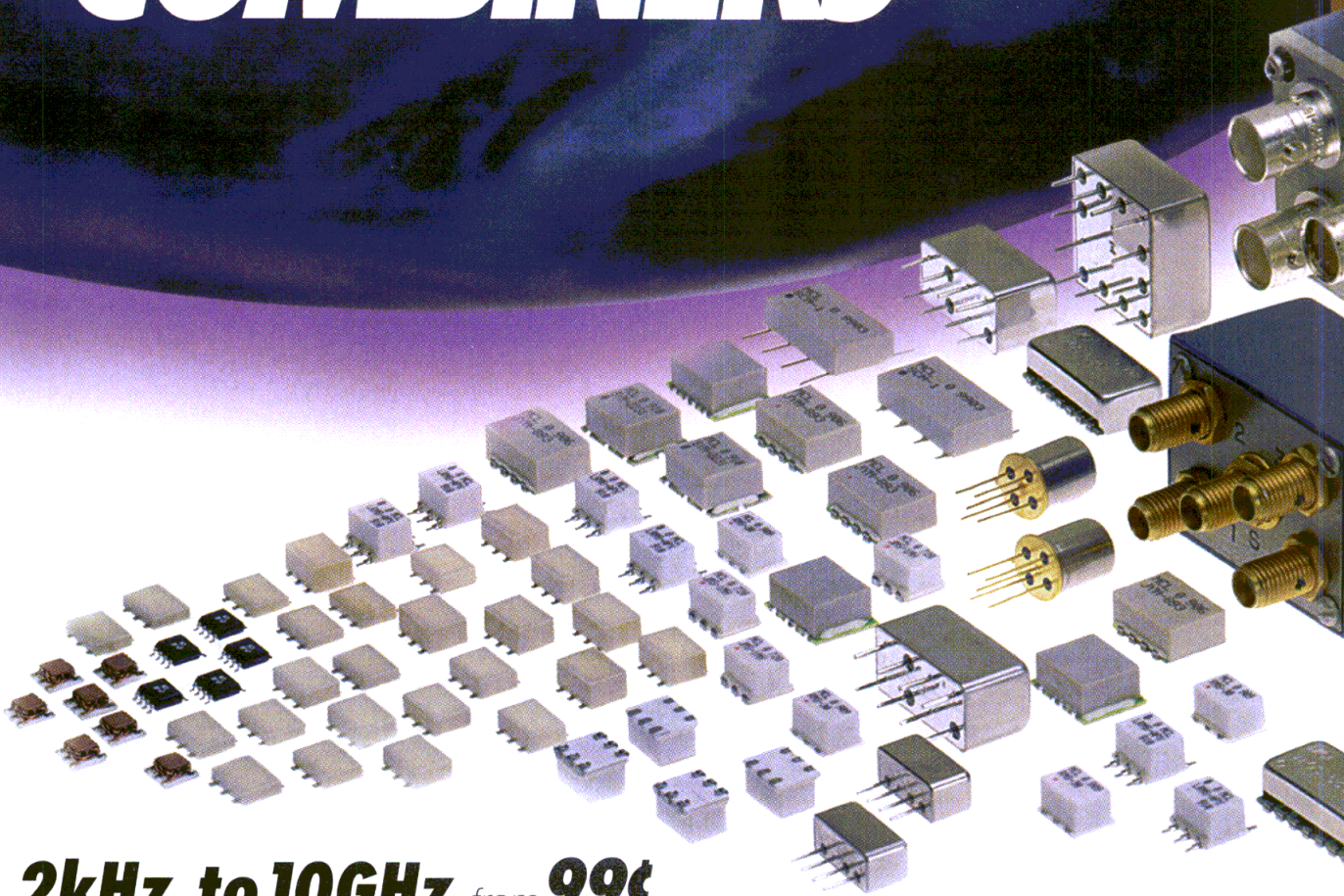
Johanson Manufacturing Corporation

Rockaway Valley Road
Boonton, New Jersey 07005
Tel 973•334•2676 Fax 973•334•2954
www.johansonmfg.com

ISO-9001 CERTIFIED

THE WORLD'S LARGEST SELECTION

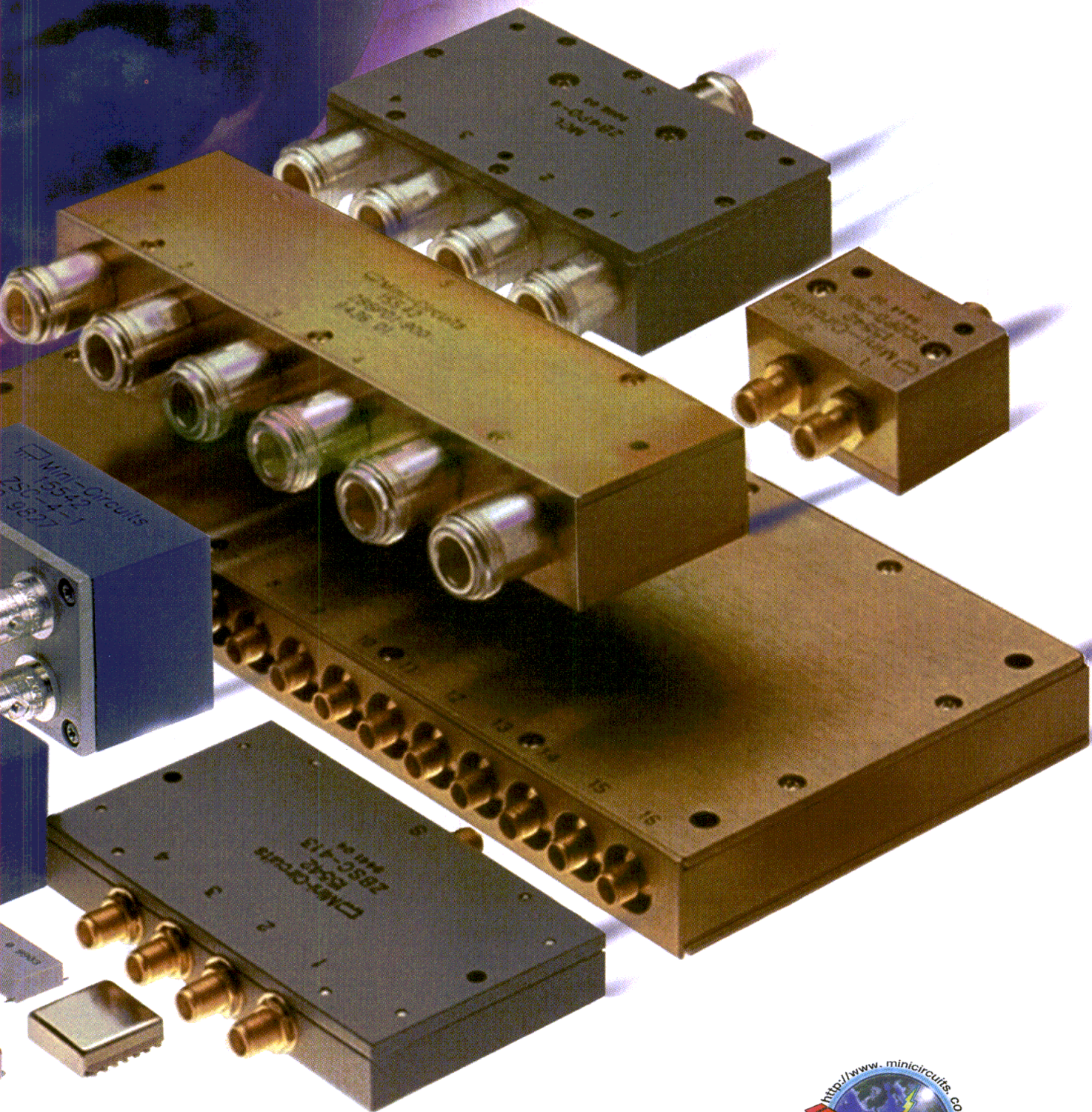
POWER SPLITTERS/ COMBINERS



2kHz to 10GHz from **99¢**

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!

Mini-Circuits...we're redefining what VALUE is all about!



see us on the web
<http://www.minicircuits.com>



 **Mini-Circuits®**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 **INTERNET** <http://www.minicircuits.com>
 For detailed specs on all Mini-Circuits products refer to • 760- pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM

ISO 9001 CERTIFIED

US 81 INT'L 91
 CIRCLE READER SERVICE CARD

F 194 Rev B

When you need Clarity and Power



Stanford Microdevices is the clear choice.

When clarity and power matter most, Stanford Microdevices delivers.

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 provides the tools to create wireless communications equipment that is smaller, lighter, more powerful at market leading prices.

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.

www.stanfordmicro.com
Make us your home page!

	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 Tj = 1 million hrs. (RTH = 97C/W typ)

SiGe HBT MMIC features include:

- Cascadable 50Ω
- Single voltage supply
- High output intercept
- +20dBm 1dB Compression Point
- Low current draw
- Low noise figure



SOT-89 package



86 package



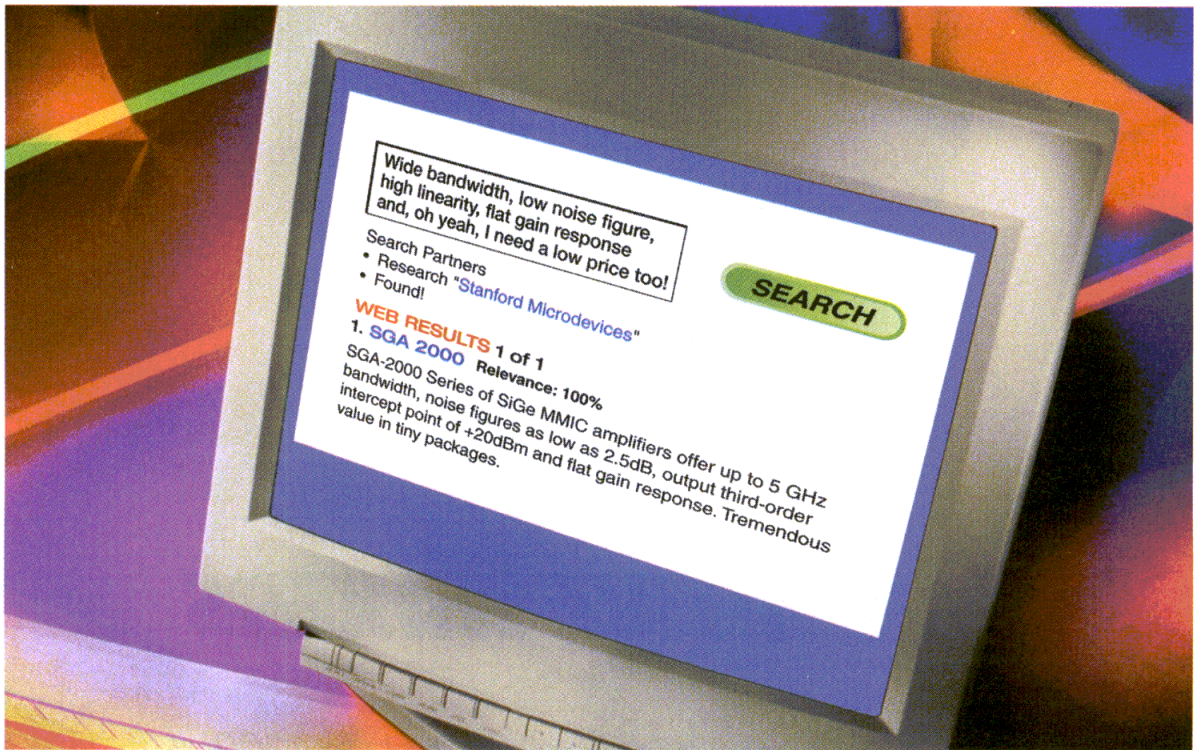
We Deliver RF Innovation

1-800-764-6642 U.S. Toll-Free

1-408-616-5400 Outside U.S.

©2000 Stanford Microdevices. All company and/or product names are trademarks and/or registered trademarks of their respective owners.

Still searching for the right amplifier for your latest design?



Successful searches end up at
www.stanfordmicro.com

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.

www.stanfordmicro.com
Make us your home page!

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
- Single voltage supply
- High output intercept
- Low current draw
- Low noise figure



86 package



SOT-363 package

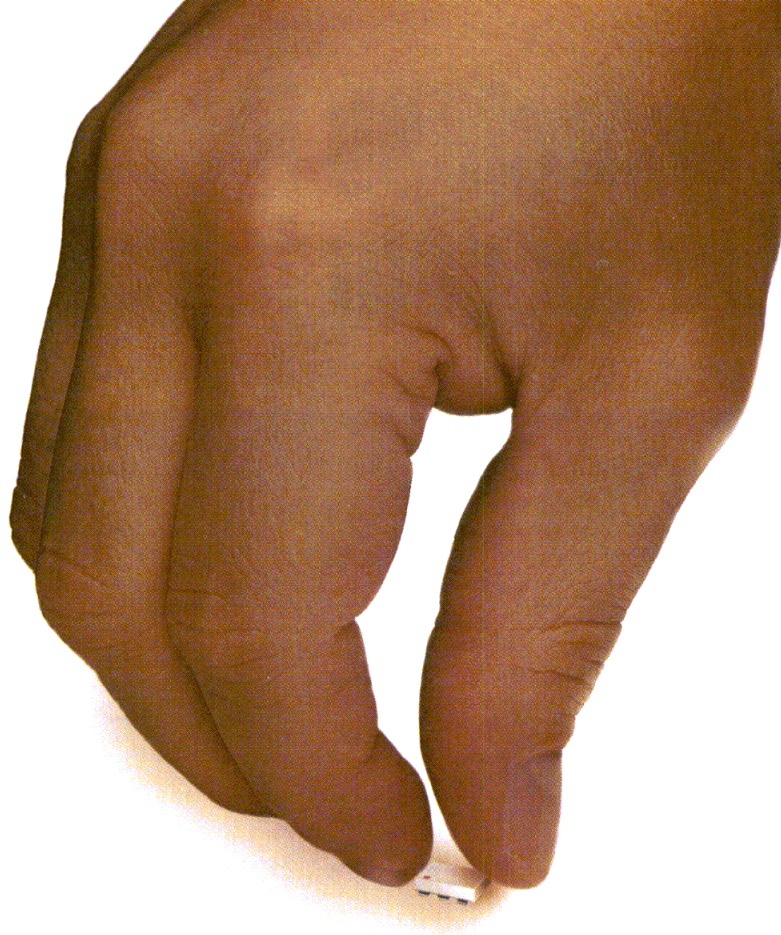


We Deliver RF Innovation

1-800-764-6642 U.S. Toll-Free

1-408-616-5400 Outside U.S.

©2000 Stanford Microdevices. All company and/or product names are trademarks and/or registered trademarks of their respective owners.



INNOVATIVE MIXERS

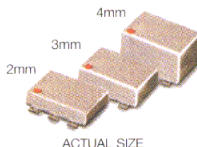
.smaller size .better performance .lower cost

200kHz to 4200MHz **\$1.99** (10-49)

WOW!



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**™



ADE Mixers...Innovations Without Traditional Limitations!

ADE* TYPICAL SPECIFICATIONS:

Model	Height (mm)	Freq. (MHz)	LO (dBm)	Conv. Loss Midband (dB)	L-R Isol. Bandwidth (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	0.5-5000	+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-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-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	2-600	+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-20H	3	1500-2000	+17	5.2	29	24	8.95

Component mounting area on customer PC board is 0.320"x 0.290".

--Specified midband. *Patent Pending.

Mini-Circuits®

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



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

ISO 9001 CERTIFIED

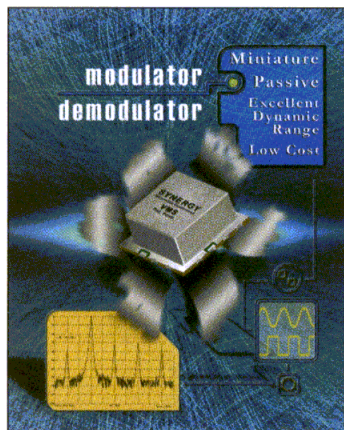
US 82 INT'L 92

CIRCLE READER SERVICE CARD

F 267 Rev I

CONTENTS

TECHNICAL FEATURES



76 On Our Cover A High Dynamic Range Miniature Modulator/ Demodulator

Synergy Microwave

The company's new VMS series of I/Q modulators and demodulators offers designers both low noise and high isolation in a small, low cost package. The patent-pending technology also provides EMI/RFI protection and moisture resistant capability. *Photo provided by Synergy Microwave.*

30 Phase Lock Loop Stability Analysis

This article gives a review of transfer functions for phase lock loops, focusing on necessary conditions to achieve steady state stability in the loop design.

— Arun Mansukhani, Motorola

42 An ASIC Driver for GaAs FET Control Components

The author offers an application note encompassing both driver selection and circuit design for gallium arsenide FET switches and digital attenuators. Special attention is given to non-linear performance as V_{opt} is varied.

— Christopher Weigand, M/A-Com, Inc.

76 Unfiltered FQPSK: Another Interpretation and Further Enhancements

Here is part one of a two-part, in-depth, theoretical discussion of unfiltered Feher-Patented Quadrature Phase-Shift-Keying, in which the authors specify a means for spectral enhancement of the transmitted waveform. An improved method of reception is also presented.

— Marvin K. Simon and Tsun-Yee Yan,
Jet Propulsion Laboratory

PRODUCTS & TECHNOLOGIES

98 Product Focus: Components for mm-Wave Systems

Here are some of the latest devices for millimeter-wave use.

102 Test Systems Enhance RF Component and Power Amplifier IC Testing

Agilent Technologies, Inc.'s new test instrumentation products address both high volume component production and RFIC testing.

104 Miniature 2.45 GHz Dielectric Filter Targets PCMCIA Card Applications

Toko America, Inc. has introduced a dielectric bandpass filter for use in wireless local area networking designs using PCMCIA cards.

Find us online at: www.amwireless.com

PRODUCTS & TECHNOLOGIES

- 106 Quadrature Modulator IC Operates up to 2.5 GHz**
Analog Devices, Inc. provides a new RF integrated circuit for communications systems using quadrature modulation.
- 108 High Speed VCXOs and Master Clock Oscillators Operate at 3.3 Volts**
Micro Networks/Anderson Laboratories offers low voltage oscillator products for high speed, high performance computing and telecommunications equipment.

GUEST EDITORIAL

- 116 The Wireless Industry Gathers for Business and Technology**
Two major upcoming industry shows, Wireless Symposium and CTIA's Wireless 2000, offer two different perspectives on wireless, one focusing on technical and design information while the other targets the business of wireless.

DEPARTMENTS

- 10 Editorial**
14 Calendar — Conferences & Short Courses
22 News
59 Products
65 Reader Service Card
111 Classified Advertising
114 Advertiser Index

Publisher

Gary A. Breed

Associate Publisher

Scott Spencer

Managing Editor

Shannon O'Connor

Art Director

Timothy Pengelly

Senior Consulting Editor

Dr. Joseph F. White

Editorial Advisors

Dr. Peter Staecker
Dr. James C. Rautio
Dr. Frederick H. Raab
Dr. Les Besser
Dr. Eli Brookner
Dr. Peter Rizzi
Dr. T.B. Ramachandran
Ben Robinson

Assistant Editor

Sherry Johnson

Associate Editor

Martina Voigt

Data Manager

Nancy Breed

Advertising Sales — East

Scott Spencer
Tel: 603-472-8261
Fax: 603-471-0716

Advertising Sales — West

Tim Burkhard
Tel: 707-544-9977
Fax: 707-544-9375

Classified & Spotlight Ads

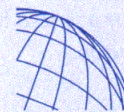
Tel: 770-908-2320
Fax: 770-939-0157

New Subscriptions and Address Changes

Mail: 4772 Stone Drive
Tucker, GA 30084
Fax: 770-939-0157

Reprints/Back Issues

Tel: 770-908-2320



NOBLE
PUBLISHING

Applied Microwave & Wireless

Noble Publishing Corporation
4772 Stone Drive
Tucker, GA 30084
Tel: 770-908-2320
Fax: 770-939-0157

E-mail: amw@amwireless.com

www.amwireless.com

High IP3

Low Noise Amplifiers



for Cellular, PCS, WLL

MODEL NUMBER	FREQ. MHZ	GAIN dB NOM	NOISE FIG. dB TYP	3RD ORDER ICP dB MIN
--------------	-----------	-------------	-------------------	----------------------

CELLULAR-BAND AMPLIFIERS

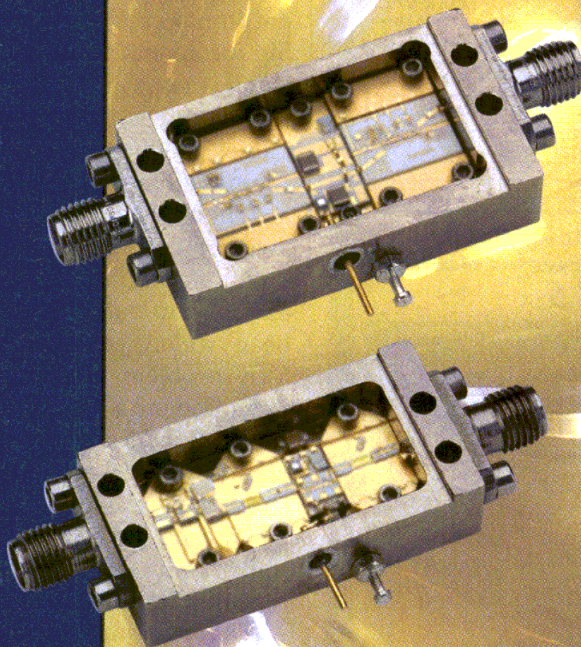
JCA01-C01	800-960	24	0.9	32
JCA01-C02	800-960	24	1.1	37
JCA01-C03	800-960	24	1.2	40
JCA01-C04	800-960	24	1.3	42
JCA01-C05	800-960	42	0.9	32
JCA01-C06	800-960	42	1.1	37
JCA01-C07	800-960	42	1.2	40
JCA01-C08	800-960	42	1.3	42

PCS-BAND AMPLIFIERS

JCA12-PC01	1710-1990	24	0.9	32
JCA12-PC02	1710-1990	24	1.1	37
JCA12-PC03	1710-1990	24	1.2	40
JCA12-PC04	1710-1990	24	1.3	42
JCA12-PC05	1710-1990	40	0.9	32
JCA12-PC06	1710-1990	40	1.1	37
JCA12-PC07	1710-1990	40	1.2	40
JCA12-PC08	1710-1990	40	1.3	42

WLL-BAND AMPLIFIERS

JCA23-W01	2300-2500	24	1.0	32
JCA23-W02	2300-2500	24	1.2	37
JCA23-W03	2300-2500	24	1.3	40
JCA23-W04	2300-2500	24	1.5	42
JCA23-W05	2300-2500	41	1.0	32
JCA23-W06	2300-2500	41	1.2	37
JCA23-W07	2300-2500	41	1.3	40
JCA23-W08	2300-2500	41	1.5	42



- Removable SMA Connectors for Drop-in/Microstrip Applications
- Competitive Pricing
- Compact Size
- Quick Delivery

JCA can customize the above amplifier specifications to meet the customer's exact performance requirements for Cellular, PCS and WLL Bands.

Delivery in 2-4 weeks ARO

JCA's catalog can now be downloaded from the Web at www.jcatech.com

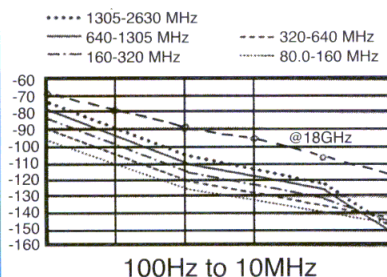
JCA
TECHNOLOGY

4000 Via Pescador, Camarillo, CA 93012 • (805) 445-9888 Fax: (805) 987-6990 • Email: jca@jcatech.com

SYNTHESIZERS PLL/DDS VT-1200

VT-1200 PLL Instruments

- Module - .1 TO 2630 MHz
- Chassis - to 20 GHz
- 1.75", 3.5" Chassis
- Excellent spectral purity
- Fine Resolution
- 110V ac, +12VDC supply
- Counter, Power Meter
- GPIB, RS-232



VT-1200-3.5



- PLL/DDS custom designs

- Gain control linear amps
- Phase control linear amps

VITCOM

Wireless, Communications,
Training and Technical Marketing
3521 Mercer Lane
San Diego CA 92122
Cell: (619) 846-1071
Fax: (619) 452-6649
Pager (619) 340-9898
email: glora18@tns.net
www.vitacom.com

Editorial

The Y2K Prevention Effort was Almost Good Enough

By Gary A. Breed
Publisher

Because I work in a high-tech industry, my friends would often ask me if I thought the Y2K problem was real and how it might affect them. My standard answer was, "I'm sure all the really big problems will be found, but some small ones will inevitably occur." One of the examples I used was that some companies might find problems processing their customers' credit cards.

I didn't realize that I was predicting my own company's future!

This column is being written on January 13 and I don't know yet if it has been widely reported that a significant Y2K problem affected many companies, including ours. Our credit card processing software had a serious bug that was not identified until three business days of the new year had passed. In those three days, credit card transactions were not cleared from temporary files when each day's activities were closed out. As a result, our bookstore customers who made purchases on January 3 got the charges to their cards repeated on the 4th and 5th! Others got double charges.

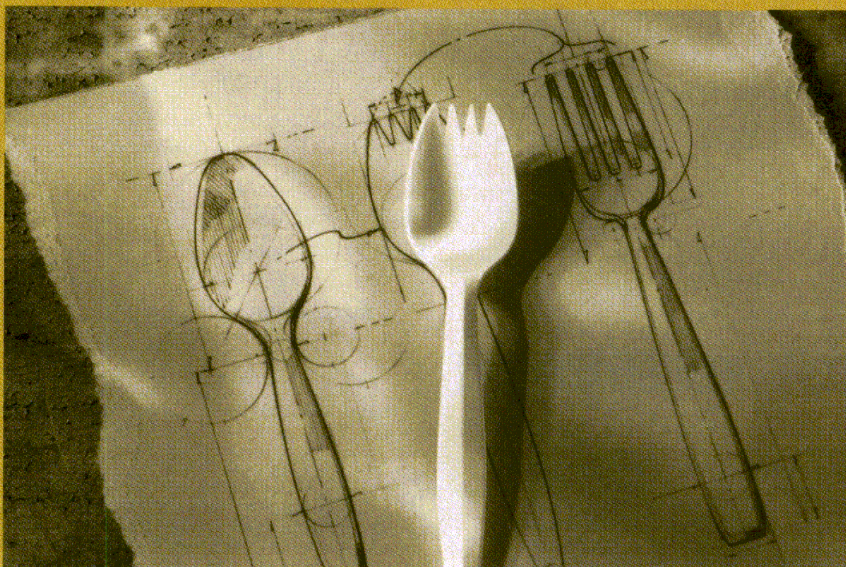
The software company claims that they began notifying users in February 1999 with a notice on their web site, but we are a registered user and received no letter, e-mail or other warning. We had no reason to visit their web site because their product was working fine and we were using an earlier upgrade that had been represented as being Y2K compatible.

For us, the end of the story is not too bad. Only a small number of people were affected and the credit card companies are working with us and the software vendor to clear up the problems. But, some of the large companies using the faulty software may have had hundreds or even thousands of transactions go wrong.

So if you have been wondering whether all that money spent on Y2K testing and software updates was worth it, the answer is "yes." Although many companies and governments around the world did nothing and suffered few problems, some potentially dangerous or disruptive problems were uncovered and fixed. (And one moderate-sized problem was missed!)

Like medical and dental exams, bank audits and termite inspections, prevention seems costly — but never as costly as the problems it prevents. ■

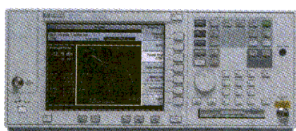




Every once in a while someone comes along with the perfect combination.

When you're testing 2G and 3G products, you can't afford to choose between accuracy and speed. But most of the time, that's exactly what you're forced to do.

We've got the perfect solution. The Agilent Technologies E4406A Vector Signal Analyzer. We designed the E4406A specifically for the manufacturing test needs of 2G and 3G base stations and components. It has unmatched test speed—up to 5 times faster than the competition. Amplitude accuracy of .5dB for critical measurements. And pre-configured measurements for



Agilent Technologies'
E4406A Vector Signal Analyzer

faster setup than traditional spectrum analyzers. So you get all the speed you want. Along with all the accuracy you need. And that's a combination you don't see very often.

For more information about our E4406A VSA, or to get a FREE copy of *Performing cdma2000 Measurements Today*, visit our web site. Or call us at the number listed below. Because whether it's today's formats or formats of the future, you still have to be perfect.

www.agilent.com/find/vsa
1-800-452-4844, Ext. 6938



Agilent Technologies
Innovating the HP Way

Circle 20

**See us at Wireless Symposium, booth #609
and CTIA, booth #3257**

CONFERENCES

FEBRUARY

February 22-25, 2000

Wireless/Portable 2000

San Jose, CA

Information: Wireless/Portable

Internet: <http://www.WirelessPortable.com>

February 28-March 1, 2000

CTIA Wireless 2000

New Orleans, LA

Information: CTIA

Tel: 1-800-421-6338 or 415-979-2250

Internet: <http://www.ctiashow.com>

MARCH

March 6-9, 2000

CARTS 2000 — Capacitor and Resistor Technology Symposium

Long Beach, CA

Information: CTI-EIA/ECA

E-mail: pwalsh@eia.org

Internet: <http://www.eia.org>

March 28-30, 2000

RTS 2000

Paris, France

Information: BRIP

Tel: + 33 01 53 17 11 44

E-mail: crey@birp.fr

Internet: <http://www.birp.com/rts>

APRIL

April 8-13, 2000

NAB2000

Las Vegas, NV

Information: NAB

Internet: <http://www.nab.org.conventions>

April 10-11, 2000

2000 IEEE Emerging Technologies Symposium on Broadband Wireless Internet Access

Dallas, TX

Information: Dr. Jon Velhl

Tel: 972-952-4190

Internet: <http://www.ieeedallas-els.org>

April 17-19, 2000

48th International Relay Conference

Lake Buena Vista, FL

Information: NARM EIA/ECA

E-mail: pwalsh@eia.org

MAY

May 1-4, 2000

**2000 GaAs MANTECH Conference
International Conference on Gallium-Arsenide
Manufacturing Technology**

Washington, DC

Information: Wes Mickanin

Tel: 503-615-9253; Fax: 503-615-8903

E-mail: wem@tqs.com

Internet: <http://www.gaasmantech.org>

May 17-19, 2000

Eurocomm 2000

Munich, Germany

Information: Jacques Keevers

Tel: +32 2 7706643; Fax: +32 2 7708505

E-mail: j.keevers@ieee.org

Internet: <http://www.eurocomm.org/2000>

May 20-26, 2000

**IEEE International Conference on Phased Array
Systems and Technology**

Dana Point, CA

Information: Dr. Michael Thorburn

Tel: 310-336-2197; Fax: 310-336-6225

E-mail: m.a.thorburn@IEEE.org

Internet: <http://www.ieee.org>

May 21-24, 2000

**50th Electronic Components and Technology
Conference**

Las Vegas, NV

Information: EIA/ECA-IEEE/CPMT

E-mail: pwalsh@eia.org

Internet: <http://www.ectc.org>

JUNE

June 7-9, 2000

**2000 IEEE/EIA International Frequency Control
Symposium and Exhibition**

Kansas City, MO

Information: IEEE Ultrasonics, Ferroelectrics and
Frequency Control Society

E-mail: pwalsh@eia.org

Internet: <http://www.ieee.org/uffc/fc>

June 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>

Products for a Wireless World

- LAN
- IMT2000
- WLL
- PCS
- WAN
- MMDS
- W-CDMA
- SATCOM
- LMDS
- mmW/Microwave Radio

MIXERS

RF Surface Mount Microwave Open Carrier

- High IIP3
- 10kHz to 26.5 GHz
- Industry Standard Packaging
- Delivery from Stock
- Best Price-Performance ratio in the Industry

Stellex offers the broadest line of RF and Microwave Mixers and Frequency Doublers in the industry, covering 10kHz to 26GHz. Stellex RF Surface Mount and Microwave Open

Carrier Mixers provide the fundamental building blocks for frequency conversions used in a broad spectrum of wireless applications. When performance and price matter, discover the value of innovative off-the-shelf solutions from Stellex.

To meet your demanding system specs, *specify Stellex!*

1-800-321-8075

Part Number	Frequency RF & LO	Frequency IF	LO Drive Level	Isolation (typ) LO/RF	Input IP3 (typ)	Conversion Loss (typ)	Package Style
CSM1-10	10 to 1,500 MHz	1 to 500 MHz	+10 dBm	40 dB	19 dBm	7.5 dB	Surface Mount
CSM1-13	10 to 1,500 MHz	1 to 500 MHz	+13 dBm	40 dB	22 dBm	7.5 dB	Surface Mount
CSM1-17	10 to 1,500 MHz	1 to 500 MHz	+17 dBm	40 dB	27 dBm	7.5 dB	Surface Mount
CSM2-10	10 to 2,800 MHz	10 to 2,000 MHz	+10 dBm	30 dB	20 dBm	7.5 dB	Surface Mount
CSM2-13	10 to 2,800 MHz	10 to 2,000 MHz	+13 dBm	30 dB	22 dBm	7.5 dB	Surface Mount
CSM2-17	10 to 2,800 MHz	10 to 2,000 MHz	+17 dBm	30 dB	27 dBm	7.5 dB	Surface Mount
MC4107	2 to 10 GHz	DC to 2 GHz	+7 dBm	40 dB	11 dBm	6.0 dB	Open Carrier
MC4110	2 to 10 GHz	DC to 2 GHz	+10 dBm	40 dB	14 dBm	6.0 dB	Open Carrier
MC4113	2 to 10 GHz	DC to 2 GHz	+13 dBm	40 dB	17 dBm	6.0 dB	Open Carrier
MC4120	2 to 10 GHz	DC to 2 GHz	+20 dBm	40 dB	23 dBm	6.5 dB	Open Carrier
MC4507	4 to 22 GHz	DC to 4 GHz	+7 dBm	32 dB	11 dBm	6.0 dB	Open Carrier
MC4510	4 to 22 GHz	DC to 4 GHz	+10 dBm	32 dB	14 dBm	6.0 dB	Open Carrier
MC4513	4 to 22 GHz	DC to 4 GHz	+13 dBm	32 dB	17 dBm	6.0 dB	Open Carrier
MC4520	4 to 22 GHz	DC to 4 GHz	+20 dBm	32 dB	23 dBm	6.5 dB	Open Carrier

* Connectorized test units available for evaluation

visit us on the web at

www.stellexms.com

**The best high performance mixers
available have a new name...**



Stanford Research Park • 3333 Hillview Avenue, Palo Alto, CA 94303-1223
Tel: 1.800.321.8075 • FAX 650.813.2030

Circle 58

See us at Wireless Symposium, booth #1539

SHORT COURSES

Comsearch Center for Technical Training

Basics of Wireless for Non-Engineers

Reston, VA February 7-8, 2000

Basics of Microwave Design

Reston, VA February 9-10, 2000

WLL and PMP Overview

Reston, VA February 15-16, 2000

WLL Theory and Design

Reston, VA February 17-18, 2000

Information: Comsearch, Tel: 1-800-318-1234; Fax: 703-476-2720; E-mail: training@comsearch.com; Internet: www.comsearch.com.

Franklin Research Group

Understanding Telecommunications

San Jose, CA February 7-8, 2000

Portland, OR February 10-11, 2000

New York, NY February 14-15, 2000

Atlanta, GA February 28-29, 2000

Information: Franklin Research Group, Tel: 201-847-7882; Fax: 201-847-1821; Internet: www.franklinresearch.com.

RTT Programmes Limited

Cellular Design

London, England February 7-9, 2000

RF Amplifier Design

London, England February 14-16, 2000

RF Oscillator Design

London, England March 13-15, 2000

RF/IF Processing

London, England March 20-22, 2000

RF System Engineering

London, England March 27-29, 2000

Information: Lorraine Gannon, Tel: +44 181 844 1811; Fax: +44 181 751 2616; E-mail: seminars@rttsys.com; Internet: www.rttsys.com.

Applied Technology Institute

Fundamentals of Radar Technology

Washington, DC February 8-10, 2000

Radar Systems Design and Engineering

Washington, DC February 15-17, 2000

Mathematical and Physical Wavelets

Newport, RI March 13-16, 2000

Satellite Communication Systems Engineering

Los Angeles, CA March 21-23, 2000

Information: ATI Defense Systems Training, Tel: 1-888-501-2100 or 410-531-6034; Fax: 410-531-1013; E-mail: ATCourses@aol.com; Internet: www.ATCourses.com.

Besser Associates

Wireless Measurements: Theory and Practice

Mountain View, CA February 14-18, 2000

Signal Integrity of High-Speed Digital Design

Mountain View, CA February 28-29, 2000

Multitone Amplifier Design

Mountain View, CA March 2-3, 2000

Introduction to RF Transceivers and Systems Components

Mountain View, CA March 6-7, 2000

RF Test Equipment Operation (laboratory course)

Mountain View, CA March 8, 2000

RF Testing for the Wireless Age (laboratory course)

Mountain View, CA March 9-10, 2000

Behavioral Modeling

Mountain View, CA March 13-15, 2000

RFIC Techniques for Wireless Applications

Mountain View, CA March 20-22, 2000

EMC/EMI and Thermal Issues for Electronic Packages and Systems

Mountain View, CA March 23, 2000

Applied RF Techniques II

Phoenix, AZ March 26-31, 2000

Introduction to Receivers, Signals and Noise

Mountain View, CA March 27-28, 2000

Information: Annie Wong, Tel: 415-949-3300; Fax: 415-949-4400; E-mail: info@bessercourse.com; Internet: www.bessercourse.com.



Microwave Waveguide Components

Where reliability and quality are paramount.

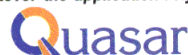
Quasar are Europe's leading manufacturer of high quality flexible/twistable waveguide, from WG8 (WR430) to WG24 (WR19) with flanges and jackets manufactured for customer specific applications.

- Fixed and Variable Attenuators
- Cross Guide and Broadwall Directional Couplers
- Broadband Waveguide Horns
- Fixed and Sliding Load Terminations
- Rigid Waveguide
- Tee Junctions
- Coaxial and Taper Transitions
- Filters & Diplexers
- Couplers, Splitters and Combiners
- Rotary Vane Attenuators

Full range
of precision
microwave
waveguide
components

Designed and manufactured in our purpose built factory in the UK to ISO9001 fast lead times and at low cost. Just take a look at our NEW "On-Line catalogue" on our NEW website.

Whatever the application rely on Quasar.



Quasar Microwave Technology Limited

Battle Road, Heathfield, Newton Abbot,
Devon TQ12 6XU, England

Tel: +44 (0)1626 834222

Fax: +44 (0)1626 832994

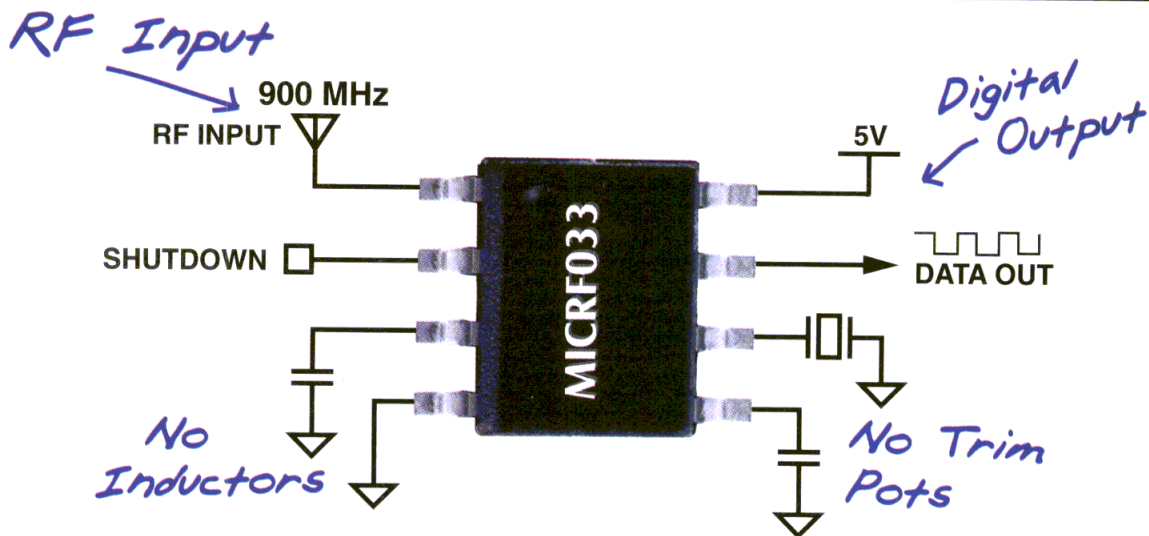
Email: sales@qmtl.com



See our NEW WEBSITE www.qmtl.com



900MHz Single-Chip RF Receiver



The Good Stuff

- ◆ Incredibly easy to design
- ◆ Easy to manufacture — fewer components and no trimming
- ◆ More reliable — no trim pots
- ◆ Lower cost
- ◆ 20 kbps data rate

The Specs

Part No.	Data Rate	Spectrum
MICRF001	4.8kbps	300 – 440MHz
MICRF011	2.5kbps (SWP), 10kbps (Fixed)	300 – 440MHz
MICRF002	2.5kbps (SWP), 10kbps (Fixed)	300 – 440MHz
MICRF022	2.5kbps (SWP), 10kbps (Fixed)	300 – 440MHz
MICRF003	5kbps (SWP), 20kbps (Fixed)	800 – 1,000MHz
MICRF033	5kbps (SWP), 20kbps (Fixed)	800 – 1,000MHz

Developed with AIT, Orlando, FL

*See data sheet for actual pinout

** Recommended resale FOB USA

Contact us for more information — Don't forget to
bookmark our website for updates!

www.micrel.com/ads.html

Literature: 1-800-401-9572

Direct: (408) 944-0800

Stocking Distributors:

Arrow (800) 777-2776 • Future (800) 388-8731

Newark (800) 463-9275 • Nu Horizons (888) 747-6046

The MICRF003/033 are the latest additions to Micrel's revolutionary QwikRadio™ single-chip RF receiver family.

QwikRadio ICs have already set a new standard for ease of use and low cost in the 300MHz to 400MHz frequency band. The MICRF003/033 brings the same benefits to the less-used and less-restrictive 900MHz band.

Simply put, they take RF-in and provide digital data-out, with no manual tuning and no external inductors.

Power consumption is just 4mA in continuous operation, and the device is designed to be duty cycled, enabling huge additional power savings.

For more information, call us or check out our website.

MICREL
The Infinite Bandwidth Company™

Calendar

University of Missouri-Rolla

Grounding and Shielding Electronic Systems

Atlanta, GA February 16-17, 2000

Orlando, FL February 22-23, 2000

Circuit Board Layout to Reduce Noise Emission and Susceptibility

Atlanta, GA February 18, 2000

Orlando, FL February 24, 2000

Information: Buddy Poe, Tel: 573-341-6061; Fax: 573-341-4992; E-mail: buddyp@umr.edu; Internet: www. umr.edu/~conted/ee.html.

University of Wisconsin at Milwaukee

EMC Printed Circuit Board Design

Tampa, FL Feb. 28-March 1, 2000

Information: Mark Schmidt, Program Assistant, Tel: 1-888-545-4700; Fax: 1-888-545-4600; E-mail: dschmidt@uwm.edu; Internet: www.uwm.edu/dept/ccee.

University of California at Los Angeles Extension

Digital Avionics Systems

Los Angeles, CA Feb. 28-March 3, 2000

Kalman Filtering

Los Angeles, CA March 13-16, 2000

Synthetic Aperture Radar: Understanding the Imagery

Los Angeles, CA March 13-17, 2000

Radar Interferometry: Principles, Processing and Applications

Los Angeles, CA March 20-24, 2000

Information: UCLA Extension, Short Course Program Office, Tel: 310-825-3344; Fax: 310-206-2815.

Northeast Consortium for Engineering Education

Antennas: Principles, Design and Measurements

San Diego, CA March 13-16, 2000

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.

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

RF, Wireless, and High-Speed Digital Training

Join a new class of engineers! Over 20,000 satisfied industry professionals profit from our courses.

Mountain View, California

Signal Integrity of High-Speed Digital Design

February 28-29, 2000

Multitone Amplifier Design

March 2-3, 2000

Introduction to RF Transceivers and System Components

March 6-8, 2000

RF Test Equipment Operation (Lab Course)

March 8, 2000

RF Testing for the Wireless Age (Lab Course)

March 9-10, 2000

Behavioral Modeling

March 13-15, 2000

RFIC Techniques for Wireless Applications

March 20-22, 2000

EMC/EMI/Thermal Issues for Electronic Packages and Systems

March 23, 2000

CDMA: The Physical Interface

April 4-7, 2000

Frequency Synthesis Technology and Applications in Wireless Systems

April 17-19, 2000

DSP Made Simple

April 18-20, 2000

Applied RF Techniques I

April 24-28, 2000

Wireless Digital Communications

May 1-5, 2000

Our most popular courses will also be held March 2000 in Phoenix, Arizona.

Visit www.bessercourse.com for our complete course catalog and the year 2000 schedule.

Private and/or custom training can be delivered at your workplace. Call 650-949-3300 for details.



February 22-25, 2000

San Jose Convention Center, San Jose, CA

Wireless Symposium
Portable by Design

Where the wireless future gets built.

Besser Associates, the Conference Director for this Penton Media Electronics Event, is discussing conference topics online right now! Visit <http://www.bessercourse.com> and connect to our open online forum.



Besser Associates™

The Worldwide Leader in RF and Wireless Training

201 San Antonio Circle, Building E, Suite 280, Mountain View, CA 94040

tel: 650-949-3300 fax: 650-949-4400 web: <http://www.bessercourse.com>

Space for all classes is limited; early registrations are encouraged. Schedule and venues subject to change. The Besser Associates name and logo are trademarks of Besser Associates, Incorporated.

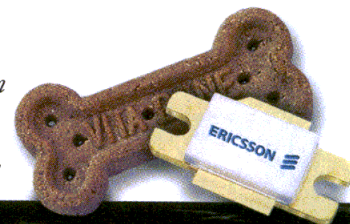
Circle 55

No Tricks Required

You don't have to do tricks to get the **GOLDMOS™** RF Power Transistors you need.

Just go to our web site **TODAY** at www.ericsson.com/rfpower

Detailed product datasheets, application notes and contact information for sample requests are all available on our web site.



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

Ericsson Microelectronics

RF Power Products

1-877 GOLDMOS (465-3667) United States
+46 8 757 4700 International

Circle 47

Delivering Technology Choices

ERICSSON 
See us at Wireless Symposium, booth #933
and CTIA, booth #7123

CALLS FOR PAPERS

ICSPAT — International Conference on Signal Processing Applications and Technology

October 19-20, 2000 — Dallas, TX

Topics: Adaptive processing, aerospace, array processing, ASICs and IP, communications, control applications, data acquisition, data commu-

nications and modems, digital filter realizations, DSP processors, DSP systems, echo cancellation and noise reduction, efficient algorithms, FPGAs in DSPs, industrial applications, instrumentation and testing, multidimensional signal processing, neural networks, parallel architec-

tures and processing, radar, reconfigurable DSPs, software, specialized applications, spectral analysis and estimation, speech recognition, telephony, VLSI architectures and wireless communications.

Authors should submit a 500- to 1,000-word abstract through the ICSPAT web site or via e-mail. Attached files should be sent in Microsoft Word or ASCII text format. Abstracts may also be mailed or faxed if necessary. Submissions should include title, topic, primary author and complete contact information, list of contributing authors, and list of any other submitted papers with which the authors are affiliated. (Authors are limited to affiliation with no more than two accepted papers.) Complete submission guidelines are available on the conference web site.

Submit abstracts to:

Deanna Young
ICSPAT, CMP Media Inc.
525 Market St., Suite 500
San Francisco, CA 94105-2713
Tel: 415-538-3860
Fax: 415-278-5390
dyoung@mfi.com
<http://www.dspworld.com>

Deadline: March 1, 2000

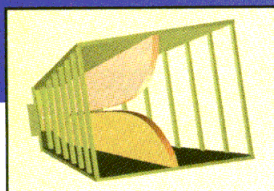
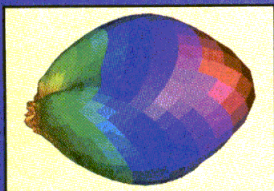
GaAs 2000

October 2-3, 2000 — Paris, France

Topics: Compound semiconductor material (including SiGe, SiC, GaN and AlGaSb), device and circuit technologies, technology CAD, reliability, yield and statistical analysis, device characterization and modeling, high speed digital devices and circuits, opto-electronic devices and applications, micro and nano-technologies, MEMs and MOEMs, MMIC for telecommunications, automotive, military and space applications, and packaging.

Authors should submit an author information form (call or e-mail to receive a form) and either two hard copies or an electronic file (.doc or .pdf) of a summary for each paper.

Wave goodbye to out of date software...



with CONCERTO

**The most advanced package
for 3D microwave design**

Applications include

- Waveguide components
- Antennas
- Resonators
- Microstrips
- Microwave heating

For further information contact:

VF VECTOR FIELDS
SOFTWARE FOR ELECTROMAGNETIC DESIGN

Vector Fields Inc
1700 North Farnsworth Avenue, Aurora, IL 60505, USA
Tel: (630) 851 1734 Fax: (630) 851 2106
Email: info@vectorfields.com
Web: <http://www.vectorfields.com>

Circle 37

CALLS FOR PAPERS

Submit to:

Professor Alain Cappy

IEMN

Avenue Poincare, BP 69

59652 Villeneuve d'Ascq, France

Tel: + 33 3 20 19 78 59

Fax: + 33 3 20 19 78 92

alain.cappy@iemn.univ-lille1.fr

Deadline: March 17, 2000

EuMC 2000 — 30th European Microwave Conference

October 2-5, 2000 — Paris, France

Topics: Microwave materials, passive components and circuits, active circuits and systems, MMICs, CAD of microwave circuits, CAD for passive components, electromagnetic field theory, antenna design, modeling and measurement, millimeter and submillimeter wave components and circuits, microwave measurements, superconducting components and subsystems, EM compatibility, packaging and remote sensing, including active and passive radars.

Authors should submit an author information form (call or e-mail to receive a form) and either six hard copies or an electronic file (.doc or .pdf) of a summary for each paper.

Submit to:

Professor Christian Rumelhard

CNAN

292 rue Saint Martin

75041 Paris Cedex 03, France

Tel: + 33 1 40 27 21 79

Fax: + 33 1 40 27 24 81

rumelhard@cnam.fr

Deadline: March 17, 2000

2000 European Conference on Wireless Technology

October 4-5, 2000 — Paris, France

Topics: Low cost, high speed silicon integrated circuits, propagation modeling for wireless multimedia, linearity at the active device and component levels, new modulation and coding schemes, advanced multi-user receivers, spatial channels and smart antennas, satellite networks, wireless LAN, UMTS, wireless access to information infra-

structure and impact of technology on system performance.

Authors should submit an author information form (call or e-mail to receive a form) and either four hard copies or an electronic file (.doc or .pdf) of a summary for each paper.

Submit to:

Professor Jacques Citerne
IRER

Campus Beaulieu, CS 14315

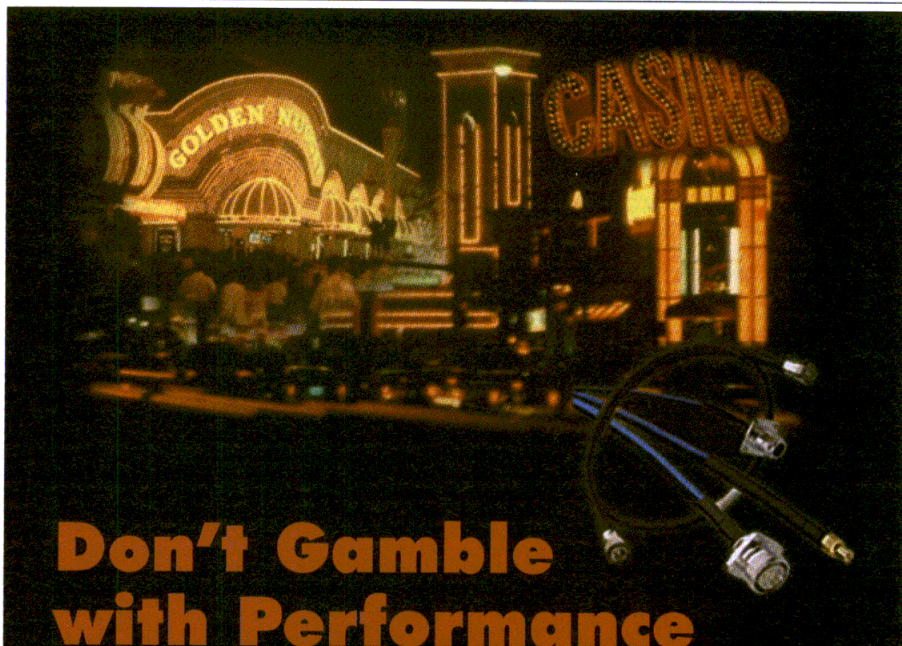
35043 Rennes cedex, France

Tel: + 33 2 99 28 65 06

Fax: + 33 2 99 38 62 48

jacques.citerne@insa-rennes.fr

Deadline: March 17, 2000




Don't Gamble with Performance

Cable Assemblies are the core of your communication system. Without the best quality, you risk a compromise in system performance. HUBER+SUHNER has been a leading designer and manufacturer of RF cable assemblies for decades.

- RF connectors and cable in standard and custom designs
- High performance, cost effective cable assemblies for your demanding applications
- Low loss, highly flexible coaxial cable with superior screening effectiveness
- Halogen-free Enviroflex™ cable to meet all environmental requirements

Don't gamble with system performance.

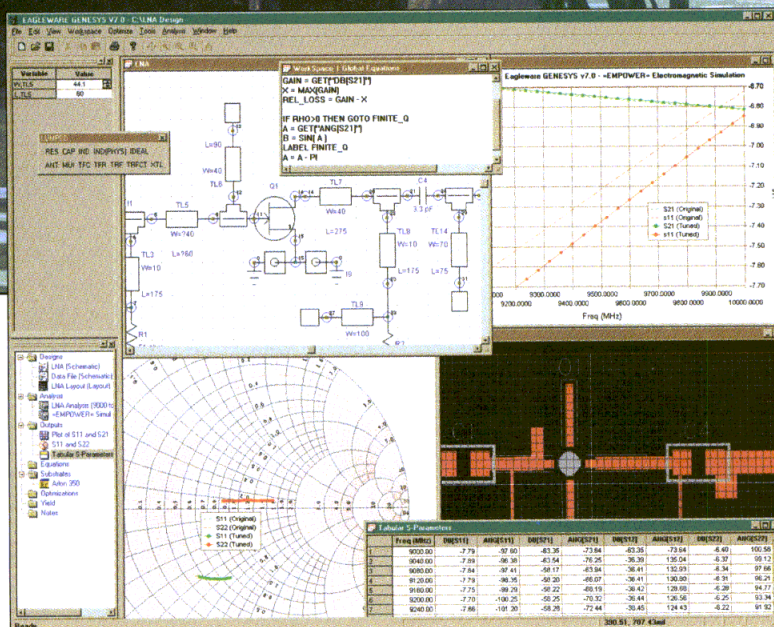
 **HUBER+SUHNER**

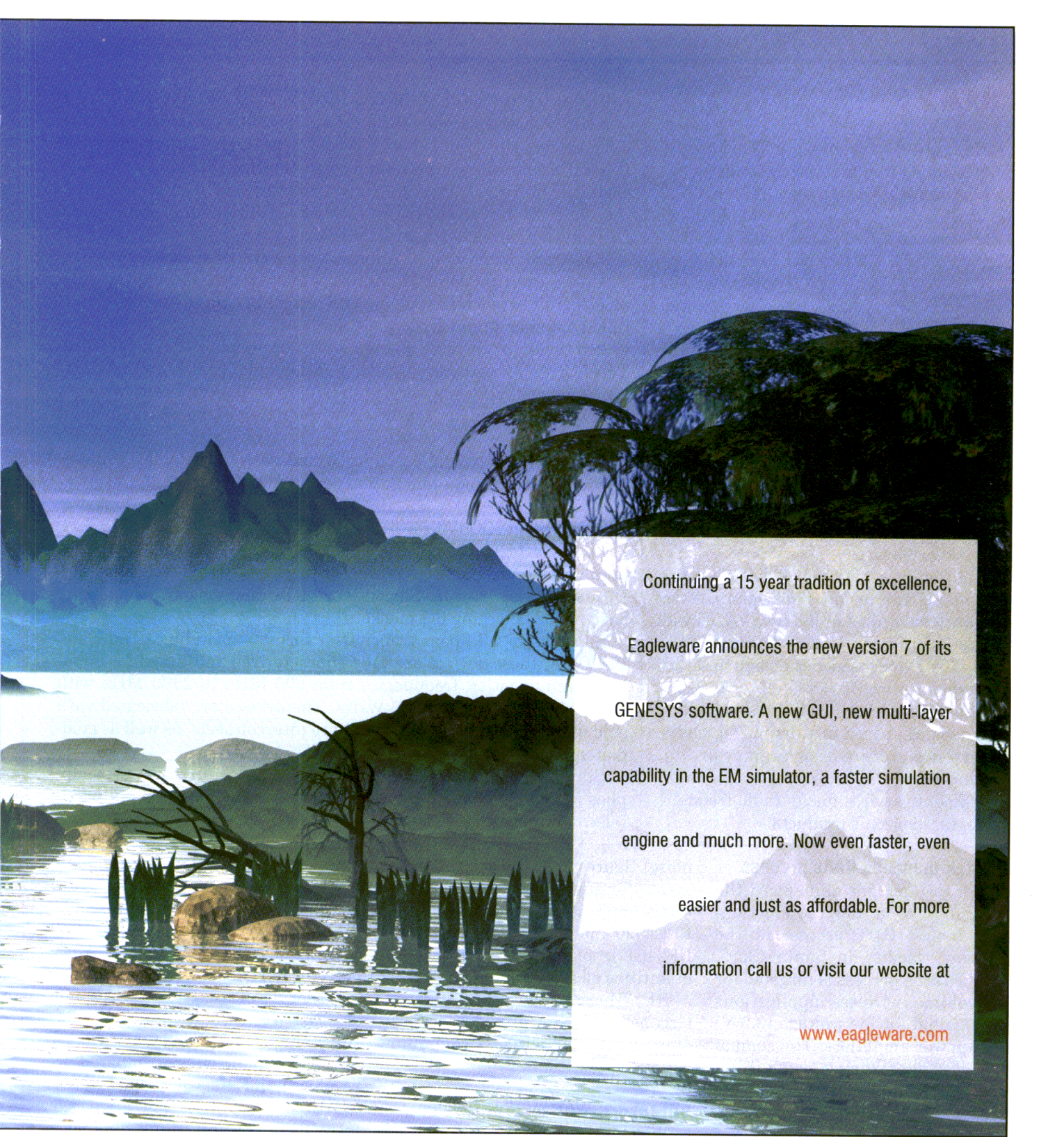
INNOVATIVE SOLUTIONS TO COUNT ON

U.S.A 802-878-0555 www.hubersuhnerinc.com
Canada 613-271-9771 www.hubersuhner.ca

Circle 76 See us at CTIA, booth #1947

PREPARE FOR THE NEXT GENESYS





Continuing a 15 year tradition of excellence,
Eagleware announces the new version 7 of its
GENESYS software. A new GUI, new multi-layer
capability in the EM simulator, a faster simulation
engine and much more. Now even faster, even
easier and just as affordable. For more
information call us or visit our website at

www.eagleware.com

fast, easy, affordable

See us at Wireless Symposium, booth #927

EAGLEWARE 

RF and Microwave Design Software

tel: 770.939.0156 | fax: 770.939.0157

Circle 52

BRIEFS

• K&L Microwave, based in Salisbury, MD, has added e-commerce capabilities to its web site, www.klmi-crowave.com. The upgraded site offers online ordering of many of the company's



stock models, including base station duplexers, tunable filters and harmonic rejection lowpass filters.

• Stanford Microdevices, based in Sunnyvale, CA, has announced the opening of a new design center in Kanata, Ontario, Canada. The facility will house RF design and test capabilities.

• L-3 Communications' Global Network Solutions (GNS) business has opened a new headquarters facility in Reston, VA, as well as regional offices in Dallas, TX, and Atlanta, GA. GNS provides design and management services for satellite, wireless local loop and microwave radio systems.

• Anadigics, based in Warren, NJ, has opened a new remote design center in Newbury Park, CA, providing design and development services for its radio frequency integrated circuit products.

Andrew transverter receives first MMDS certification

Andrew Corporation, through its recently acquired Conifer Corporation subsidiary, has received type certification from the Federal Communications Commission for the Ultraflex[®] two-way customer premise transmit/receive transverter. This certification is the first to be given to an MMDS (Multichannel Multipoint Distribution Service) transverter.

The transverter, one of Andrew's wireless local loop subscriber products, can function as a multi-channel analog and digital video receive unit, while transmitting and receiving data to and from multiple customer premise modems and terminals. A GPS frequency-locked oscillator corrects for signal drift over time and temperature. The FCC type certification covers variable data rates and modulation schemes, allowing service providers to use different wireless cable modems and set-top boxes without certifying the individual brand designs.

Andrew Corporation, based in Orland Park, IL, supplies communications systems equipment and services worldwide.

Stanford Microdevices introduces LDMOS device line

Stanford Microdevices Inc. has announced the availability of a family of high-linearity power transistors based on Laterally Diffused Metal Oxide Silicon (LDMOS) technology, supporting designs for emerging 3G markets.

Suitable for all linear transmitter formats including CDMA and W-CDMA, these devices are fully characterized and tuned for popular communication frequencies from 800 MHz to 2400 MHz with power levels from 10 to 120 Watts. The devices are fabricated with gold metallization and gold bond-wire interconnects, as well as gold-plated packages for higher reliability.

Stanford Microdevices, headquartered in Sunnyvale, CA, supplies radio frequency integrated circuits for the wireless and wired telecommunications markets.

Celeritek launches GaAs process

Celeritek Inc. has announced the availability of a new production-ready InGaP HBT process at the company's facility in Santa Clara, CA. The GaAs process is targeted for high-volume wireless applications and is suited for low voltage (3.0 V) linear power amplifiers. The company is also introducing a family of InGaP HBT amplifier modules.

Celeritek develops GaAs radio frequency integrated circuits for wireless communications.

RF Micro Devices offers new line

RF Micro Devices has introduced the company's first component produced using SiGe HBT technology.

The RF2461 is a CDMA/FM low noise amplifier/mixer 900 MHz downconverter providing excellent

noise figure and linearity performance for dual-mode CDMA/FM cellular applications. Offered in an LPCC-20 4 mm x 4 mm package, the RF2461 is priced at \$1.87 each in quantities of 10,000.

RF Micro Devices, based in Greensboro, NC, provides proprietary RFICs for wireless communications applications.

ABI report: WAP market to boom

Wireless Access Protocol-based handsets will be the next "big thing" in wireless, according to a report from Allied Business Intelligence.

By 2005, one-third of all user handsets will use WAP, the report says, with more than 500 million WAP-based handsets expected to be shipped between 2000 and 2005.

Digital will remain important, the

report says, with the digital/dual-mode handset marketplace to grow at 29 percent a year through 2005. Analog-only users, however, will drop from 34 percent in 1998 to 5 percent by 2005.

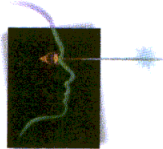
Other wireless access devices will also see growth, but the market for smartphones and handhelds will be relatively small when compared to wireless handsets, the report says.

ABI is an Oyster Bay, NY-based technology research think tank specializing in communications and emerging technology markets.

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.

IC

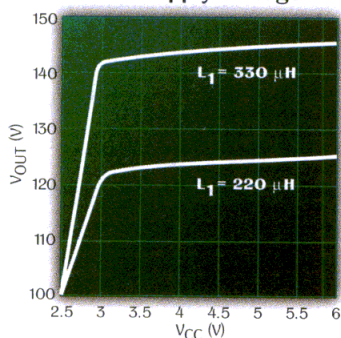
A Quiet Revolution In EL Drivers



Why the TK659xx?

Because it is a brighter and quieter EL driver.

Peak to Peak Lamp Voltage vs. Supply Voltage



Output is independent of variations of input voltage.

Available in 10 lamp frequencies

175 Hz	300 Hz
200 Hz	325 Hz
225 Hz	350 Hz
250 Hz	375 Hz
275 Hz	400 Hz

The new TK659xx series of EL drivers operates with a breakthrough voltage waveform with controlled rise and fall times. This improves efficiency while reducing audible and RF noise.

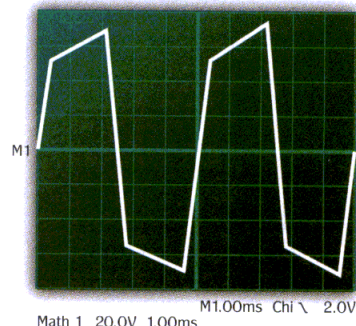
Further noise reduction is achieved with a fixed frequency PWM boost circuit operating above 20kHz. This boost circuit regulates the output independent of variations in battery voltage, to assure consistent brightness and color.

The peak current control of the TK659xx series allows use of Toko's miniature EL coils (D31FU, D32FU, and D52FU) without fear of saturation, while reducing overall circuit space.

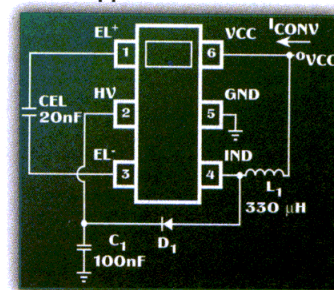
The TK659xx series is housed in a small, SOT-23L package, making it ideal for devices where noise and board space are critical. This includes wireless phones, caller IDs, PDAs, MPEG players, handheld computers, GPS, digital cameras, watches, clocks, radios, calculators, portable instruments, radar detectors — anything with an EL panel.

Call us or check our web site for details on the TK659xx.

TK659xx Voltage Waveform Controlled Rise and Fall Times



Application Circuit



Note: L₁=Toko Low Profile D52FU

TOKO

IC Toko™

Toko America, Inc.
1250 Feehanville Drive, Mt. Prospect, IL 60056
1-800-PIK-TOKO Fax: 847-699-1194
<http://www.ICToko.com>

Circle 69

See us at Wireless Symposium, booth #538

BUSINESS AND FINANCE

Signal Technology acquires Advanced Frequency Products

Signal Technology Corporation has announced that it has acquired privately-held Advanced Frequency Products (AFP), based in Andover, MA. Financial terms of the transaction were not disclosed.

Signal Technology, based in Danvers, MA, produces electronic components and systems for telecommunications. AFP provides high-frequency millimeter wave and microwave transceivers for the broadband wireless communications infrastructure market.

Motorola NSS receives contracts

Motorola Inc.'s Network Solutions Sector has received two new contracts to provide cellular network equipment for systems in Israel and Ghana.

Under a contract with Pele-Phone Communications, Motorola NSS will expand the company's existing CDMA digital cellular network in Israel with additional infrastructure equipment. The contract is valued at \$122 million.

A separate agreement with Ghana Telecommunications Company Ltd. calls for the installation of a new GSM digital cellular network in Ghana. The contract is worth \$41.5 million.

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

Adaptive Broadband signs contract

Adaptive Broadband™ Corporation has signed a \$225 million, five-year contract to provide its AB-Access fixed wireless broadband equipment to Telecom Wireless Corporation. Adaptive Broadband, based in Sunnyvale, CA, is a data networking solutions company developing technology for the deployment of broadband wireless communication over the Internet.

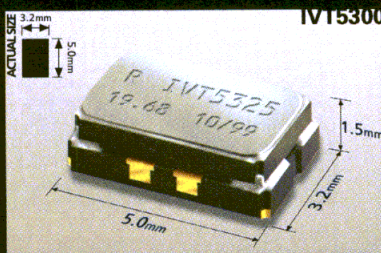
Giga-tronics awarded contract

The Instrument Division of Giga-tronics Inc., based in San Ramon, CA, has received a follow-on order for VXI synthesizers and down converters from ManTech Test Systems Inc., of Chantilly, VA. The contract is worth \$3.3 million.

Giga-tronics' Instrument Division manufactures instruments and automatic test systems for wireless communications. ManTech Test Systems is a subsidiary of ManTech, which provides automatic test equipment to the defense and commercial markets.

Rakon's integrated TCXO's just got smaller!

The leaders in crystal technology have taken miniaturization even further. Featuring outstanding temperature stability performance, and no frequency perturbations, at low cost.



The minute IT5300 and IVT5300 have a footprint of only 5x3.2mm and retain all the features of the IT/IVT7500 series oscillators.

The 5300 series employ an analogue integrated circuit (IC) for temperature compensation. And like our 7500 series this IC has no erratic frequency jumps, unlike previous digital compensation attempts.

The unit can operate on any supply voltage between 2.7 and 5.5 volts, and consumes only 1.2mA typically. Clipped sinewave frequency output ranges from 14MHz to 26MHz are available. Standard frequencies available for sample deliveries include: 19.44MHz, 19.68MHz, 16.8MHz, and 26MHz.

FREQUENCY CHARACTERISTICS		Min	Max	Unit
Parameter	Test Condition			
Frequency range	Frequency range available	14.0	26.0	MHz
Frequency calibration	Frequency at 25 deg. C. (+/- 0 deg. C. from Note 1)	0.3	1.0	± ppm
Frequency stability over temperature	Referenced to frequency reading at 25 deg. C. Temp. varied at rate of 2 deg. C. per minute (Note 2)	1.0	15.0	± ppm
Temperature range	The operating temperature range over which the frequency stability is measured (Note 3)	40.0	85.0	Degrees C
Frequency perturbations	Peak to peak amplitude of frequency perturbation within the operating temperature range (Note 1)	0.1	1.0	± ppm
Frequency drift	Maximum 24 hours reading every 7 degrees C. over the operating temp. range (Note 1)	0.08	1.00	± ppm/deg. C
Short Term Variance	1 second Std. (Note 1)	0.2	1.0	± ppm
Long term stability	Frequency drift over 1 year (Note 1)	0.5	1.0	± ppm
POWER SUPPLY				
Supply voltage	Able to operate on any voltage between Min & Max values	2.7	5.5	V
Current	At Min. supply voltage	1.2		mA
CONTROL VOLTAGE				
Control voltage range	Determined by model without (Note 4)	0.75	2.75	V
Frequency tuning	Frequency shift from Min. to Max. control voltages (Note 4)	0.0	10.0	± ppm
Frequency tuning linearity	Deviation from straight line (Note 1)	0.0	70.0	%
Port input impedance		50.0		± Ohms
OSCILLATOR OUTPUT				
Output waveform	Clipped sinewave			
Output voltage level	At min. supply voltage	1.0	2.0	V
SSB PHASE NOISE	Measured at fundamental or open suspension			
SSB Phase noise density	100% offset	-40.0	-45.0	dBc/Hz
SSB Phase noise density	10% offset	-40.0	-45.0	dBc/Hz
SSB Phase noise density	100% offset	-100.0	-105.0	dBc/Hz
SSB Phase noise density	10% offset	-100.0	-105.0	dBc/Hz
SSB Phase noise density	10% offset	-100.0	-105.0	dBc/Hz
MANUFACTURING INFORMATION				
Warranty and return	At 100% without approval resulting process and normal solder reflow processes.			
Shipping description	Type and reel (20000s max)			
SPECIFICATION NOTES				
Note 1	The Max. value is the standard specification. Values down to Min. are available.			
Note 2	A Max. frequency stability over the temperature is required to be specified.			
Note 3	The operating temperature range needs to be specified.			
Note 4	Control voltages provided. The control range is not between 0.0V to 2.5V.			
Note 5	The value is required to be specified between Min & Max.			

Product can be found at: http://www.rakon.com/models/browse-model?model_id=1&model_type=0

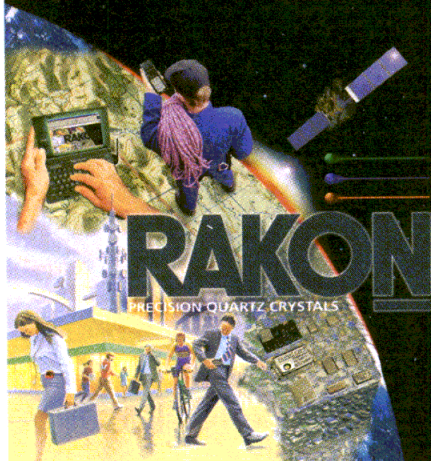
When size does matter, Rakon continues to lead the way - providing the TCXO of choice for cellular phones, wireless modems, two way pagers and many other wireless applications.

RAKON LIMITED

1 Pacific Rise, Mt Wellington,
Private Bag 99943, Newmarket,
Auckland, New Zealand.
Fax: +64-9-573 5559 Phone: +64-9-573 5554

View and download product information from our Web site or e-mail: sales@rakon.com

www.rakon.com



MATCHLESS STABILITY

Voltronics J Series Chip Trimmer Capacitors



Actual Size 

Any model,
up to
50,000 pieces...
Stock to 4
weeks!

- Stability of $\pm 1\%$
- Usable to over 1 GHz
- Designed for reliable vacuum pickup
- Capacitance ranges from 0.4 - to 40 pF

The J Series delivers unexcelled stability for demanding applications, from wireless base stations to CATV amplifiers, cordless phones to pagers, heart monitors to wireless microphones.

To get all of the details,
visit our web site at
www.voltronicscorp.com.

The Trimmer Capacitor Company

Voltronics 

INTERNATIONAL CORPORATION

100 Ford Road • Denville, NJ 07834

973.586.8585 • FAX : 973.586.3404

e-mail: info@voltronicscorp.com

BUSINESS AND FINANCE

Crown Castle, One 2 One sign contract for mobile network in Northern Ireland

Crown Castle International Corp.'s UK subsidiary, Crown Castle UK Limited, and wireless service provider One 2 One have signed a \$160 million agreement for a new mobile network in Northern Ireland.

Crown Castle will provide a turnkey solution for One 2 One, including all cell planning, acquisition, design, build, operation and maintenance for the mobile network. The agreement will run for an initial term of eleven years. Crown Castle already operates approximately 100 tower sites in Northern Ireland and these sites will provide the backbone for the new network. One 2 One is the world's first all digital mobile network and is a wholly owned subsidiary of Deutsche Telekom.

Crown Castle International Corp., based in Houston, TX, provides communication sites and wireless network services as well as related infrastructure and network support services, in the United States and the United Kingdom. One 2 One, the world's first all digital mobile network, is a wholly owned subsidiary of Deutsche Telekom.

L-3 purchases training division from Raytheon

L-3 Communications has acquired Raytheon's Training Devices and Training Services (TDTS), headquartered in Arlington, TX, and Binghamton, NY. The transaction is valued at \$160 million.

TDTS provides high fidelity, fully integrated simulator training products, such as flight simulators and pilot training systems for aircraft and helicopters, combat vehicle trainers, and training support services. Its products and services are used by U.S. and foreign military agencies and prime contractors.

L-3 Communications supplies secure communication systems and products, microwave components, avionics and ocean systems and telemetry, instrumentation, space and wireless products.

Proxim acquires Wavespan Corporation

Proxim Inc., based in Sunnyvale, CA, has acquired Wavespan Corporation of Mountain View, CA. The transaction is valued at approximately \$14.4 million.

Proxim is a supplier of spread spectrum wireless LAN products to OEMs and wireless solutions providers. Wavespan is a developer of wireless broadband access solutions.

ECI Telecom receives \$20 million order

ECI Telecom Ltd.'s wholly-owned subsidiary, InnoWave ECI Wireless Systems Ltd., has announced a \$20 million order from Atlantic Telecom, a subsidiary of Atlantic Telecom Group PLC, to deliver fixed wireless access solutions in the UK.

Under the agreement, InnoWave's MultiGain Wireless (MGW) systems will be deployed in Atlantic Telecom's new license area in northwest England, as well as its existing operating systems in Scotland. The system uses frequency hopping CDMA technology.

InnoWave ECI Wireless Systems Ltd. provides fixed wireless access systems and wireless local loop (WLL) products and solutions. ECI Telecom, based in Petah Tikva, Israel, provides integrated network solutions for digital communications and data transmission systems.

TSMC, TASM announce merger plans

Taiwan Semiconductor Manufacturing Company (TSMC) and TSMC-Acer Manufacturing Corporation (TASMC) have announced that they have signed an agreement to merge TASMC with and into TSMC. The financial value of the transaction was not disclosed.

TSMC, based in Hsin-Chu, Taiwan, is a semiconductor foundry offering processes including CMOS logic, mixed-mode and BiCMOS.

Wireless Facilities receives new contract

Wireless Facilities Inc., based in San Diego, CA, has signed a three-year contract with Advanced Telecom Corp. to provide network deployment services for the company's build-out of its Internet Protocol (IP) networks. The value of the contract was not disclosed.

Wireless Facilities designs, deploys and manages wireless networks worldwide. Advanced Radio Telecom Corp., headquartered in Bellevue, WA, provides local IP services to metropolitan areas nationwide.

Micronetics receives order for assemblies

Micronetics Wireless Inc., based in Hudson, NH, has announced that its Micronetics/Components Group has been awarded an order from Daimler Chrysler Aerospace to supply microwave integrated assemblies for the European Fighter Aircraft. The value of the agreement was not disclosed.

Micronetics Wireless manufactures broadband test equipment and components, as well as microwave components and subassemblies.

Com-Net acquires Ericsson's radio systems business

Com-Net Critical Communications, based in Pittsburgh, PA, has acquired Ericsson Inc.'s Private Radio Systems operations, located in Lynchburg, VA. The new company will be called Com-Net Ericsson Critical Radio Systems. The value of the transaction was not disclosed.

Com-Net provides radio network solutions for the public safety and service markets. Ericsson, based in Stockholm, Sweden, provides communications products and services worldwide.

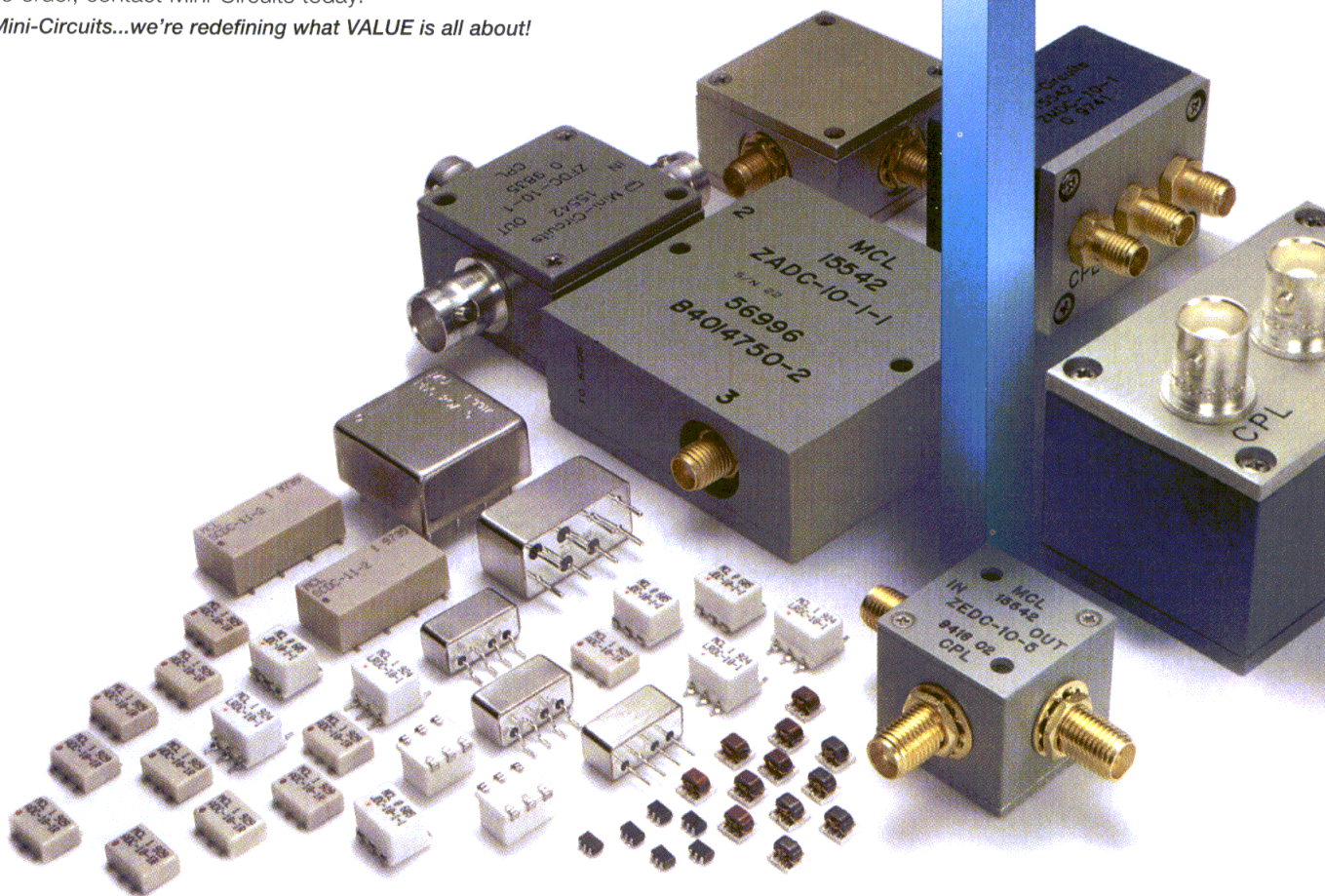
broadband directional couplers

10kHz to 2600MHz 6 to 30dB

Achieve accurate power sampling with high directivity and very little insertion loss using Mini-Circuits surface mount, plug-in, and coaxial directional couplers. Finding the right model for your design layouts is easy with our large, off-the-shelf selection of over 100 models in 6 to 30dB coupling ratios. Choose from broadband 50 and 75 ohm couplers capable of handling input power as high as 25 watts. High performance bi-directional couplers for monitoring forward and reflected power up to 10W are available as well. Now, highly accurate power sampling and value pricing have merged! The result...Mini-Circuits broadband directional couplers.

To order, contact Mini-Circuits today!

Mini-Circuits...we're redefining what VALUE is all about!



Mini-Circuits®

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



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

ISO 9001 CERTIFIED

US 83 INT'L 93

CIRCLE READER SERVICE CARD

F 309 Rev. Org.

DIVERSITY



COMPONENTS

When the crowd wants **variety**,
a true artist delivers.

RFMD has **ready-to-ship** components for
every wireless application. Transceivers,
power amps, quad mods – we've got a
million of 'em – loaded with onboard features
and **designed to perform**.

Special requests? No problem – our
engineers choose from **six process
technologies** to create a custom IC
in tune with your specs.

When you need a **proven performer**,
depend on RFMD. And just wait 'til you
see what we do for an encore . . .

DIVERSITY – it sets us apart.



Proprietary, State-Of-The-Art
RF Integrated CircuitsSM

7628 Thorndike Road
Greensboro, NC 27409-9421

Phone 336.664.1233
Fax 336.664.0454

Mention diversity when contacting us.



www.rfmd.com

TM & © 1999, RF Micro Devices, Inc.

Circle 16

**See us at Wireless Symposium, booth #110
and CTIA, booth # 6715**

Phase Lock Loop Stability Analysis

This article presents a review of PLL transfer functions with attention to the conditions required for steady-state stability

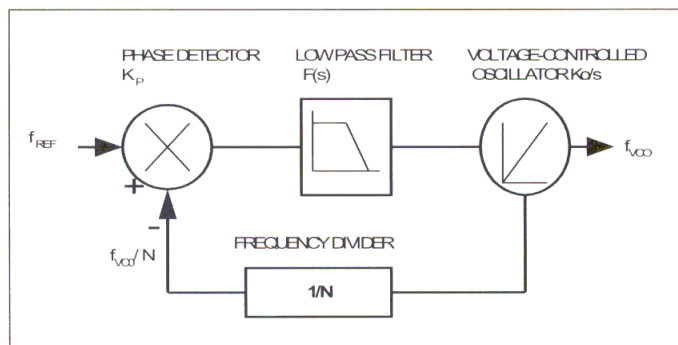
By Arun Mansukhani
Motorola, Inc.

Phase lock loops (PLLs) are key components of modern communication systems. Frequency synthesizers, FM demodulators and clock recovery circuits are some applications of PLLs. An important aspect of PLL design is the steady state stability of the loop. This article examines this aspect of PLL design, particularly the effect of loop filter on PLL stability.

PLLs are negative feedback control systems comprising of a phase-frequency detector (PD), a loop filter, a voltage-controlled oscillator (VCO) and a frequency divider. The function of the PD is to generate an output waveform based on the difference in phase (and frequency) between the input signal and a fixed reference. This is followed by a loop filter, normally a lowpass filter (LPF), whose function is to filter out any high frequency harmonics from the phase detector and to provide a DC signal output; followed by a VCO that generates a high frequency signal controlled by the DC input signal. A sample of the VCO output signal is then fed back to the input of the PD as the input waveform and compared in phase (and frequency) to a fixed reference. In a locked condition, the PLL output signal is locked in phase (and frequency) to the fixed input reference, i.e. the output phase has a fixed differential from the input phase.

According to control loop theory, the transfer function of the PLL is (assuming $N = 1$):

$$\begin{aligned} (\theta_1 - \theta_0)K_P F(s)K_0 / s &= \theta_0 \\ (1 + K_P F(s)K_0 / s)\theta_0 &= \theta_1 K_P F(s)K_0 / s \end{aligned} \quad (1)$$



▲ Figure 1. Block diagram of a PLL.

$$\begin{aligned} T(s) = \frac{\theta_0}{\theta_1} &= \frac{K_P F(s)K_0 / s}{(1 + K_P F(s)K_0 / s)} = \\ \frac{K_P F(s)K_0}{s + K_P F(s)K_0} &= \frac{G(s)}{1 + G(s)} \end{aligned}$$

where

$T(s)$ is the closed loop PLL transfer function in the frequency domain (θ_1 and θ_0 being the input and output signal respectively),

$G(s) = K_P F(s)K_0 / s$ is the open loop transfer function (complex) of the PLL,

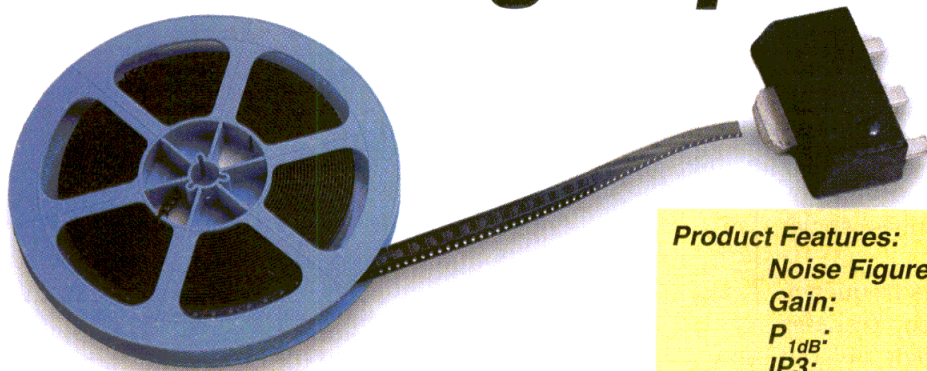
K_P is the transfer function of the phase detector in Volts/ Hz,

K_0 / s is the transfer function of the VCO in Hz/ volts, and

$F(s)$ is the transfer function of the loop filter.

Note that this is the transfer function of the PLL when the loop is closed. The block diagram of the PLL is shown in Figure 1.

Now in Production Packaged pHEMTs!



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.

If this isn't surprising enough, call (800) 737-6937 and ask about our volume pricing available through Richardson Electronics Distribution, in quantities up to 10,000 each.

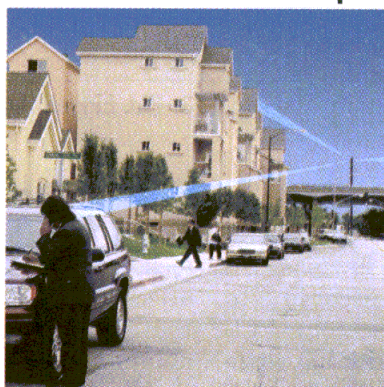
Model Number	Noise Figure	Gain	P_{1dB}	IP3
LP750SOT89	0.7 dB*	14 dB	24 dBm	40 dBm
LP1500SOT89	0.5 dB*	16 dB	27 dBm	44 dBm
LP3000SOT89	0.5 dB*	15 dB	29 dBm	46 dBm

*with optimum Noise Figure biasing

Base Stations



Wireless Local Loop



W-CDMA/IMT 2000



Visit our website, <http://www.FiltronicSolidState.com>



To get your CD-ROM featuring complete information on Filtronic Solid State products,



email: sknight@filss.com
or fax (408) 970-9950

3251 Olcott Street, Santa Clara, CA 95054-3095 / (408) 988-1845 / FAX (408) 970-9950

Before we examine the PLL closed loop transfer function in detail, it is important to examine the stability of the PLL. A PLL is unstable when the denominator of the closed loop transfer function is equal to zero. For this to occur,

$$1 + G(s) = 0$$

$$G(s) = -1, \text{ or} \quad (2)$$

$$G(s) = 0 \text{ dB @ } \angle -180^\circ \text{ (magnitude/phase angle)}$$

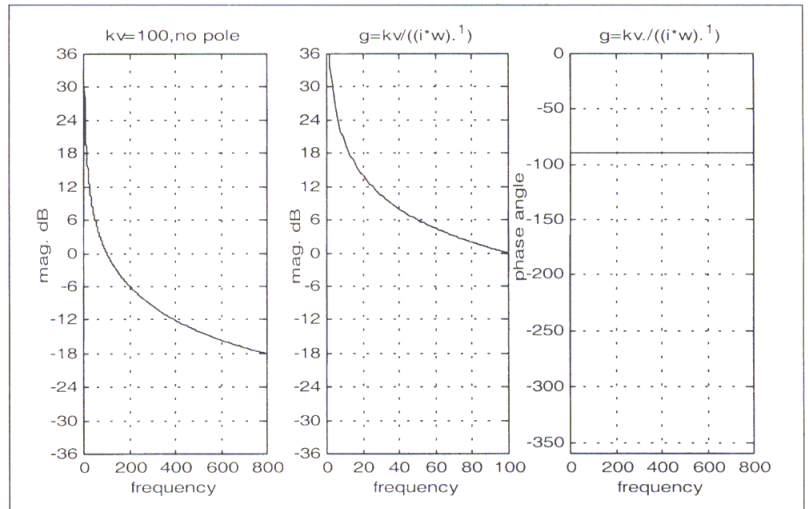
Hence, the PLL is unstable at the frequency where the magnitude of the open loop transfer function is unity and the phase angle is -180 degrees. Because stability is an important aspect of any PLL design, the condition of unity open loop gain and a phase angle of 180 degrees must be avoided.

PLL response with no loop filter

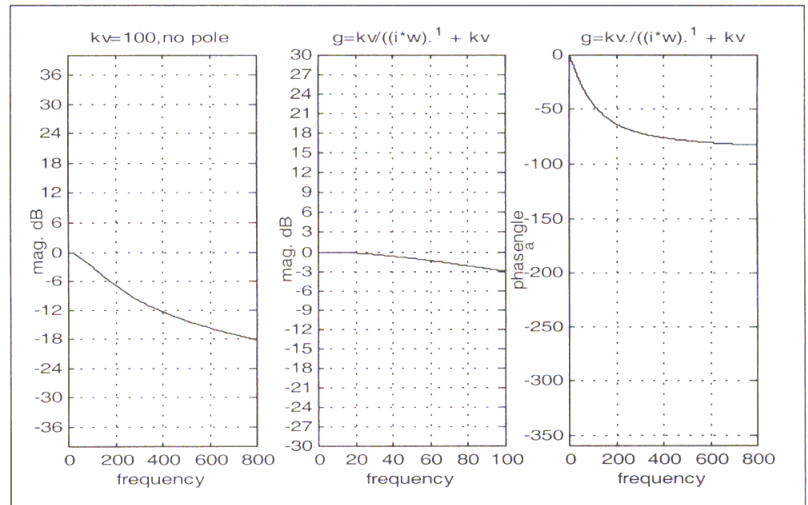
To further understand the PLL transfer function response and stability, let us examine the case when there is no loop filter. With $F(s) = 1$ (i.e. no loop filter), the PLL closed loop transfer function becomes (3),

$$\frac{\theta_0}{\theta_I} = \frac{K_P F(s) K_0 / s}{(1 + K_P F(s) K_0 / s)} = \frac{K_P K_0}{s + K_P K_0}$$

which is the transfer function of a LPF with DC gain of unity and a 3 dB cutoff frequency of $K_P \times K_0$. Therefore, an increase in the DC gain of the phase detector and/or the VCO results in a wider loop, which in turn results in higher phase noise in the PLL. Also, the open loop gain has a slope of 6 dB per octave or 20 dB per decade for all frequencies. The phase angle is always -90 degrees at all frequencies. Hence, with no low-pass filter in the loop, the PLL is always stable, according to the stability criteria. But the main drawback of a PLL design with no loop filter is that the designer has little or no control over the loop response. Figures 2 and 3 show a plot of the open and closed loop transfer function (gain and phase vs. frequency). The plot was done on MatLab using the absolute value function (called *abs*) to compute the magnitude of the transfer function and the angle function (called *angle*) to compute the phase angle. Also, the plot commands — plot (w, abs) and plot (w, angle) — were used to plot magnitude and phase vs. frequency.

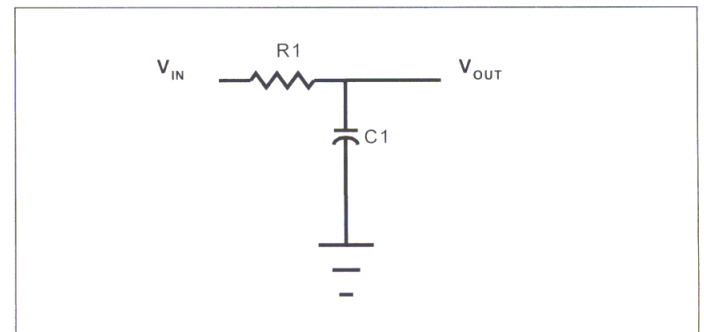


▲ Figure 2. PLL open loop transfer function with no loop filter.



▲ Figure 3. PLL closed loop transfer function with no loop filter.

function of a LPF is to filter out any high-frequency harmonics in the loop that might cause the loop to go out of lock, and also to stabilize the loop. Adding a LPF also affects the loop response including parameters such as the loop time response τ_r , loop bandwidth ω_C and the damping factor ∂ of the loop. Figure 4 shows the low



▲ Figure 4. Single pole loop filter.

PLL with a single loop filter

In most PLL designs, a low pass filter is used. The

600S

ULTRA-LOW ESR

MICROWAVE CAPACITORS

new
from
ATC

- LOWEST ESR IN CLASS – TYPICALLY 80 mΩ @ 1 GHz
- HIGHEST WORKING VOLTAGE FOR 0603 NPO
- BROADEST VALUE RANGE
- LOW COST, WITH THE SUPERIOR PERFORMANCE AND RELIABILITY YOU EXPECT FROM ATC

INTRODUCING ATC'S 600S ULTRA-LOW ESR CAPACITORS, DESIGNED AROUND RF AND MICROWAVE APPLICATIONS TO SUPPORT REQUIREMENTS WHERE LOW LOSS AND HIGH PERFORMANCE ARE PARAMOUNT. FOR USE IN:

- CELLULAR BASE STATION EQUIPMENT
- HIGH Q FREQUENCY SOURCES
- BROADBAND WIRELESS SERVICES
- SATCOM
- POINT-TO-POINT / POINT-TO-MULTIPOINT RADIO

to learn more

Click here

www.atceramics.com

American
Technical
Ceramics

FOR ATC'S
EUROPEAN
SALES OFFICES,



SEE OUR WEBSITE

SPECIFICATIONS

ATC SERIES	600 S
CASE SIZE:	0603
CAP. RANGE:	UP TO 100 pF
WVDC:	250 V
ESR @ 1 GHz:	80 mΩ TYP.
DIELECTRIC:	NPO
MARKING:	EIA CODE
PACKAGING:	TAPE & REEL PLUS OPTIONS
OPTIONS:	SPECIAL TESTING & PACKAGING

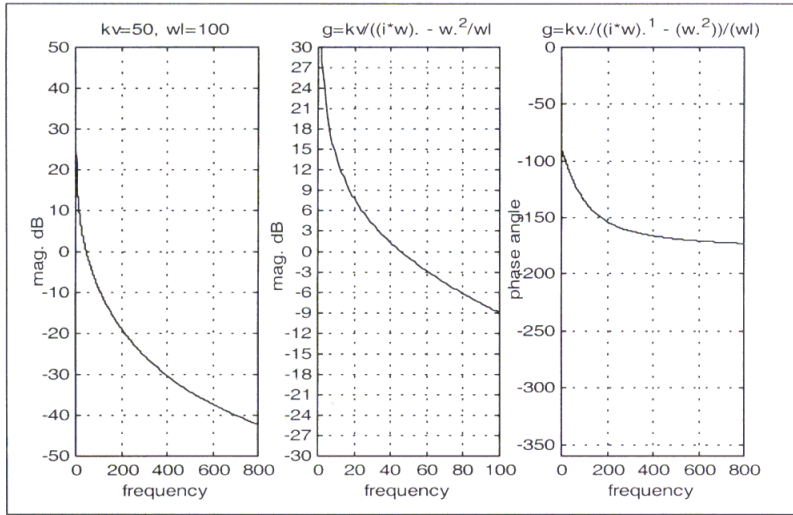
PHONE: 516-622-4700 • FAX: 516-622-4748 • E-MAIL: SALES@ATCERAMICS.COM

ISO 9002
REGISTERED
COMPANY

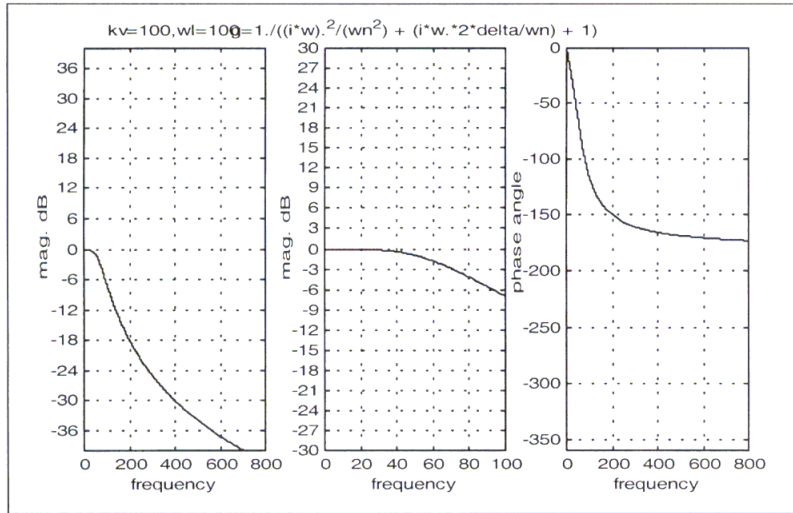


Circle 50

See us at Wireless Symposium, booth #732



▲ Figure 5. PLL open loop response with single pole LPF.



▲ Figure 6. PLL closed loop response with single pole LPF.

pass filter that is commonly used in PLL designs. The filter is a one pole low-pass filter with a 3 dB cutoff frequency at ω_L .

Therefore, in this case,

$$F(s) = \frac{1}{s / \omega_L + 1} \quad (4)$$

Substituting equation 4 in equation 1 gives

$$T(s) = \frac{\theta_0}{\theta_I} = \frac{K_P F(s) K_0 / s}{1 + K_P F(s) K_0 / s} = \frac{K_V / s(s / \omega_L + 1)}{1 + \frac{K_V}{s(s / \omega_L + 1)}} = \frac{1}{(s^2 / \omega_N^2) + s(2\delta / \omega_N) + 1} \quad (5)$$

where

$$\begin{aligned} K_V &= K_P K_0 \\ \omega_N &= (K_V \omega_L)^{1/2} \\ \delta &= \omega_N / (2K_V) \end{aligned}$$

Using a low-pass filter with a cutoff frequency of ω_L , the PLL closed loop response is a 2nd order low-pass filter transfer function, centered at the VCO frequency. A characteristic of the second order low pass response is that the slope of the filter drops at a rate of 12 dB/octave. The term ω_N is defined as the natural frequency of the loop and the term δ is defined as the damping factor of the loop. Using equation 5 we can derive ω_C , which is

$$\omega_C = \omega_N \left(1 - 2\delta^2 + (2 - 4\delta^2 + 4\delta^4)^{1/2} \right)^{1/2}$$

for $\delta < 1$

ω_C is the 3 dB bandwidth of the PLL. Knowing ω_C , we can determine the time it takes for the PLL output to rise to 90 percent of its final value, which is approximately

$$\tau_r = 2.2 / \omega_C$$

Therefore, given the cutoff frequency ω_L of the low pass filter and the values of K_P and K_0 , we can determine the natural frequency ω_N of the loop, and subsequently determine the PLL loop bandwidth ω_C . Knowing this, we can then calculate the time τ_r it takes for the PLL to settle to its final frequency value.

In order to determine the stability of the loop with a single pole low-pass filter in the loop, we must examine the open loop transfer function of the PLL. As stated before, the open loop transfer function is given by the function $G(s)$ and is equal to:

$$G(s) = K_P F(s) K_0 / s = K_P K_0 / s(s / \omega_L + 1) = \frac{K_V}{s(s / \omega_L + 1)} \quad (6)$$

The open loop transfer function has two poles — one at DC and the other at ω_L . Note that at every pole, the gain slope drops at a slope of 6 dB per octave. The gain at DC is infinite; as the frequency increases, the magnitude of the transfer function drops at a slope of 6 dB per octave (due to the presence of the pole at DC). When the frequency reaches ω_L , the gain drops at a slope of another 6 dB per octave (a total slope of 12 dB per octave after

When your system designs call for high performance, **LOW PROFILE**, low cost, frequency **SYNTHESIZERS**, look into Synergy Microwave's JPLH & JPLL series of frequency synthesizers.

Available in surface mount packages, standard models cover the frequency range of 1000 to 2500 MHz and come in optimized signal bandwidths.

Fast switching speeds and low spurious reference sidebands are other important

features of these products. Connect these low profile, high performance synthesizers to a stable external reference source and you are ready to go.

For additional information, contact Synergy's Sales and Applications Team:

Synergy Microwave Corporation

201 McLean Boulevard, Paterson, NJ 07504

Phone: (973) 881-8800 Fax: (973) 881-8361

E-mail: sales@synergymw.com

World Wide Web: www.synergymw.com

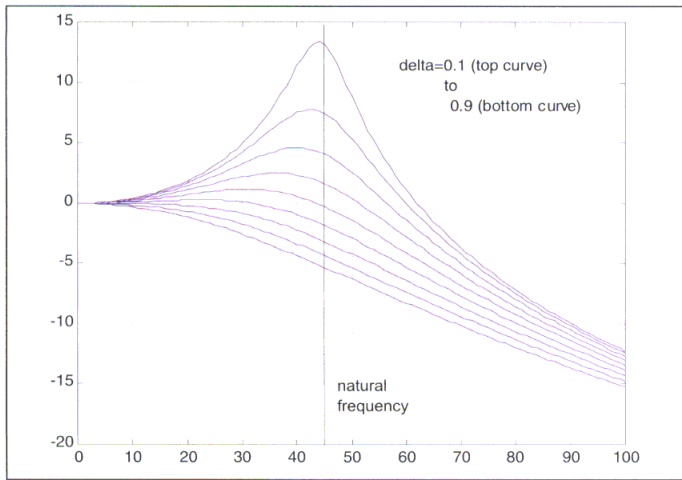
SYNTHESIZERS



SYNERGY[®]
MICROWAVE CORPORATION

Circle 15

See us at Wireless Symposium, booth #1209



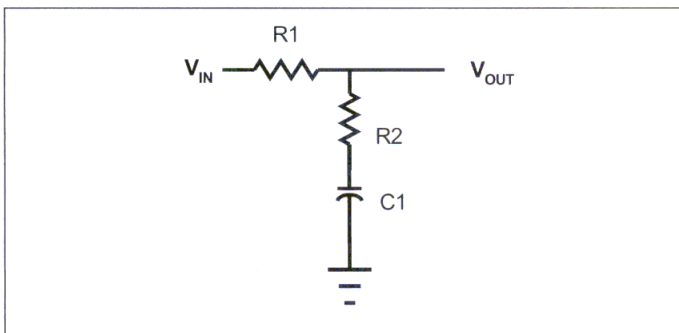
▲ **Figure 7. Closed loop gain response vs. frequency for different damping factors (ζ).**

two poles). The PLL is unstable at the frequency where open loop gain crosses the unity gain line at a slope of 12 dB per octave and the phase is -180 degrees. This condition can be observed by plotting the open loop gain and phase response using MatLab. The condition of instability can be avoided by the selection of the pole frequency of the loop filter. As the pole frequency ω_L decreases, the open loop gain intersects the unity gain axis at 12 dB/octave, the phase angle approaches -180 degrees and the PLL becomes unstable. The PLL approaches instability. This can be observed either by decreasing ω_L while observing the gain and phase response on Matlab or by examining the phase response of the open loop transfer function, which is

$$\phi = -\tan^{-1} - (\omega_L/\omega)$$

Clearly, as ω_L decreases, the phase angle approaches -180 degrees.

One disadvantage of using a single pole filter is that both the closed loop bandwidth and the damping factor of the closed loop response of the PLL depend on the loop filter bandwidth. The designer cannot independently set the loop bandwidth without affecting the amount of transient overshoot. This deficiency can be



▲ **Figure 8. Pole-zero filter.**

easily overcome if a pole-zero loop filter is used. See Figures 5 and 6 for the open and closed loop response of the PLL with a single pole loop filter.

When designing a PLL, it is important to choose the damping factor such that the loop time response has very little overshoot. The percent of overshoot is defined as the time it takes for a PLL to settle at a given frequency. A high percent overshoot can cause the loop to go out of lock. Figure 7 is a plot of the closed loop gain response vs. frequency for different values of damping (from $\zeta = 0.1$ to 0.9 in increments of 0.1 , 0.707 being the design goal).

PLL response with a pole-zero loop filter

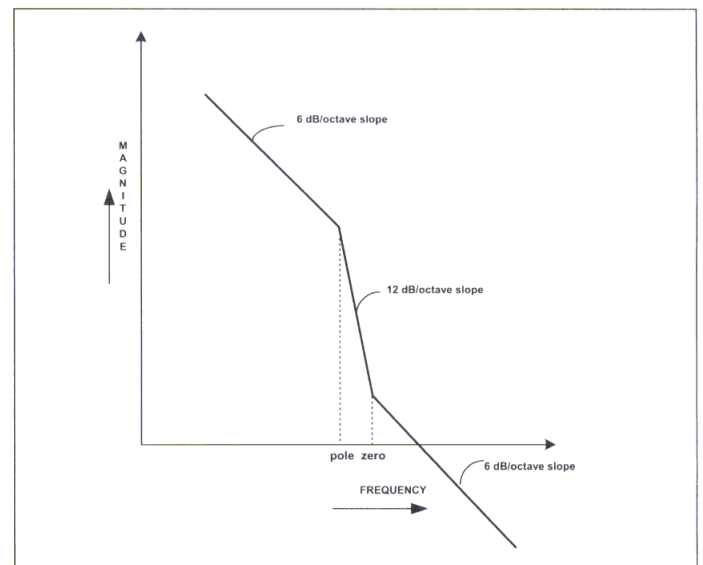
Another way to control the loop response is by using a pole-zero filter in the PLL (see Figure 8). A pole-zero filter is a low pass filter with a pole frequency ω_p and a zero frequency ω_z . The addition of a pole in the transfer function causes the transfer function slope to drop at a rate of 6 dB per octave whereas the addition of a zero in the PLL transfer function has the opposite effect. For example, the addition of a zero frequency increases the slope by a 6 dB/octave. This phenomenon is illustrated in Figure 9.

The pole-zero filter transfer response is given by

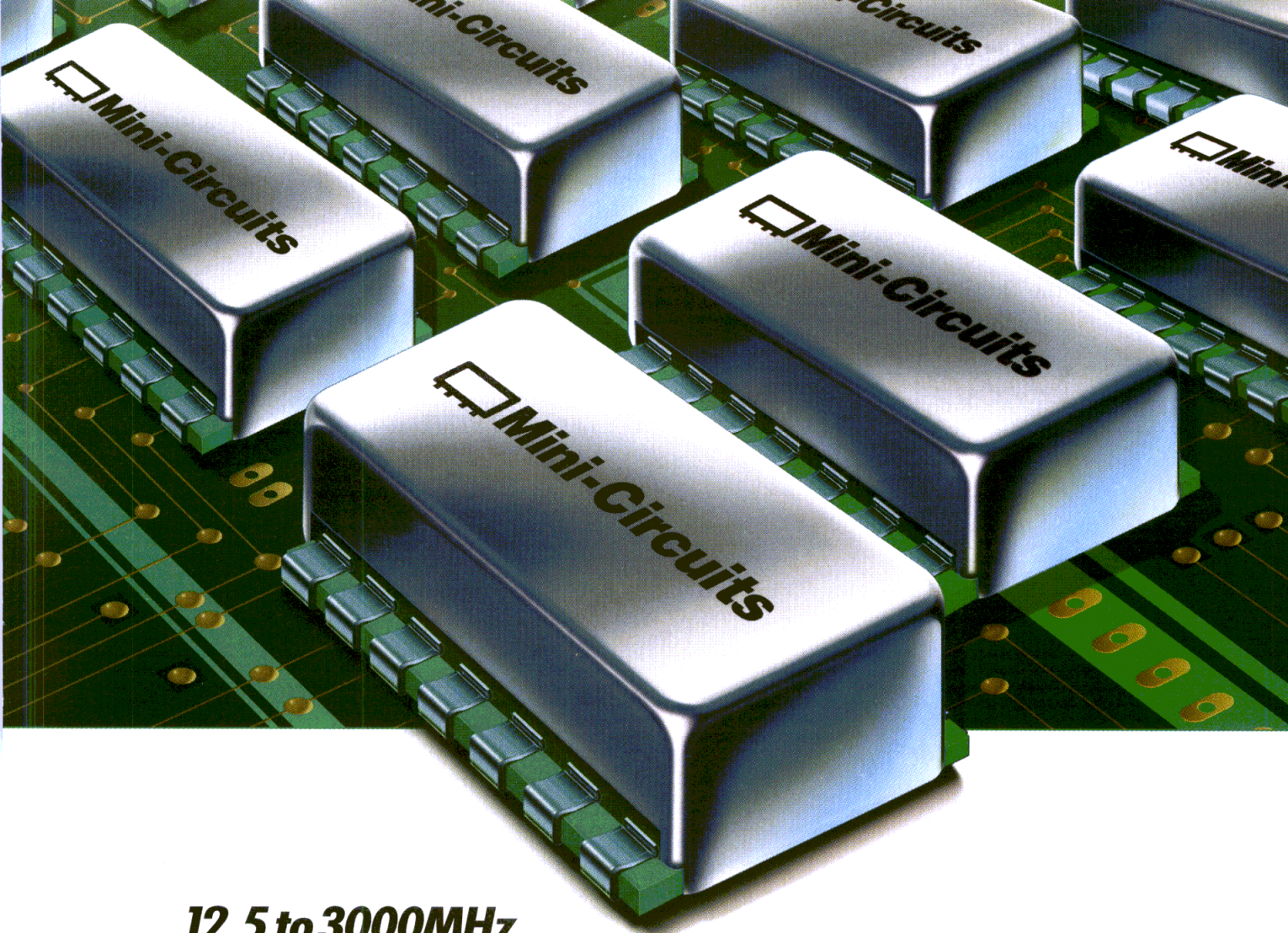
$$F(s) = \frac{s/\omega_z + 1}{s/\omega_p + 1} \quad (7)$$

where ω_z is the zero frequency and ω_p is the pole frequency. The open loop transfer function is:

$$G(s) = \frac{K_V F(s)}{s} = \frac{K_V (s/\omega_z + 1)}{s(s/\omega_p + 1)} \quad (8)$$

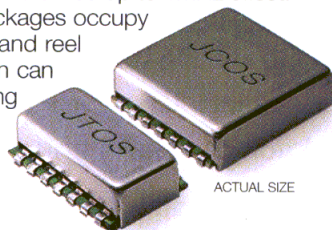


▲ **Figure 9. PLL open loop gain response with a pole-zero loop filter.**



12.5 to 3000MHz SURFACE MOUNT VCO's from \$13⁹⁵

Time after time, you'll find Mini-Circuits surface mount voltage controlled oscillators the tough, reliable, high performance solution for your wireless designs. JTOS broadband models span 12.5 to 3000MHz with linear tuning characteristics, low -120dBc/Hz phase noise (typ. at 100kHz offset), and excellent -25dBc (typ) harmonic suppression. JCOS low noise models typically exhibit -132dBc/Hz phase noise at 100kHz offset, and phase noise for all models is characterized up to 1MHz offset. Miniature J leaded surface mount packages occupy minimum board space, while tape and reel availability for high speed production can rocket your design from manufacturing to market with lightning speed. Soar to new heights...specify Mini-Circuits surface mount VCO's.



Mini-Circuits...we're redefining what VALUE is all about!

JTOS/JCOS SPECIFICATIONS

Model	Freq. Range (MHz)	Phase Noise (dBc/Hz) SSB@ 10kHzTyp.	Harmonics (dBc) Typ.	V _{tune} ** 1V to:	Current (mA) @+12V DC Max.	Price Sea. (5-49)*
JTOS-25	12.5-25	-115	-26	11V	20	18.95
JTOS-50	25-47	-108	-19	15V	20	13.95
JTOS-75	37.5-75	-110	-27	16V	20	13.95
JTOS-100	50-100	-108	-35	16V	18	13.95
JTOS-150	75-150	-106	-23	16V	20	13.95
JTOS-200	100-200	-105	-25	16V	20	13.95
JTOS-300	150-280	-102	-28	16V	20	15.95
JTOS-400	200-380	-102	-25	16V	20	15.95
JTOS-535	300-525	-97	-28	16V	20	15.95
JTOS-765	485-765	-98	-30	16V	20	16.95
JTOS-1000W	500-1000	-94	-26	18V	25	21.95
JTOS-1025	685-1025	-94	-28	16V	22	18.95
JTOS-1300	900-1300	-95	-28	20V	30	18.95
JTOS-1550	1150-1550	-101	-20	***	30	19.95
JTOS-1650	1200-1650	-95	-20	13V	30	19.95
JTOS-1750	1350-1750	-101	-16	***	30	19.95
JTOS-1910	1625-1910	-92	-13	12V	20	19.95
JTOS-1950	1550-1950	-103	-14	***	30	19.95
JTOS-2000	1370-2000	-95	-11	22V	30 (@8V)	19.95
JTOS-3000	2300-3000	-90	-22	***	25 (@5V)	20.95
JCOS-820WLN	780-860	-112	-13	***	25 (@9V)	49.95
JCOS-820BLN	807-832	-112	-24	14V	25 (@10V)	49.95
JCOS-1100LN	1079-1114	-110	-15	***	25 (@8V)	49.95

Notes: *Prices for JCOS models are for 1 to 9 quantity. **Required to cover frequency range. ***Tuning Voltage for JTOS-3000 is 0.5 to 12V, JTOS-1550, JTOS-1750, and JTOS-1950 is 0.5 to 20V, and JCOS-820WLN and JCOS-1100LN is 0 to 20V. For additional spec information and details about 5V tuning models available, consult RF/IF Designer's Guide, our Internet Site, or call Mini-Circuits.

DESIGNER'S KITS AVAILABLE

K-JTOS1 \$149.95 (Contains 1ea. all JTOS models except JTOS-25, -1000W, -1300 to -3000).
K-JTOS2 \$99.95 (Contains 1ea. JTOS-50, -100, -200, -400, -535, -765, -1025).
K-JTOS3 \$114.95 (Contains 2ea. JTOS-1300, -1650, -1910).

Mini-Circuits®

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



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

ISO 9001 CERTIFIED

US 88 INT'L 98
CIRCLE READER SERVICE CARD

F 234 Rev. E

In this case, the location of the pole is always before the zero frequency. Given the pole frequency location, a zero can be placed after the pole (as shown in the Figure 9) so as to avoid the magnitude from crossing the unity gain axis at a slope of 12 dB per octave, and therefore avoiding instability.

To determine the closed loop response, simply plot $T(s)$,

$$T(s) = \frac{\theta_0}{\theta_I} = \frac{K_P F(s) K_0 / s}{(1 + K_P F(s) K_0 / s)} \quad (9)$$

where

$$F(s) = \frac{s / \omega_Z + 1}{s / \omega_P + 1}$$

The transfer function of $T(s)$ is

$$T(s) = \frac{(s\omega_Z + 1)}{s^2 / \omega_P K + (1 + K / \omega_Z)s + 1} \quad (10)$$

where $\omega_N = (\omega_P K)^{1/2}$ and

$$\partial = (.5)(1 / K + 1 / \omega_Z)\omega_N$$

Therefore, selecting the pole frequency sets the natural frequency (and subsequently the loop bandwidth) and selecting the zero (based on the pole location in the

open loop gain response) determines the desired percentage overshoot. Therefore, a pole-zero filter allows the designer to select the loop bandwidth and the damping factor independently and still achieve stability.

Summary

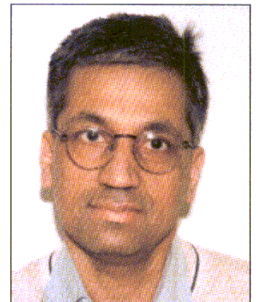
Steady-state stability is an important criterion in PLL design. Stability can be determined by examining the transfer function of the PLL in an open state. As seen, a condition of open loop gain of unity and a phase angle of -180 degrees must be avoided for stable operation of the PLL. This can be accomplished by the proper selection of the loop filter parameters. ■

References

1. J. Smith, *Modern Communication Circuits*, McGraw-Hill, New York.
2. G. Nash, "Phase-Locked Loop Design Fundamentals," Motorola Application Notes (AN-535), Motorola Semiconductors, Phoenix, AZ.

Author information

Arun M. Mansukhani is an RF Systems Engineer with Motorola, Inc. in Piscataway, NJ. He has more than 16 years of experience in RF design. Presently, he is working on next-generation digital cellular system design. Please e-mail him for a copy of the PLL MatLab programs. He may be reached at 732-878-8435 or by e-mail at Arun_Mansukhani-W15392@email.mot.com.



Year 2000 coverage in *Applied Microwave & Wireless*:

Issue	Editorial Topics
March	Filter Design, Satellite Systems, Minaturized Components
April	Frequency Synthesis, Test Equipment, Front-end RFICs
May	Power Transistors, Precision Components, Digital Signal Processing
June	Coax and Waveguide, Broadcasting, Capacitors and Inductors
July	Wireless Data, Impedance Matching, GaAs and SiGe Technologies
August	Wireless Broadband, Oscillator Products, Using Distributors
September	Wireless Chipsets, Noise Analysis, Education Update
October	Couplers and Combiners, Transistors, Circuit Analysis
November	Power Amplifiers, EM Analysis, Filter Technologies
December	Test Methods, Connectors, Space Systems

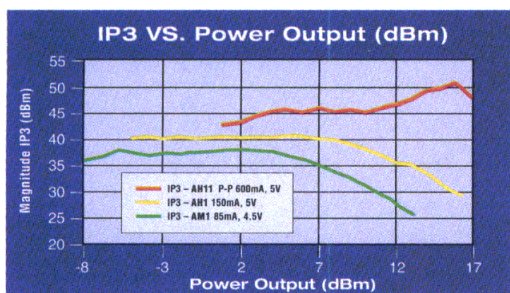
The information you need — engineering techniques, products and technologies!

CRANK IT UP

**ALL NEW WITH
Higher Power, +50dBm IP3**

**LOWER POWER
High Performance**

Need Higher Power? You need Watkins-Johnson's new AH11 amplifier.



WJ High Dynamic Range Amplifiers

Product	Frequency (MHz)	IP3 (dBm, typ.)	P1dB (dBm, typ.)	NF (dB, typ.)	Bias current (mA, typ.)
AH11	250-3000	47	27	3.7	600
AH1	250-3000	41	21	2.9	150
AM1	250-3000	36	18	2.6	75

Ultra high IP3 is what our new AH11 is all about. Combined with a very low noise figure, it's the perfect choice for today's multichannel wireless systems. Drawing only 600mA, the AH11 delivers 17dBm of linear output power with an IP3 of 50dBm. A great price combined with the outstanding linear efficiency makes this versatile amplifier perfect for multiple sockets, reducing overall part count.

Need Lower Power? Both the AH1 and AM1 offer low noise figures which, together with their inherent high IP3, deliver superior performance at the best price in the industry.

For more details, call our toll free number or fax us at 650-813-2447. Email us at wireless.info@wj.com to request data sheets and a complete catalog.

The Communications Edge™



Visit us on the web at
www.wj.com

1-800-WJ1-4401



WATKINS-JOHNSON

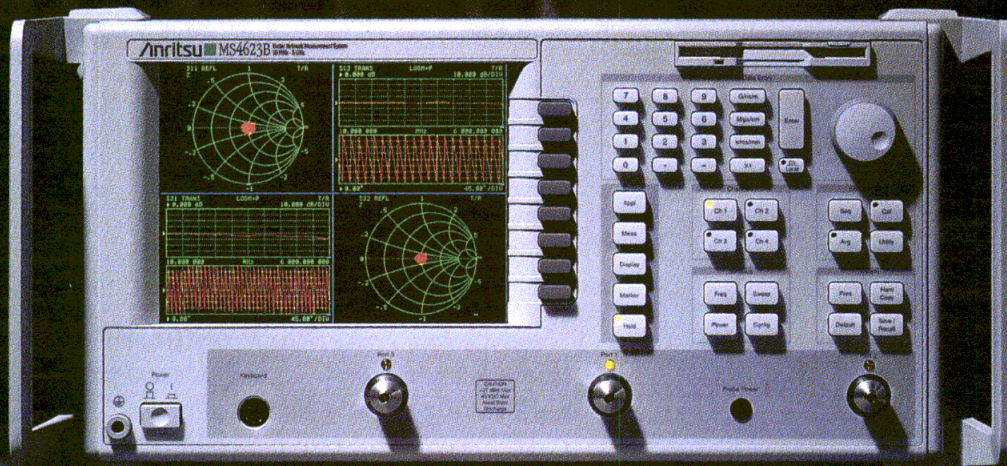
Distributed In U.S.A. by Nu Horizons Electronics: 888-747-6846; Richardson Electronics: 800-348-5580
In Europe call WJ: +44-1252-661761 or your local Richardson Electronics Office: France: (01) 55 66 00 30; Germany: (089) 890 214 0; Italy: (055) 420 10 30 UK: (01753) 733010

Circle 60

See us at Wireless Symposium, booth #732
and CTIA, booth #6415

**Our Competitors
Contend Individual
Instruments Are
Better.**

**At Least, Until
They Build Theirs.**





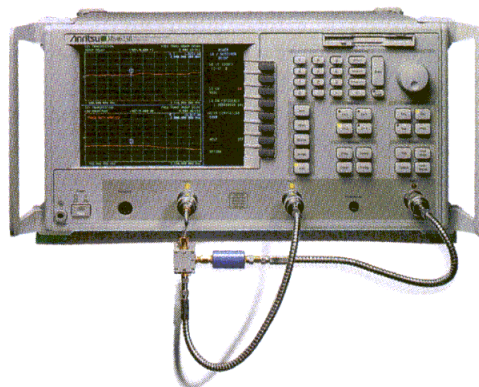
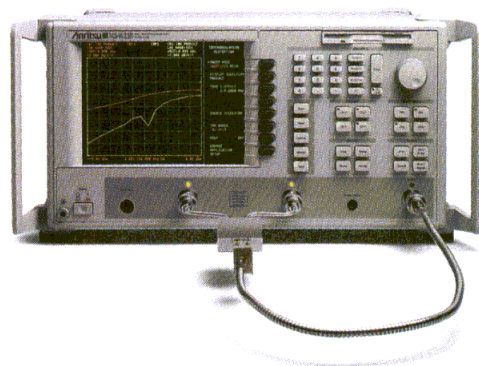
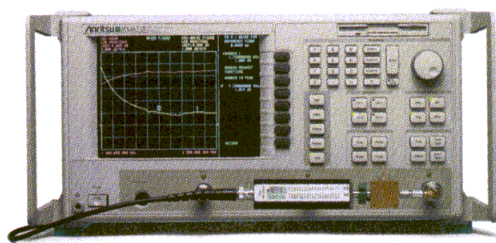
To us, it's the
Scorpion®
Vector Network
Measurement

System. To the competition,
it's a wake-up call. Because
Scorpion is the first VNA
that can do the job of five
different instruments. One
box performing all those
common RF measurements
you need to make. Like
S-parameters. Noise figure.
Intermodulation distortion
(IMD). Harmonics. Gain
compression. And Frequency
Translated Group Delay. All
with a single connection.

Impressed? Visit our website
at www.global.anritsu.com.
Or call 1-800-ANRITSU and
hear even more. The Scorpion
Vector Network Measurement
System. One box that does it
all. It's that simple.

See Scorpion And More At
Wireless Symposium 2000
In Booth #219.

See us at CTIA Booth #2957



Are You Measuring S-Parameters On 3-Port Devices?

Simply connect your diplexer, coupler or circulator and tune any of the nine S-parameters using a correct 3-port calibration. Why settle for multiple 2-port calcs when measuring a 3-port device?

Need To Measure Noise Figure?

Quickly and easily switch applications and begin taking data. Spend your time making measurements, not searching for cables and interconnecting instruments. Combine S-parameter and noise figure measurements and say good-bye to inaccurate results caused by DUT mismatches. Try finding anything else that can do that!

Don't Get Bent Out Of Shape Making Distortion Measurements.

With two integrated synthesizers, Scorpion makes IMD measurements in a flash, eliminating complex test set-ups using VNAs, signal generators and spectrum analyzers. Sweep power and frequency and see the whole picture of your DUT's performance. Of course, you could do this with individual instruments, if you like writing software.

Test Frequency Translation Devices?

Scorpion can accurately characterize your mixers and other FTDs for isolation, match, conversion loss, noise figure and frequency translated group delay (FTGD). All with a single connection to one instrument. Add one external synthesizer and Scorpion can easily orchestrate a complete swept mixer IMD measurement.



Scorpion Vector Network Measurement System

©1999 Anritsu Company Sales Offices: United States and Canada, 1-800-ANRITSU, Europe 44(01582)433200, Japan 81(03)3446-1111, Asia-Pacific 65-2822400, South America 55(21)527-6922, <http://www.anritsu.com>

Anritsu

One world. One name. Anritsu.

An ASIC Driver for GaAs FET Control Components

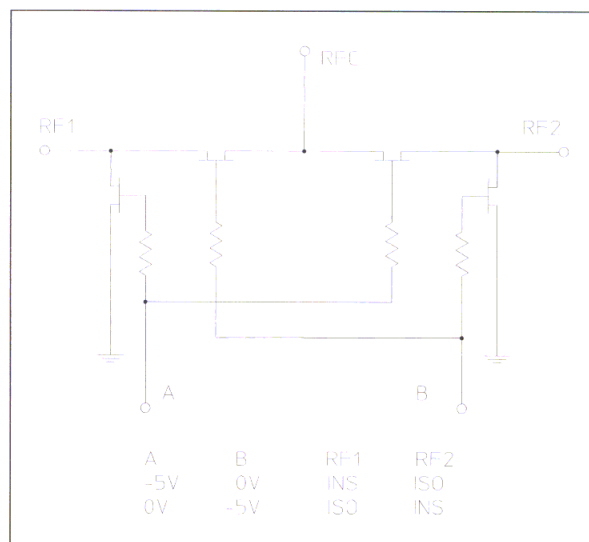
This application note covers driver selection and circuit design for FET switches and attenuators, including non-linear performance as V_{opt} is varied

By Christopher Weigand
M/A-COM, Inc.

The use of a plastic packaged ASIC driver enables the designer to convert from a TTL or CMOS input voltage to the complementary drive signals required for GaAs FET switches and digital attenuators. These ASICs are available in single (SWD-109) and quad (SWD-119 and DR65-0001) channel devices.

GaAs FET control components require complementary drive voltages, because most switching devices have both series and shunt FETs. An example is the case of a SPDT switch, with the series shunt configuration shown in Figure 1. In the "on" arm, the series FET would be on and the shunt FET would be off. When a sufficient negative voltage is applied to the gates of the FETs, they are turned off. This negative voltage gradually becomes lower as the pinch-off voltage of the FETs is lowered for low voltage applications. The negative operating voltage for "off" FETs was typically -7 volts when GaAs control components were first introduced. This standard is now typically -5 volts, with many GaAs control components operating at -3 volts in battery powered devices.

Because the FETs operate in depletion mode, they are "on" when no volts are applied to the gate, and "off" when a negative voltage less than the pinch-off voltage is applied to the gate. It should be noted that GaAs FETs in control components have the same doping in both the source and drain, and that the gate is centrally located between the source and drain. Therefore, the source and drain are interchangeable. Most data sheets show that the control voltage for an on FET is between -0.2 and 0 volts. Due to the increasing use of FETs with lower pinch-off voltages, it is recommended that CMOS logic be used to drive GaAs FET control



▲ Figure 1. A typical SPDT FET switch circuit.

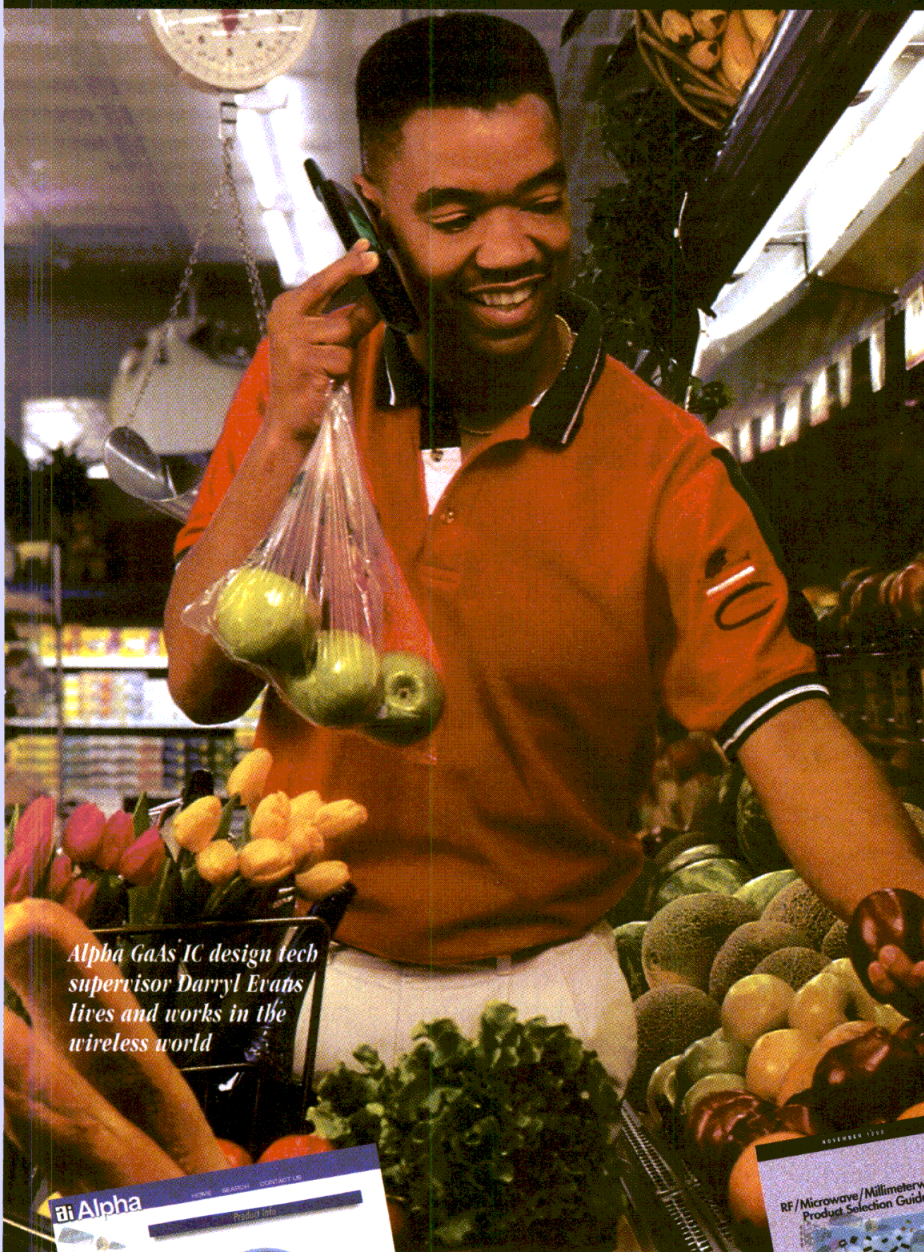
components so that the "low" control voltage for on FETs is between -0.1 and 0.0 volt.

Block diagram of ASIC GaAs FET driver

There are three basic elements in a GaAs FET driver circuit — the TTL input buffer section, a voltage translator, and complementary output buffer stages. The input section has TTL trip points, but it was designed to accept CMOS drive circuitry as well. There is an advantage to driving the ASIC with CMOS in that the positive quiescent current will be under $100 \mu\text{A}$ when a CMOS control is used. ΔI_{cc} is approximately 1.5 mA at V_{cc} of -2.1 volts, which means that the positive bias current will increase when the input logic is a TTL high.

The TTL input stage provides an input to the voltage translator that is either 0 volts or 5

WIRELESS MARKET



Alpha GaAs IC design tech supervisor Darryl Evans lives and works in the wireless world

At Alpha...wireless is our expertise

• **GaAs RF ICs**

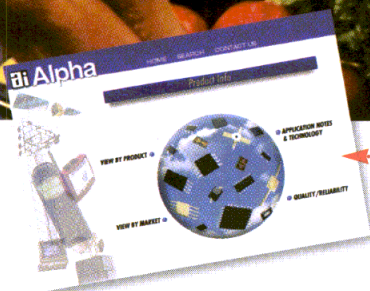
- Power Amplifiers
- Switches
- Attenuators
- Directional Couplers
- Power Dividers

• **DISCRETE SEMICONDUCTORS**

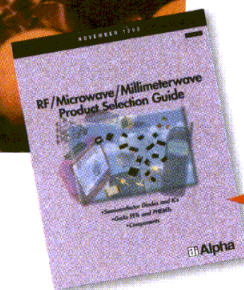
- Varactor Diodes
- PIN Diodes
- Receiving/Schottky Diodes
- Attenuators
- FETs
- Chip Capacitors

• **MILLIMETERWAVE PRODUCTS**

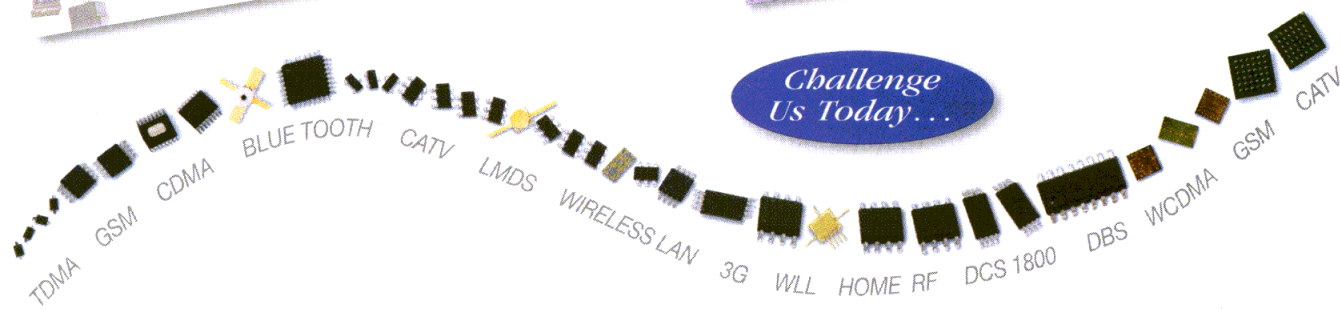
- Amplifiers (LNA, Power)
- Mixers
- Attenuators
- Switches
- Control Products



For the latest new products & technology
www.alphaind.com



GaAs RF ICs
Discrete Semiconductors
Millimeterwave Products
Register on our web site or call today for your Alpha catalogs!



Challenge Us Today...

CALL OR SURF TODAY
781-935-5150 Dial "0" www.alphaind.com

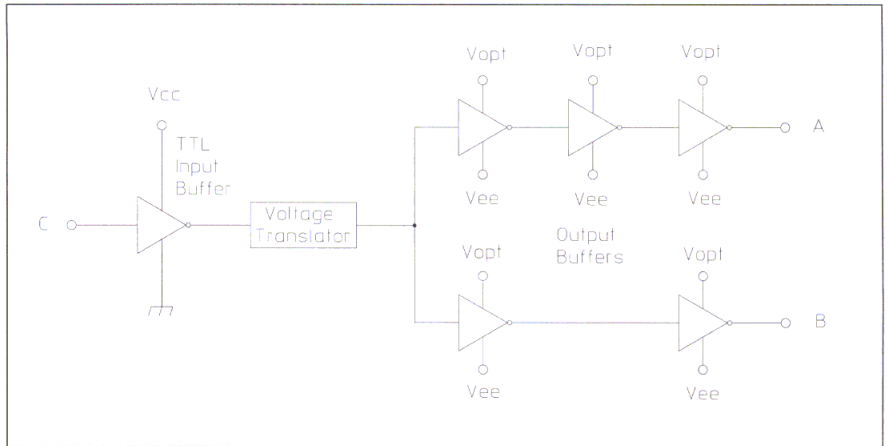
20 Sylvan Road • Woburn, MA 01801 USA

Circle 71

Alpha

from concept to solution...your wireless source
See us at Wireless Symposium, booth #423
and CTIA, booth #4423

volts. The voltage translator takes the signal from the output of the TTL buffer and translates it down to between V_{ee} (the negative supply voltage), and V_{opt} . The output buffering serves two purposes. There is an additional inverting buffer on the path to the A_n output than there is going to the B_n output, which provides the complementary outputs of V_{opt} and V_{ee} . The successive buffer stages use larger transistors at each stage to be able to drive capacitive loads on the control lines.



Advantages of using an ASIC FET driver ▲ Block diagram of an ASIC driver.

There are several key advantages of using an ASIC silicon driver to drive GaAs circuitry. A silicon driver has quiescent currents that are in microamps, where on-chip GaAs drivers use several milliamps. Because the silicon driver provides complementary V_{opt} and V_{ee} voltages, the GaAs MMIC can operate down to DC when V_{opt} is set to zero volts. With an on-chip GaAs driver and a standard CMOS drive, the RF input would need to be centered at +5 volts potential, which would require pull-up resistors and DC blocking capacitors. Because the silicon ASIC driver provides negative control voltages, the ground bond pads on the GaAs MMICs can be bonded directly to ground, which improves the high frequency performance compared to floating grounds, which would be required if standard CMOS drivers were used with 0 volts and V_{cc} for the rails.

M/A-COM sells three ASIC drivers. DR65-0001 is a quad FET driver designed to be a low cost driver. To minimize cost and die size, the load capacitance requirement was dropped from 25 pF to 4 pF. SWD-119 is a quad FET driver that has fast switching speed, on the order of 20 ns typical, and is designed to have a pinout that is directly compatible with quad digital attenuators sold by M/A-COM. SWD-109 is a single channel FET driver with the same performance as SWD-119.

Interface with RF switches

For RF switches, it is usually desirable to have a TTL "1" be the control for the "on" arm. For this to be true, the A output of the FET drivers is connected to the series FETs and the B output is connected to the shunt FETs. To maximize switching speed, the FET driver should be located physically close to the switch.

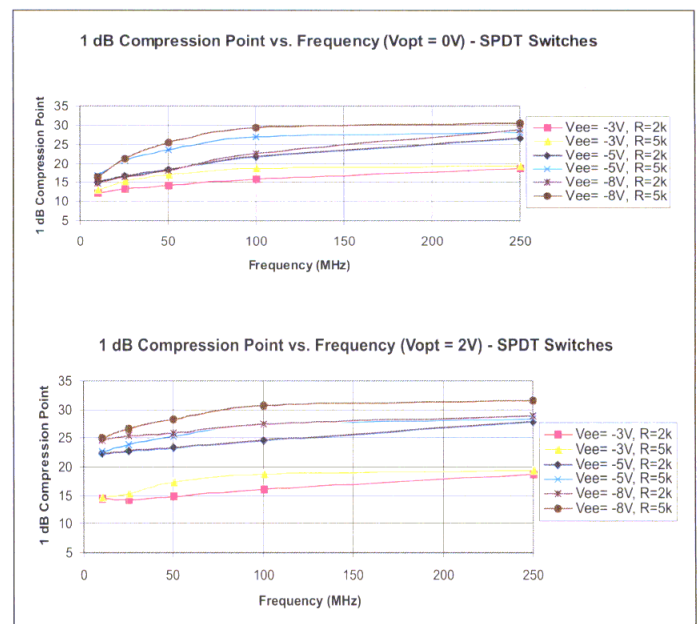
For fast RF switching the RF lines of the switch need to be at ground potential (see Figure 7). The control voltages on a switch are the gate voltages. V_{gs} should be 0 volts for an "on" FET, and -5 volts typically for an "off" FET. If the RF lines are blocked by capacitors, the source voltage is DC blocked, so V_{gs} is not well defined and will vary depending on the MMIC leakage currents.

When a DC block is required, in most cases a 10 kohm shunt resistor or a shunt inductor on the RF common arm will usually suffice to provide adequate switching performance.

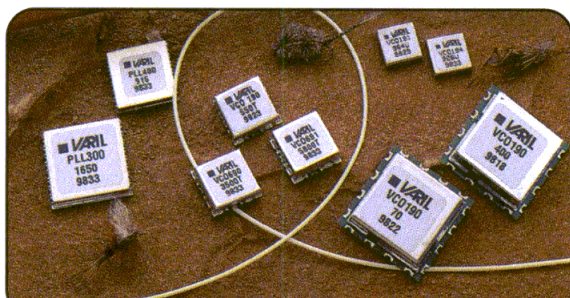
Interface with digital attenuators

The SWD-119 is designed to interface directly with digital attenuators such as the AT-220 four bit attenuator, as shown in the diagram of Figure 8. With the controls to the SWD-119 coming in from the left, the drive lines to the FETs are a direct pin-pin connection to the GaAs FET attenuator. The logic is set up so that a control "0" gives the insertion loss state, and a control "1" sets a bit to the attenuation state.

To drive a 5 bit attenuator a single and quad driver would be used. In most applications the driver outputs are connected directly to the attenuator inputs. In

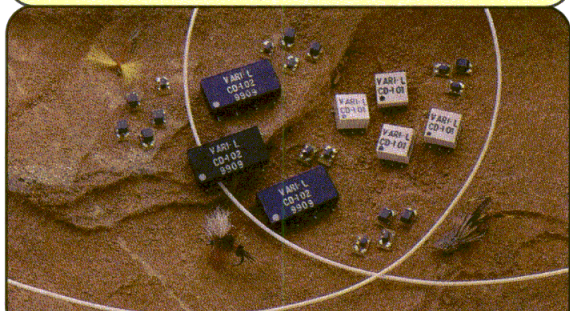


▲ Figure 3. 1 dB compression point vs. V_{opt} , V_{ee} , gate resistors, and frequency (DC to 250 MHz).



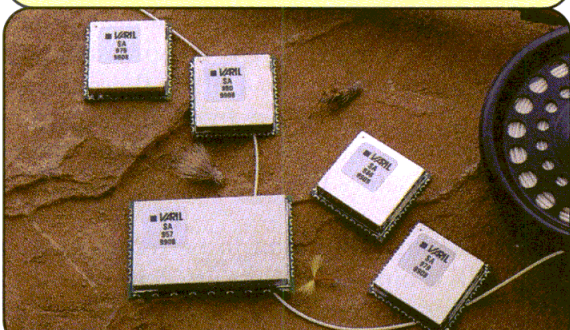
Commercial Signal Sources

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



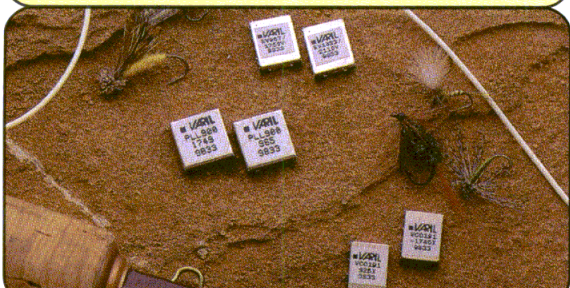
Commercial Signal Processing

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



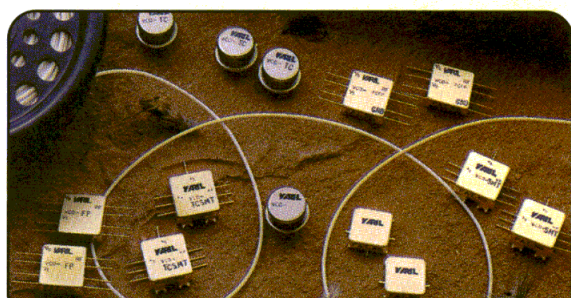
Commercial Special Assemblies

- Special Frequency Conversion Modules
- Special Frequency Generation Modules



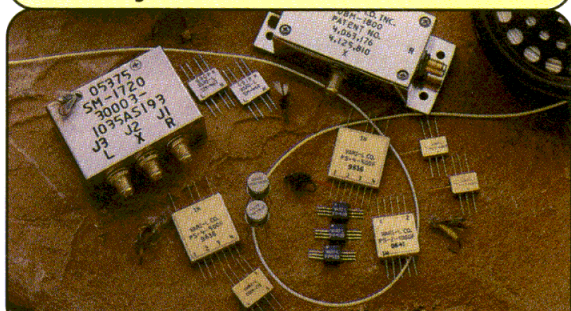
Subscriber Signal Sources

- Miniature Voltage Controlled Oscillator Modules
- Miniature PLL Synthesizer Modules



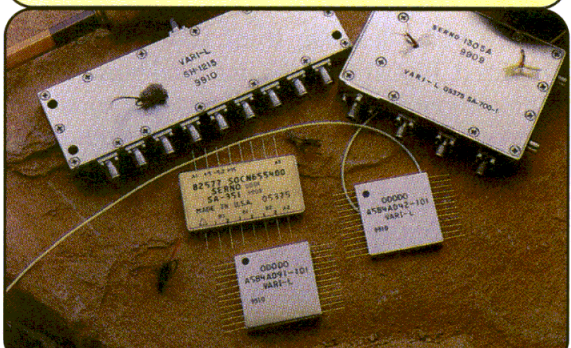
Military Signal Sources

- Ruggedized High Performance Hybrid
- Voltage Controlled Oscillators



Military Signal Processing

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



Military Special Assemblies

- Ruggedized Special Frequency Generation Assemblies
- Ruggedized Special Frequency Conversion Assemblies
- Ruggedized Special RF Distribution Assemblies

VARI-L

We Have A Part In Your Future

4895 Peoria Street

Denver, Colorado 80239

☎ 303.371.1560

fax 303.371.0845

e-mail: sales@vari-l.com

VARI-L is a precision manufacturer of RF components for a wide range of aerospace, commercial, military, space and subscriber applications.

At VARI-L, our continued focus on research and development and commitment to enhancing manufacturing technology is intended to ensure that "We have a part in your future."



**PROUDLY MADE
IN THE USA**

Contact the VARI-L Sales Department for your special microwave and RF component assembly needs.

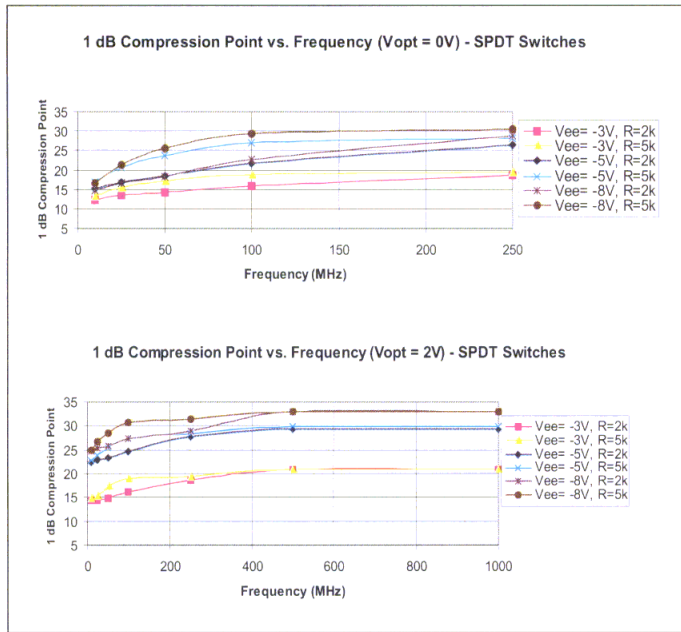
ISO 9001 Certified

VARI-L Company, Inc.

www.vari-l.com

Circle 64

See us at Wireless Symposium, booth #436



▲ **Figure 4. 1 dB compression point vs. V_{opt} , V_{ee} , gate resistors, and frequency (DC to 1000 MHz).**

instances where video leakage from the control lines must be minimized, filtering can be installed between the driver and the attenuator. The filtering would consist of a single shunt capacitor in most cases, which would slow the switching speed.

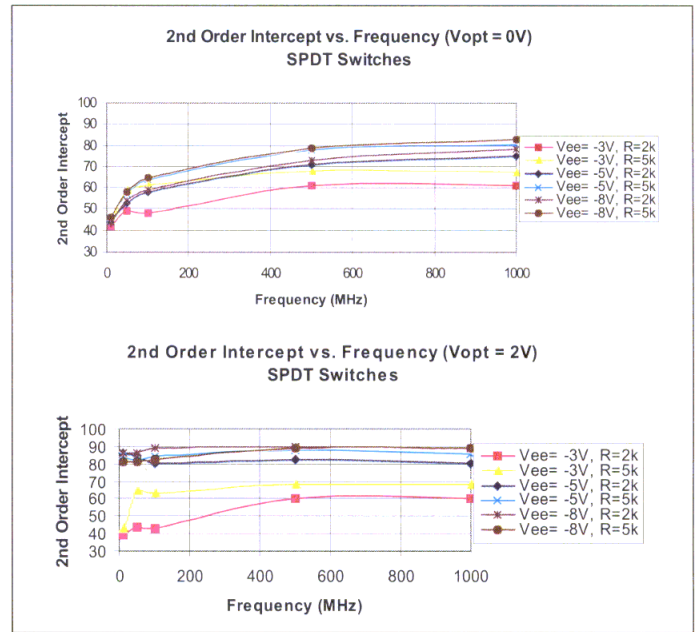
Most of the newer M/A-COM attenuators have an internal 10 kohm shunt resistor, but in older attenuators it may be necessary to provide a DC return at either the RF IN or RF OUT port.

Without the DC return, all bits will be accurate relative to each other, except that the reference loss state will have degraded performance, and may have up to 0.5 dB more loss than it would be with a DC return. The other bits do not exhibit this problem because they contain a shunt element that provides a DC return.

Non-linear performance with $V_{opt} = 0\text{ V}$ and 2 V

1 dB compression, second order intercept, and third order intercept were evaluated as a function of V_{opt} , V_{ee} , gate resistors, and frequency. This was done to reevaluate the non-linear performance after the pinch-off voltages of the FETs were lowered and the ion implanter was changed to increase the FET breakdown voltages. We measured the non-linear performance of two SPDT switches. One switch was the SW-313, which uses the MASW4030G die, which has 5 kohm gate resistors. In the other switch, we replaced the MASW4030G die with the MASW6010G die, which has 2 kohm gate resistors. See the graphs in Figures 3, 4, and 5 for plots of 1 dB compression, second order intercept, and third order intercept vs. V_{opt} , V_{ee} , gate resistors and frequency.

There are some key points to note relative to the plots.



▲ **Figure 5. Second order intercept vs. V_{opt} , V_{ee} , gate resistors and frequency.**

For the -3 volts data, there are significant unit-to-unit variations below 100 MHz. The compression points in a single wafer lot varied up to 4 dB so there needs to be a significant guard band at low frequencies. With -3 volts control, there was significantly better performance with 5 kohm gate resistors than there was with 2 kohm gate resistors.

There was little variation in performance above 500 MHz so 1 dB compression plots are done over two ranges to better demonstrate the performance at low frequencies. The performance at low frequencies will be comparable for IP2 and IP3.

Switching speed vs. gate resistance

There are two primary factors that limit the switching speed of GaAs FET switches, the transmission line inductance between the driver and the MMIC and the RC time constant on the MMIC. The RC time constant on the MMIC will increase by a factor of 2.5 as the gate resistance is increased from 2 kohm to 5 kohm. Unless very fast switching speed is required, a 5 kohm is sufficient for adequate switching performance.

Summary

The basic performance of the ASIC driver for GaAs control components was described. Special attention was paid to the performance as V_{opt} , R_{gate} and V_{ee} were varied as a function of frequency. For 3 volt performance there was significant unit-unit variation at low frequencies, and increasing gate resistance improved non-linear performance. At $V_{ee} = -5\text{ volts}$ there was improvement in the non-linear performance, with only small changes

SURFACE MOUNT **RF TRANSFORMERS**

Over 100 off-the-shelf models...



4kHz to 2200MHz from **\$195** ea. (qty. 1-9)

What makes Mini-Circuits your single source for surface mount RF transformers? Variety, availability, performance, and price! From wide band transformers with low droop and fast risetime capabilities for pulse applications, to a particular impedance ratio from 1:1 through 1:36 specified for a wide range of impedance coverage, we will work with you on your design challenges. Tangible benefits such as very high dielectric breakdown voltage, excellent amplitude and phase unbalance for balanced to unbalanced applications, and easy to use surface mount package styles make Mini-Circuits

surface mount transformers a great value. Our new ADT transformers are changing the face of RF transformer design with patent pending **it**™ Innovative Technology delivering small size, low cost, and better performance. This same leading edge transformer expertise can also develop your custom designs at catalog prices. So, simplify your transformer search...Big Time! Capitalize on the quality, design know-how, and off-the-shelf variety from Mini-Circuits. Call today!

Mini-Circuits...we're redefining what VALUE is all about!

 **Mini-Circuits®**

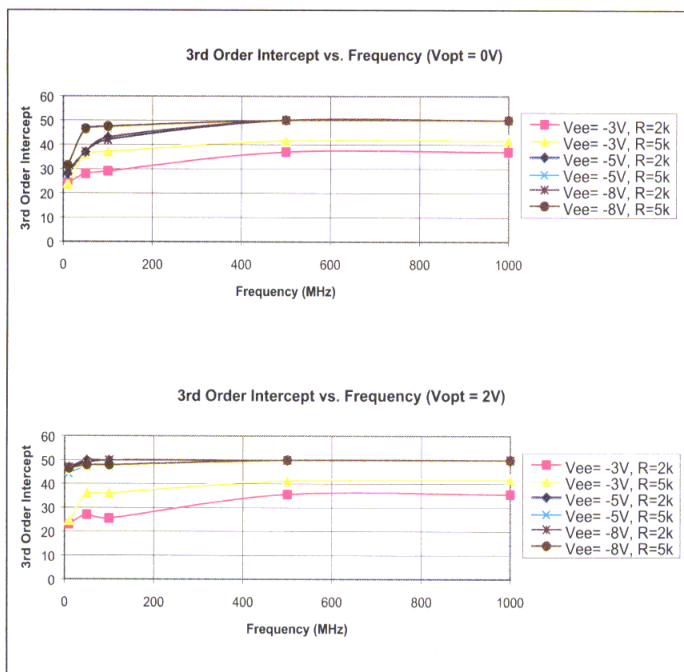
US 86 INT'L 96
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 **INTERNET** <http://www.minicircuits.com>

For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE • EEM • MICROWAVE PRODUCT DATA DIRECTORY • WWW.RFGLOBALNET.COM

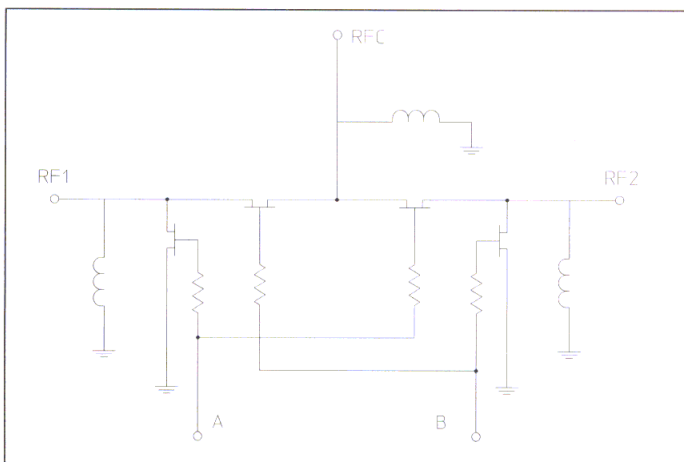
ISO 9001 CERTIFIED

F 290 Rev Orig

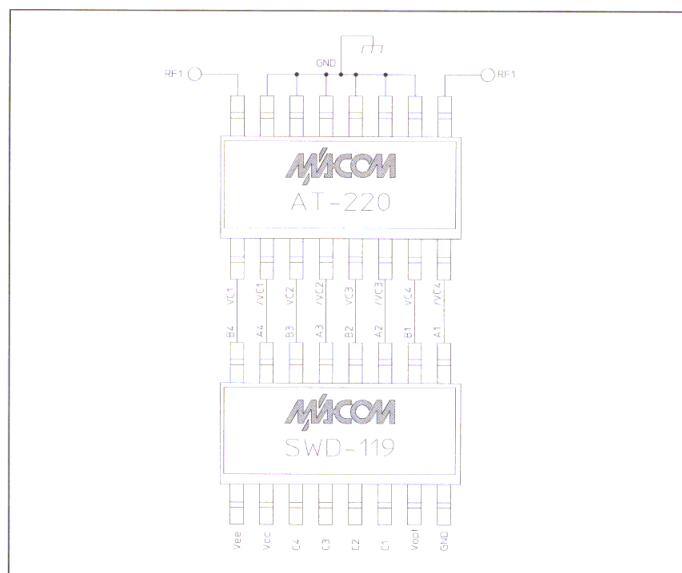


▲ **Figure 6.** Third order intercept vs. V_{opt} , V_{ee} , gate resistors and frequency.

as gate resistance was varied. There was still fairly significant roll-off in non-linear performance with $V_{ee} = -5$ volts. With $V_{ee} = -8$ volts, and $V_{opt} = +2$ volts, the non-



▲ **Figure 7.** SPDT switch with GND returns on RF ports.



▲ **Figure 8.** SWD-119 driving the AT-220 digital attenuator.

linear performance was the best. There was much less variation across frequency for $V_{ee} = -8$ volts. ■

References

1. C. D. Weigand, "Updated Methods for Driving GaAs FET Control Devices — Introducing a New Silicon Driver," p. 337, 1993 M/A-COM Engineering Conference Digest.

Author information

Christopher Weigand received a BSEE from Tufts University in 1977 and an MSEE from Tufts University in 1979. From 1979 until 1981, he worked at Hughes Aircraft Company on the design and development of satellite ground stations. From 1981 until 1989, he designed passive components, phase modulators and subassemblies for ANZAC. He has been with M/A-COM since 1989, and currently is a Principal Engineer in the RF & Microwave Components product line. He has designed GaAs MMIC switches, digital attenuators and digital phase shifters. He has been the project engineer for the PHS diversity switch product line. He may be reached via email at weigand@tycoelectronics.com.

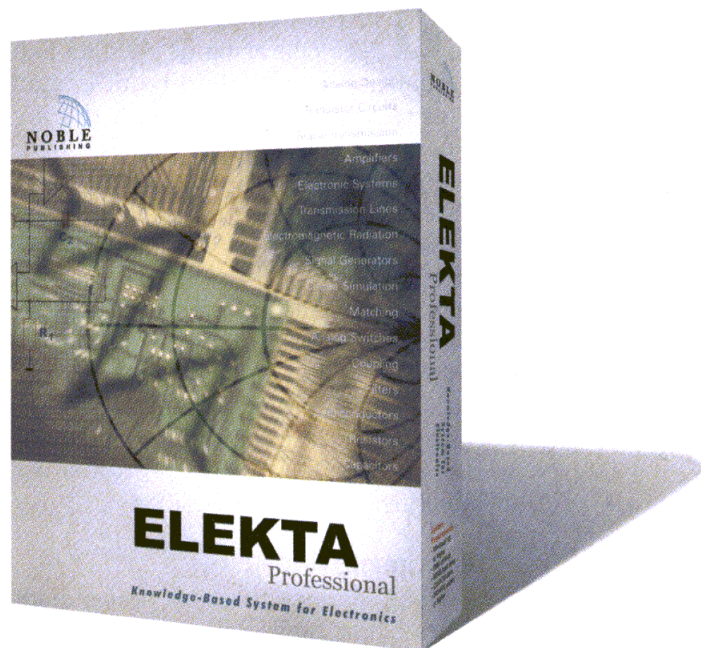
You have questions...

How many microvolts is 85 dBm at 50 ohms?
 What is the spectral content of QPSK?
 What the resistor color code and standard values?
 How do digital IIR and FIR filters work?
 What mixer spurs result from 70 MHz RF and 18.1 MHz LO?
 How does an active filter work?
 How do I wind a 120 nH inductor?
 What capacitor resonates with 2.2 μ H at 10.7 MHz?
 What VSWR corresponds to 12 dB return loss?
 What s the effect of reducing Q from 300 to 100?
 What is Miller effect?
 How do I perform two-port transformations?
 How is bias set on bipolar transistors and FETs?
 What are the basics of SPICE analysis?
 What do all those noise parameters mean?
 How do I make a 700 Hz active bandpass filter?
 What are Maxwell s equations?
 Can I graph the $\sin(x)/x$ curve?
 What dimensions do I need for a 50 ohm microstrip?
 How do I match 25 +j40 ohms to my 75 ohm system?
 Where can I find a review of Kirchoff s Laws?
 How much antenna gain does my system need?
 How do I bias a BFR91 or 2N2222 transistor?
 Will I get bad crosstalk between lines on my p.c. board?
 Can I perform basic transfer function math?
 How can a beginner learn about components at RF?
 What s the difference between linear and non-linear?
 What is the capacitance of two 1 l cm plates spaced 1 mm?
 Why do we use feedback?
 I know RF, but where can I find digital basics?
 Can I do vector to scalar conversions?
 What is the AC impedance of a parallel R-C network?
 What is a conductor's skin depth at 900 MHz?
 What do those thermal resistance numbers mean?
 Can I visualize the field lines between capacitor plates?
 What is the mismatch loss of a 5.22:1 VSWR?
 How do I simulate a darlington pair amplifier?
 What are the resistor values for a 50 ohm 6 dB pad?
 Should I use a pi or tee matching network in my circuit?

ELEKTA

Professional

has the answers!



**SPECIAL
INTRODUCTORY OFFER**

\$89

**shipped FREE within US and Canada
(\$109 shipped worldwide)**

This is a limited time offer



For information or to order contact:
 Noble Publishing, 4772 Stone Drive, Tucker GA 30084
 Tel: 770-908-2320 • Fax: 770-939-0157
www.noblepub.com

**See us at Wireless Symposium
Booth #1441**

* Dealer inquiries invited

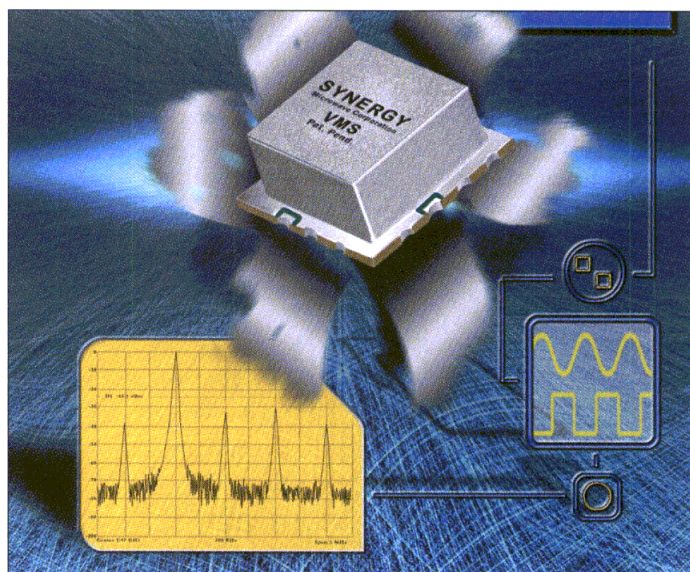
A High Dynamic Range Miniature Modulator/Demodulator

This month's cover features a new patent-pending product line with low noise figure and high isolation

Most commercially available integrated modulators/demodulators operating at cellular band frequencies and higher require many external components and lack the high dynamic range and low noise figure demanded by modern communication systems. Synergy's unique patent pending VMS series of I/Q modulator and demodulator technology allows the designer to select a low cost design with a high dynamic range in a package as small as 0.5 in. \times 0.5 in. \times 0.22 in., capable of withstanding harsh reflow environment during automated assembly. The package is EMI/RFI protected with moisture resistant capability.

Description

Many manufacturers of active modulators claim high dynamic range when operated with low level (-20 dBm or lower) signals. Active modulators based on Gilbert Cell technology need plenty of external circuitry, including supply decoupling and tuning networks. When direct current (DC) is involved for biasing the internal devices, designers may run into unwanted spurious signals unless special care is taken in decoupling various parts of the modulator. The external circuitry also increases the required p.c. board real estate. Another suggested approach makes use of sub-harmonic modulators where the even harmonic of the local oscillator (LO) mixes with two incoming intermediate frequency (IF) signals of the same strength. The two IF signals are separated by 90 degrees in phase, resulting in either an upper sideband or a lower sideband



▲ Synergy Microwave announces the VMS series of I/Q modulator/demodulator products.

RF signal in the case of a single sideband (SSB) modulator. In the case of a demodulator, this approach will result in two IF signals of similar strength differing in phase by 90 degrees, commonly known as a quadrature IF mixer. The carrier rejection is high due to the fact that the sub-harmonic mixers used in the modulator offer higher isolation at the even harmonics of the LO. However, the signal handling capability may be lower (depending on the design) than that of a fundamental type, resulting in inferior intermodulation products.

Figure 1 shows the block diagram of a typical modulator where two double balanced mixers (DBMs), whose IF ports are DC coupled, are interconnected with a 90 degree hybrid on one

...the future of wireless

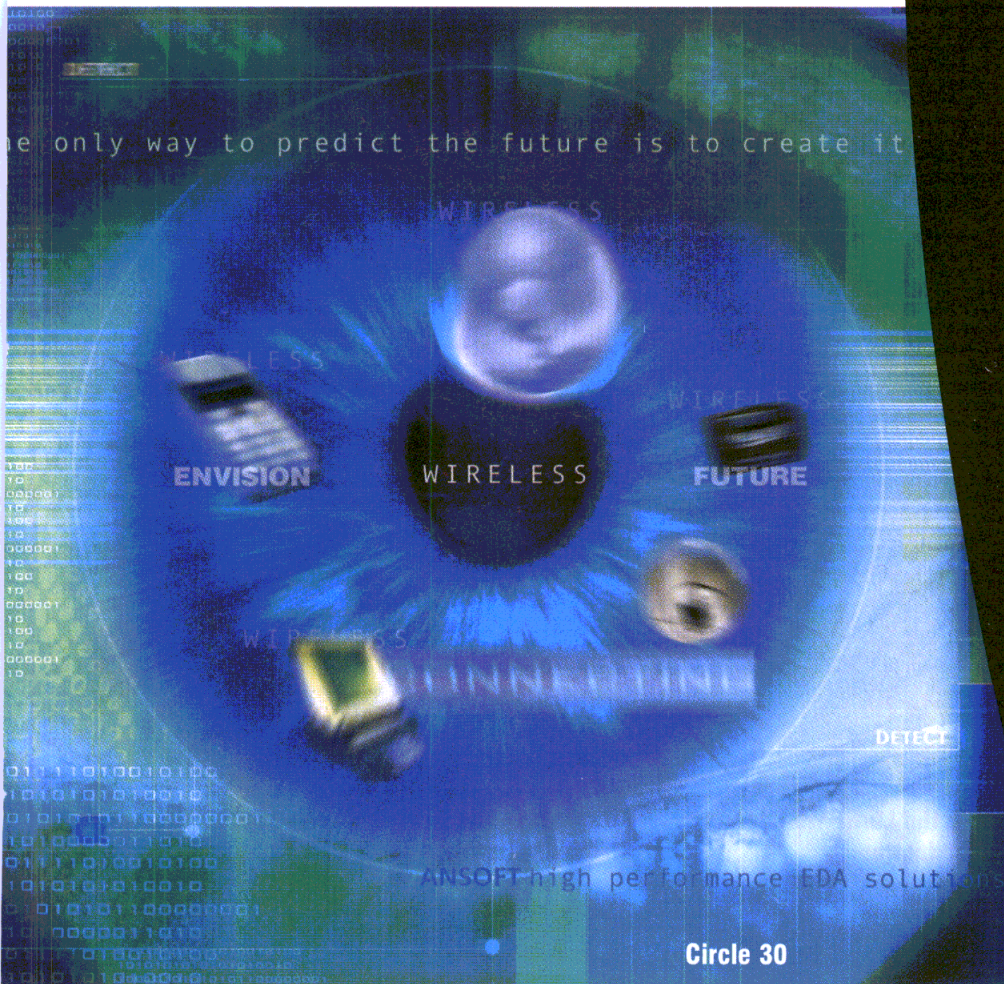
Look inside that future and see the invisible!

Visit Ansoft Booth #1109

ANSOFT Serenade Design Environment

Simulation tools that look deep inside your designs,
eliminate the invisible hurdles, and turn your vision into reality.

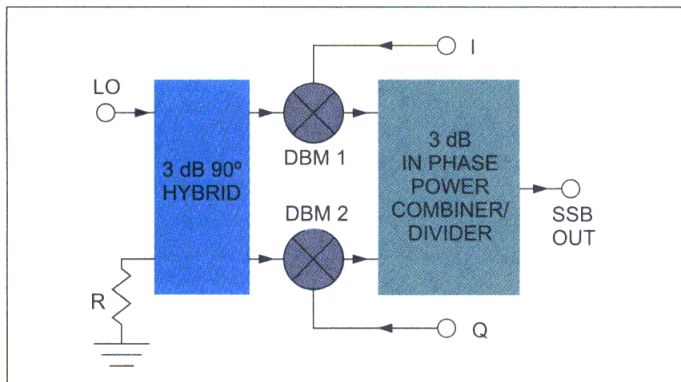
Envision



high performance EDA

www.ansoft.com

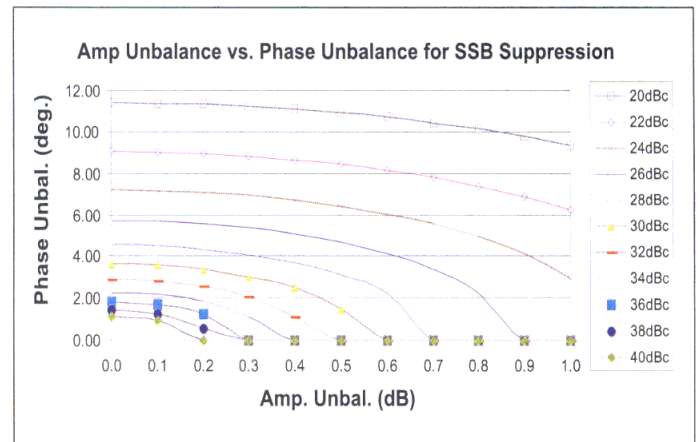
Circle 30



▲ **Figure 1. Block diagram of a typical modulator where IF ports are DC coupled and are interconnected with a 90 degree hybrid on one side and an in-phase divider/combiner on the other side.**

side and an in-phase divider/combiner on the other side. The carrier rejection of the modulator is directly related to the LO to RF isolation of the mixers, whereas, the single sideband (SSB) rejection is related to the combined amplitude and phase balance of the various components within the modulator. Figure 2 shows the plot of amplitude unbalance vs. phase unbalance for various values of SSB rejection. From the figure, it is evident that for 40 dB SSB rejection, one has to maintain the phase and amplitude balances as low as 1 degree and 0.1 dB respectively. The noise figure (NF) in decibels (dB) of the passive modulator is typically no more than 1 dB higher than the conversion loss of the modulator, whereas active modulators have poorer noise figure resulting in lower signal-to-noise ratio.

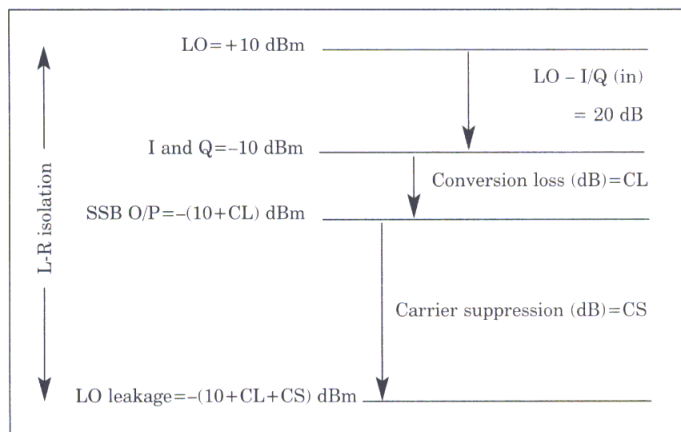
The modulator used in the VMS series (patent pending) reduces component count, including transformers, which are the main source of degraded phase and amplitude response at higher frequencies. The transformers used in this modulator provide higher frequency coverage with excellent phase and amplitude balance, crucial to higher sideband rejection. Also, the transformers pro-



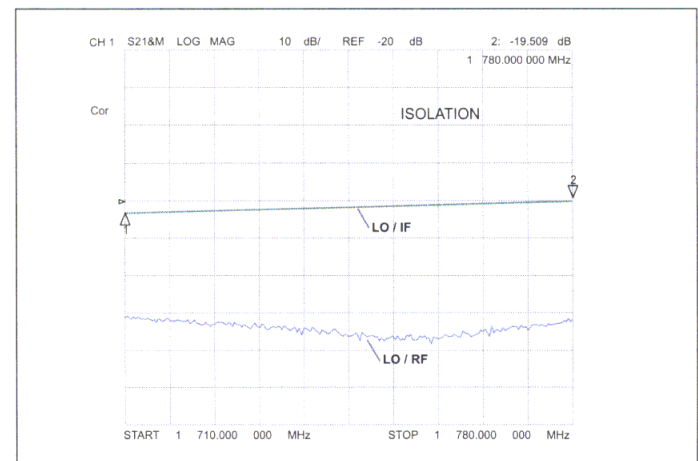
▲ **Figure 2. The plot of amplitude unbalance vs. phase unbalance for various values of SSB rejection.**

vide improved isolation resulting in better carrier rejection. The 1 dB compression point of the modulator, coupled with carrier and sideband rejection, determines the dynamic range of the modulator. The 1 dB compression can be improved (different model) by using higher level Schottky diodes (four are used to form a ring/cross over quad), where the level is expressed by the forward voltage drop (V_f) of the diode for a given current. There is a practical limit to this. The typical values for V_f are 225 mV, 350 mV and 550 mV. One can take advantage of the fact that the effective value of V_f can be increased by connecting as many diodes as practical in series, keeping in mind the package size and the frequency response limitations. When too many diodes are housed in a single package (multiples of 4 or as required), the cost becomes prohibitive.

Assuming the package size and frequency response of the diode is the same irrespective of the V_f , the basic design of the modulator remains unchanged. The bandwidth limitation comes from that of the 90 degree hybrid used in the modulator. For the smallest unit, the bandwidth is typically 10 percent. The third order intermod-

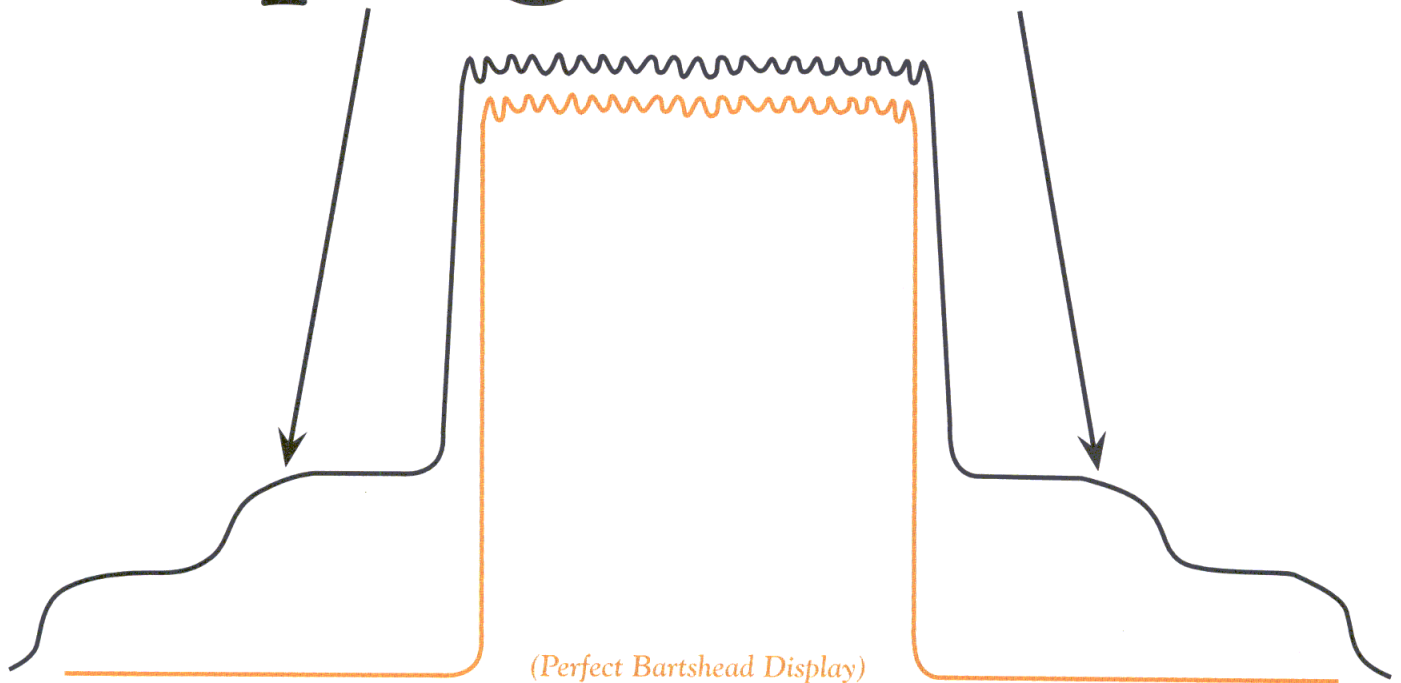


▲ **Diagram 1. Relationships to help calculate the LO/RF isolation for each of the DBMs used in the modulator.**



▲ **Figure 3. Typical isolation for a PCS band unit.**

Danger. Sloping Shoulders.



Spectral growth can compromise the most precise CDMA technologies. Often, the difficulty lies in the transmission equipment, a potent source of distortion or the "shoulders" you see on your display. Now there are amplifiers that help you eliminate shoulders, keep the space between carriers narrow and optimize bandwidth.

AR "S" Series amplifiers are uniquely linear. Thanks to their exceptional design, CDMA signals get amplified but distortion stays low. You quickly pinpoint problems when testing your driver amp (or other transmission equipment) because you know the one place it's not coming from (the AR test amp).

"S" Series amplifiers offer a broad band that accommodates the 0.8 to 0.9 GHz, 1.85 to 1.99 GHz and 3.5 GHz frequencies used in wireless transmission. Plus spurious emissions and noise figures that are unusually low.

Email us for a copy of our new microwave brochure and specs at info@ar-amps.com.

www.ar-amps.com/amw/shoulders

ISO 9001
Certified

Copyright © 1998 Amplifier Research. The orange stripe on AR products is Reg. U.S. Pat. & Tm. Off.

AR **AMPLIFIER
RESEARCH**

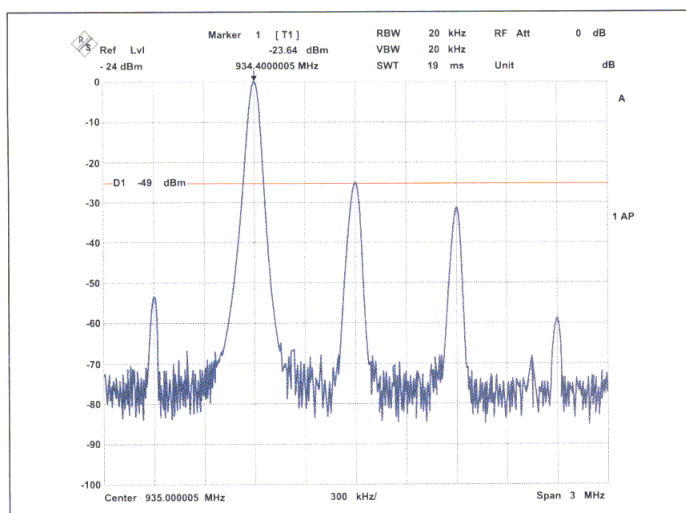
The Force Behind The Field.

USA 215-723-8181 or 800-933-8181 for an applications engineer.

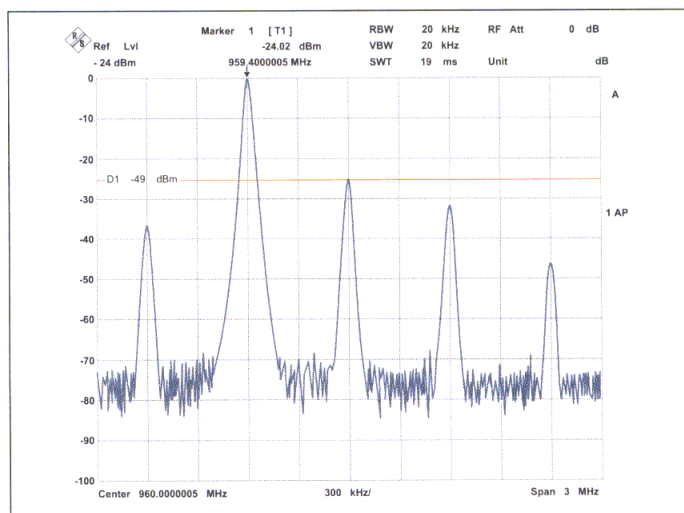
In Europe, call EMV—Munich: 89-614-1710 • London: 01908-566556 • Paris: 1-64-61-63-29 • Amsterdam: 31-172-423-000

Circle 32

See us at Wireless Symposium, booth #913



▲ **Figure 4. Carrier and sideband performance at low cellular band for the VMS-935 model.**



▲ **Figure 5. Carrier and sideband performance at high cellular band for the VMS-935 model**

ulation product (IP3) depends on the V_f of the Schottky diode, the L/R, L/I and R/I isolations in the mixers and the impedance match at all ports.

Importance of LO/RF isolation

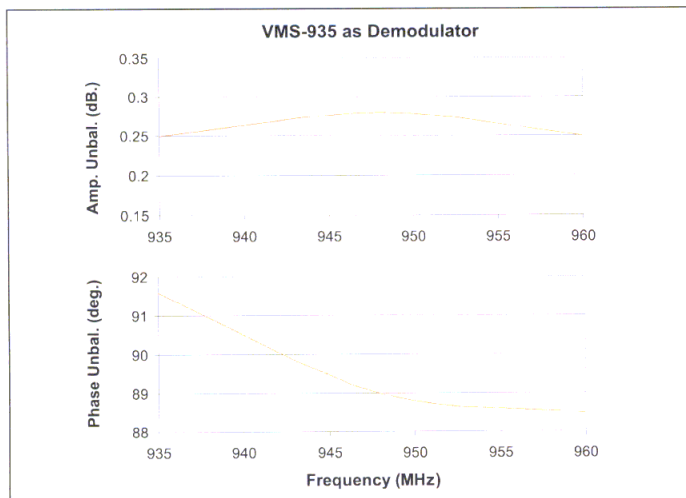
As pointed out earlier, the LO to RF isolation determines the carrier rejection in the modulator. Diagram 1 helps the designers to calculate the LO/RF isolation for each of the DBMs used in the modulator. The isolation number for each of the DBMs will decrease by 3 dB, due to the combining effect in the in-phase combiner. In the diagram below, we will assume that the modulator is being driven by a LO drive of +10 dBm and the I and Q levels are -10 dBm each.

For a carrier rejection of 30 dB and a typical conversion loss of 5 dB, the LO/RF isolation of the modulator will be 55 dB and each of the DBMs will have 52 dB of isolation. At higher frequencies, it is difficult to reach

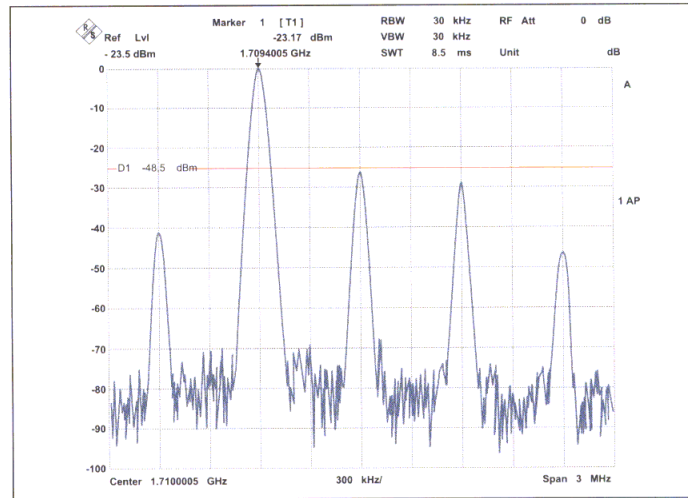
this figure with a conventional approach, while the new approach can easily achieve this in smaller size. Figure 3 shows a plot of typical isolation for a PCS band unit. LO/RF isolation is better than 50 dB, while the LO/IF isolation is 20 dB.

Performance

Two models, VMS-935 and VMS-1710, operating in the popular 935 to 960 MHz cellular and 1710 to 1780 MHz PCS frequency bands, are selected to highlight the performance of the new technology. For each of these applications, the I and Q levels are set at -10 dBm each with a 90 degree phase difference between them at 600 kHz, while the LO level is fixed at +10 dBm. Figures 4 and 5 display the carrier and sideband performance in the cellular band for the VMS-935 model, showing that the SSB rejection is 30 dB (min.) across the band. With minor modifications, VMS-935 can be used as a demod-



▲ **Figure 6. The amplitude and phase unbalances across the full band of 935-960 MHz.**



▲ **Figure 7. Carrier and sideband performance at low PCS band for the VMS-1710 model.**

New NEC Bipolar Transistors

Higher f_T s, Lower $1/f$

New, Smaller Packages

Oscillators & Buffer Amps

With the best $1/f$ performance available, these devices help you achieve the phase noise your design demands. They're also available in Twin Transistors.

Part Number	Corner Freq*	V_{CE}	I_C	Package
NE856M03	3 KHz	3 V	30 mA	M03
NE685M03	5 KHz	3 V	5 mA	M03

*Review Application Note AN1026 on our website for more information on $1/f$ noise characteristics and corner frequency calculation.

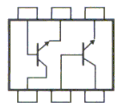
LNAs

Need low noise and high gain in an ultraminiature package for your hand-held wireless products? These new high frequency NPN transistors deliver!

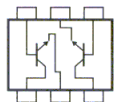
Part Number	Description	NF	Gain	Freq	Package
NE687M03	11 GHz f_T LNA	1.2 dB	13 dB	1 GHz	M03
NE661M04	25 GHz f_T LNA	1.2 dB	22 dB	2 GHz	M04
NE662M04	23 GHz f_T LNA	1.1 dB	20 dB	2 GHz	M04

Twin Transistor Devices

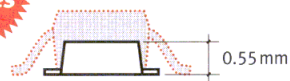
Cascode LNAs, cascade LNAs and oscillator/buffer combinations are just three possible uses of these versatile devices. *Matched Die* versions pair two adjacent die from the wafer to help simplify your design, while *Mixed Die* versions — an NEC exclusive — let you optimize oscillator performance while achieving the buffer amp output power you need. 40 different combinations available.



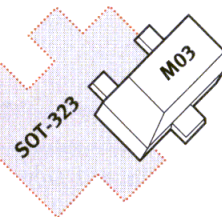
Part Number	Description	Q1 Spec	Q2 Spec
UPA810TC	Matched Die/Cascode LNA	NE856	NE856
UPA814TC	Matched Die/Cascode LNA	NE688	NE688



Part Number	Description	Q1 Spec	Q2 Spec
UPA826TC	Matched Die/Osc-Buffer Amp	NE685	NE685
UPA840TC	Mixed Die/Osc-Buffer Amp	NE685	NE681

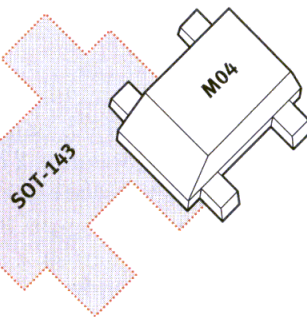


- **Flat Lead** design reduces parasitics and improves electrical performance
- **Low Profile** package is ideal for PCMCIA and other space-constrained designs



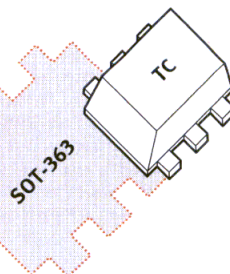
New M03

Half the footprint area of a SOT-323



New M04

Half the footprint area of a SOT-143



New TC Twin Transistors

Half the footprint area of a SOT-363

Data Sheets and Application Notes are available at www.cel.com

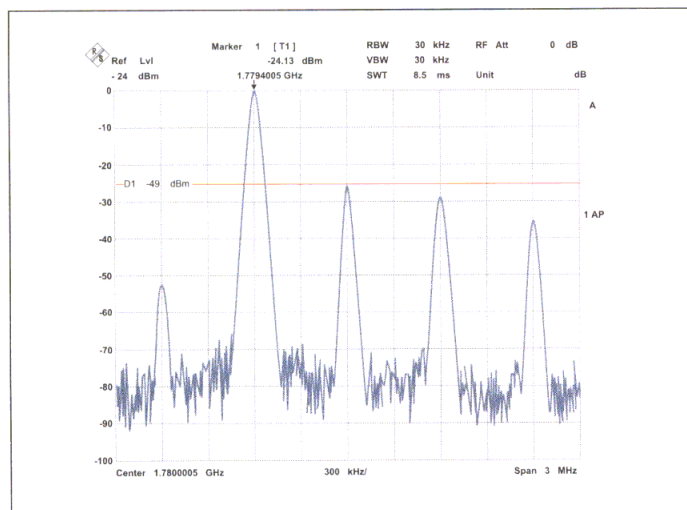
CEL California Eastern Laboratories

NEC

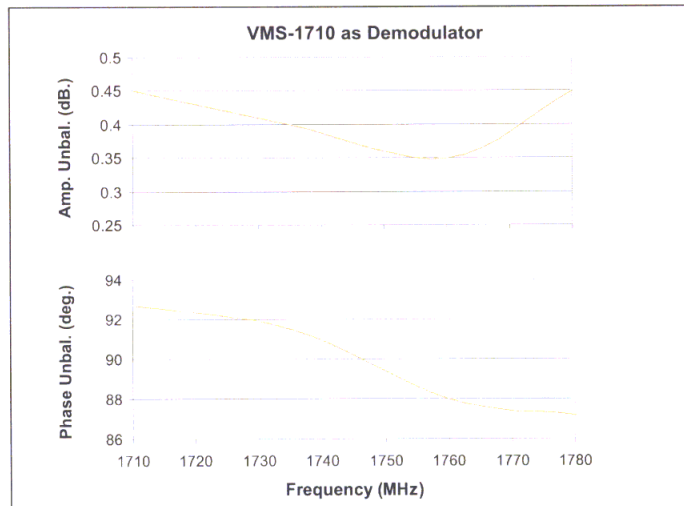
Santa Clara, California ■ 408 988-3500 ■ Fax-on-Demand 800-390-3232 (US & CANADA)

DISTRIBUTORS: Arrow (800) 525-6666 Repron Electronics (888) REPRON

Mouser Electronics (800) 346-6873 Electro Sonic (800) 567-6642 (CANADA)



▲ **Figure 8. Carrier and sideband performance at high PCS band for the VMS-1710 model.**



▲ **Figure 9. The amplitude and phase unbalances across the full band of 1710-1780 MHz.**

ulator, and Figure 6 shows the amplitude and phase unbalances across the full band of 935-960 MHz. The amplitude balance is within 0.3 dB and the phase balance is within ± 1.7 degrees.

Figures 7 and 8 highlight the carrier and sideband performance in the PCS band for the VMS-1710 model, where the SSB rejection is 27 dB (min.) and the carrier rejection is 25 dB. VMS-1710 can be tuned to function as a demodulator, and Figure 9 shows the amplitude and phase unbalances across the full band of 1710-1780 MHz. The amplitude balance is within 0.45 dB and the phase balance is within ± 3.0 degrees. The plots shown

in Figures 4, 5, 7 and 8 also display products that are related to the harmonics of the I and Q signals mixing with the LO. For higher dynamic range, it is highly recommended that the modulator be operated in the linear range. Units designed for higher compression points offer lower levels of the above products.

The outline drawing and the recommended layout of mounting pads for the VMS series modulators is shown in Figure 10.

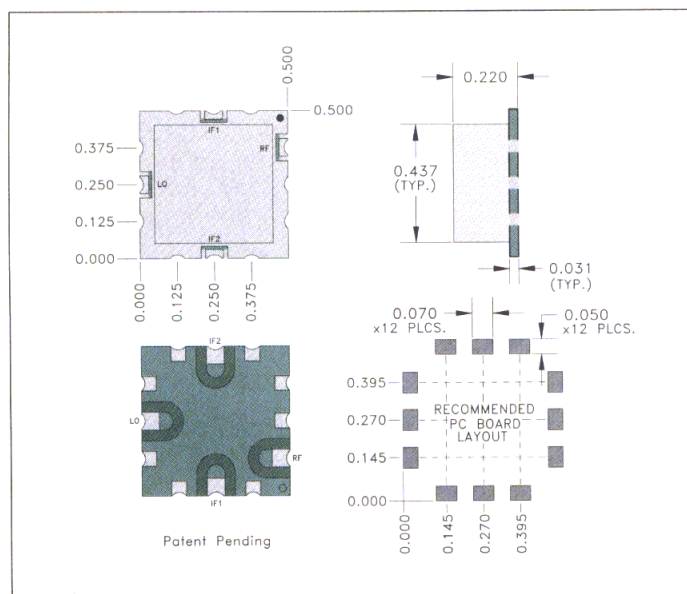
Conclusions

The exceptional RF performance of the new lower cost modulator is demonstrated through the above examples. This new design can be manufactured consistently in large volume and will be available in various packages as needed. The frequency of operation can be easily extended to 3 GHz and more using printed transmission lines for transformers, 90 degree hybrids and an in-phase combiner/divider. This unique approach combines a better noise figure and dynamic range with reduced cost in external circuitry, and requires much less real estate on printed circuit board.

For more information, contact:

Synergy Microwave Corporation
201 McLean Blvd.
Paterson, NJ 07504
Tel: 973-881-8800
Fax: 973-881-8361
E-mail: sales@synergymwave.com

Or circle Reader Service #200



▲ **Figure 10. The outline drawing and the recommended layout of mounting pads for the VMS series modulators.**



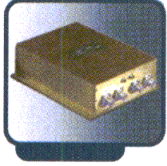
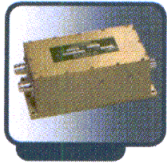
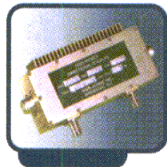
WERLATONE

SINCE 1965

Werlatone, Inc.
2095 Route 22 P.O. Box 47
Brewster, NY 10509
914.279.6187
FAX.279.7404



www.werlatone.com



high power RF devices

Directional Couplers | Combiners | Dividers | 90°/180° Hybrids

Building blocks of the past.



Building blocks of the wireless future.



Now there's a cost-cutting, time-saving alternative to building Power Amps from scratch.

Still designing high-power RF amplifiers the old-fashioned way? Design with QuikPAC amplifier components instead. Their consistent quality, outstanding performance and low unit price make switching to QuikPACs easy and cost-effective.

Using QuikPACs instead of ordinary transistors shortens design cycles and allows you to dedicate more time to innovation. Or simply be more productive. And because we've done some of the integration for you, your RF amplifiers will actually be easier and less expensive to manufacture.

Want more design flexibility? QuikPACs let you choose how much integration you want while retaining total control over the stages that make your designs unique. Replace one stage with one QuikPAC or many stages with many QuikPACs. It's up to you.

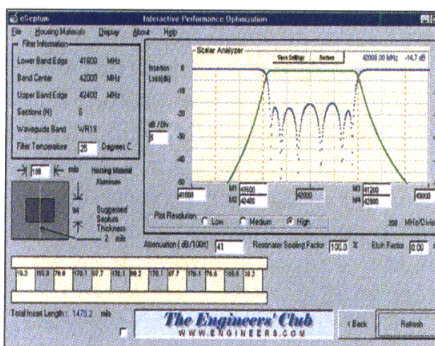
See how easy it is to switch to Xemod QuikPAC high-power RF amplifier components—the building blocks of the wireless future. For more information, call 1-408-733-7229 or visit www.xemod.com.

Xemod, Inc. • 333 Soquel Way • Sunnyvale, CA 94086 • 408-733-7229

CAD/CAE SOFTWARE

Waveguide filter program

The Engineers' Club offers eSeptum®, an e-plane waveguide filter design and evaluation program. It allows the user to manipulate up to 14 variables, including etch factor, waveguide tolerances,



temperature, scaling factors, band-pass ripple, septum widths and resonator lengths. eSeptum can investigate manufacturing tolerances. Housing materials include pre-programmed temperature coefficients. Output data can be graphical or tabular, and the program's graphing utility allows exporting of files into plotting and graphing programs. The program runs on Windows® 95/98/NT and is priced at \$895 plus shipping.

The Engineers' Club
Circle #157

DesignGuides help set up initial design

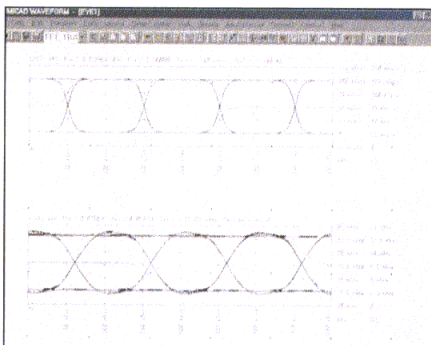
Agilent Technologies has introduced a new option for its Advanced Design System (ADS) EDA automation software. DesignGuides provide key specifications and circuit display page templates to allow users to begin the design and simulation process immediately. The DesignGuides have been developed cooperatively by industry experts and Agilent's EEsof EDA group. Electronic seminars are provided with some of the guides on CD-ROM to provide further insight into the topic. The topics available now include power amplifier design, linearization tech-

niques for power amplifiers, oscillator design, phase-locked loop design and microwave passive circuit design. Future guides are planned for RF board, RFIC and communication system design. Agilent DesignGuides are priced between \$5000 and \$10,000 each, depending on the complexity.

Agilent Technologies, Inc.
Circle #158

Time domain analysis

Optotek announces the availability of a time domain transient analysis simulator, MMICAD WAVEFORM™, which allows the prediction of waveforms in fast,



nonlinear circuits where s-parameter data can be imported and used in the simulation. With this capability, the user can address complex frequency-dependent effects in passive circuits, such as the variation of effective dielectric constant and loss of a microstrip with frequency in a broadband circuit. GaAs FET and HEMT models are included in addition to the SPICE diode model. The program is designed for stand-alone operation, and it can be used with other components of the MMICAD software suite. MMICAD WAVEFORM is priced from \$7,500.

Optotek Ltd.
Circle #159

EM software adds optimization and parametrics

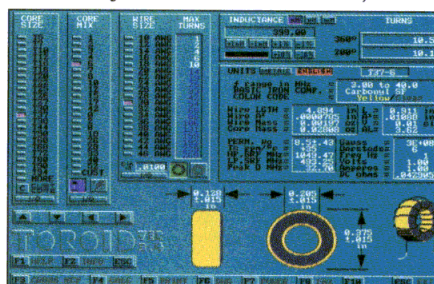
Ansoft Corporation has introduced Ansoft HFSS version 7.0, integrating a new module called Optimetrics™. New design features allow users to predict

unwanted resonances in components, reduce problem size with more powerful absorbing boundary conditions and customize the interface to streamline the design process. Ansoft HFSS is a full-wave 3D electromagnetic simulator that enables the design of connectors, high frequency packages and antennas. With Optimetrics, the user can import parametric simulation results directly into the optimizer. The engineer can quickly identify the highest performance design that is least sensitive to manufacturing tolerances. A new matrix solver has been developed to obtain the speed necessary for optimization. On Windows machines, multiple processors are supported to additional speed improvement.

Ansoft Corporation
Circle #160

Toroid inductor design

The program TOROID version 3.4 is available from J. Bellora & Associates. TOROID calculates the necessary number of turns, wire



length, self-resonant frequency and other parameters required for accurate design using iron core toroids. Complete data on standard cores is included, showing color codes, iron composition, temperature coefficient and physical dimensions. Custom sizes and permeabilities may also be selected. The program can be used by small laboratories or hobbyists to quickly evaluate surplus toroids or unmarked parts. The TOROID PRO version is priced at \$99.95 and \$49.95 for additional copies.

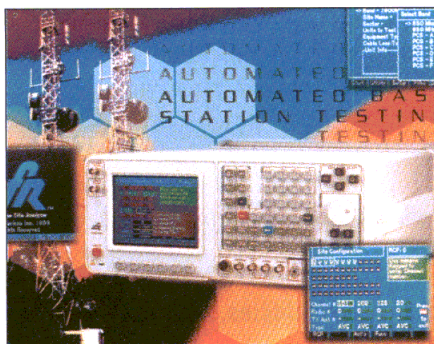
J. Bellora & Associates
Circle #161

Products

TEST EQUIPMENT

TIA/EIA-136 automated base site analyzer

The 1900 Base Site Analyzer (BSA) from IFR, Inc. is a comprehensive tester that addresses field installation and troubleshooting needs for TIA/EIA-136 infrastructure equipment. Test times are



reduced using the 1900 with IFR's AutoCell automated test software, which completely verifies modulation quality, adjacent channel power, analog and digital mode output power. It will also perform RSSI calibration test for dual-diversity and newer quad-diversity receivers. The 1900 also has the ability to fully test AMPS base stations, and it can serve as a full-feature 2 GHz service monitor with spectrum analyzer and tracking generator. The 1900 is priced at \$43,995, with options available for testing Lucent, Ericsson and Nortel base station equipment.

IFR, Inc.

Circle #162

We can get you out of some tight spots!

Harbour's HPF "High Performance Foam" Flexible Coaxial Cables curve, twist, and snake their way into those hard-to-reach spots that more rigid cables just can't touch. This ultimate flexibility ensures the best performance for applications on **Wireless and Cellular Communications, Personal Communications Systems, and Antenna Systems.**

A unique manufacturing process makes stripping the dielectric from the center conductor clean and easy. Every time. Most importantly, Harbour's high-strength, closed cell **foam polyethylene** dielectric with a composite braid configuration ensures low attenuation, a high degree of shielding effectiveness, and long term reliability.

A standard **polyethylene jacket** prevents weathering, abrasion, and chemical damage. For indoor applications, a PVC jacket is offered for **CATVR rating** and high performance materials are offered for **CATVP**

plenum rating. Popular cables include **HPF195, HPF240, and HPF400** with sizes ranging from .100" to .500" in diameter.

Both cable and connectors are available from stock.



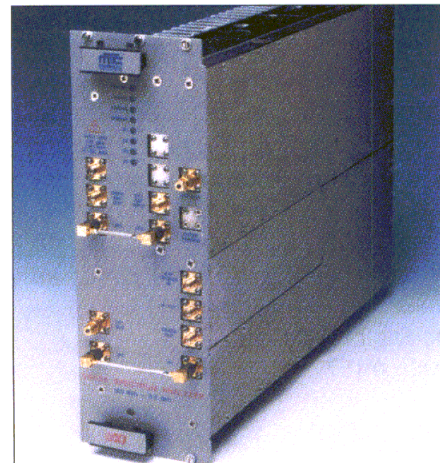
Harbour
INDUSTRIES
High Performance Wire & Cable

4744 Shelburne Road Shelburne, Vermont 05482
Phone (802) 985-3311 • Fax: (802) 985-9534
email: sales@harbourind.com
www.harbourind.com

See us at Wireless Symposium, booth #1220
and CTIA, booth #3784

VXI spectrum analyzer

Morrow Technologies now offers the Model V9035, a fully program-



mable Spectrum Analyzer covering the frequency range of 100 kHz to 3500 MHz. It is designed for use in VXI cellular and PCS production test systems as well as other VXI-based test applications. The analyzer achieves 0.5 ppm frequency accuracy with digital tuning and it has an amplitude range of -120 to +20 dBm with an absolute level accuracy of ± 0.5 dB. Overlay drawings establish test limits and thresholds for any application. Also featured is a fast measurement speed of <150 μ s/step and 2 Hz resolution.

Morrow Technologies Corp.

Circle #163

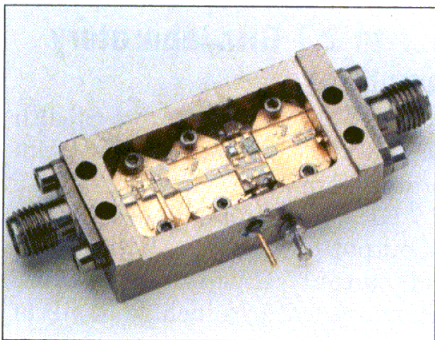
Circle 22

Products

AMPLIFIERS

Ultra-broadband amplifier

JCA Technology introduces the JCA222-B01 ultra-broadband amplifier for EW and ECM applications. The amplifier covers 2.0 to 22.0 GHz with a minimum gain of 30 dB

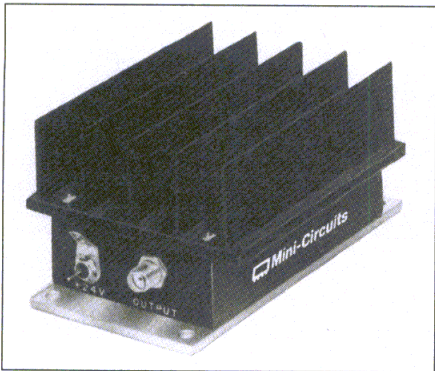


and a maximum gain response variation of ± 2.0 dB. Typical noise figure is 3.75 dB and power output is +18 dBm at 1 dB compression. Options include drop-in style packages, alternate gains and temperature compensation.

JCA Technology
Circle #164

+29 dBm power for VHF and cellular applications

Mini-Circuits' new ZHL-3010 coaxial amplifier provides high IP3 of +46 dBm (typ.) over the frequency range of 50 to 1000 MHz.



Operating from a 12 VDC power supply, the amplifier delivers a typical gain of 35 dB ± 0.6 dB and +29 dBm power output at 1 dB compression. VSWR is typically 2.0:1 input and 1.6:1 output in the mid to upper frequency range. The ZHL-3010 includes a heat sink and SMA

female connectors. The unit is priced at \$179.95 in small quantities (1 to 9).

Mini-Circuits
Circle #165

GaAs dual-band integrated power amplifier

Motorola's MRFIC1859 offers a single-chip solution for power amplification in dual-band GSM/DCS phone designs. This integrated power amplifier includes an on-chip voltage generator that permits single-supply operation. A gate-drain



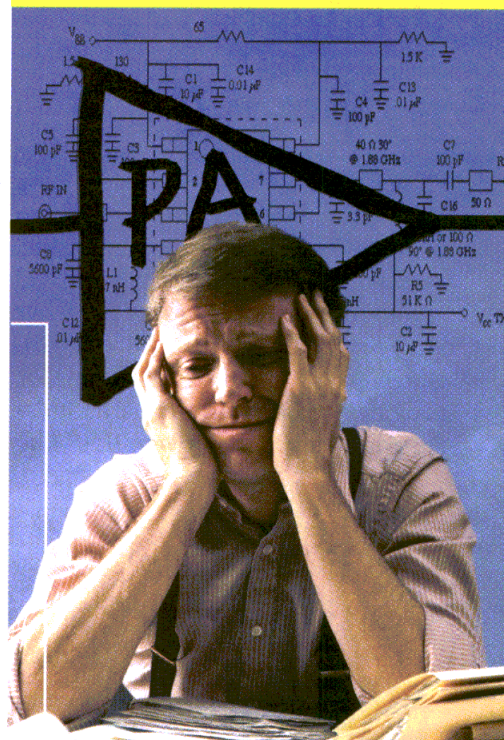
switching function protects the devices from over current situations by applying gate bias before the drain voltage is switched on. At 900 MHz, the amplifier provides 3 watts peak power for nominal 2 watt phone designs, with 2 watt peak power at 1800 MHz for 1 watt phones. The device is GPRS compatible and can also be used in PCS1900 cellular phones. The 3.6 volt MRFIC1859 is priced at \$5.95 each in \$10,000 quantity.

Motorola SPS
Circle #166

7 watt CDMA amplifier

Ophir RF offers Model GRF2030, providing 7 watts linear power output in the 1.805 to 1.880 GHz frequency band. High efficiency operation is obtained using unique microstrip networks and advanced GaAs FET devices. Reliability is enhanced with a voltage-regulated bias supply and EMI/RFI filtering. The amplifier can be used in many general purpose linear applications.

Ophir RF
Circle #167



I JUST NEED:

- ✓ LINEAR POWER
- ✓ NO EXTERNAL MATCHING
- ✓ SINGLE SUPPLY
- ✓ SMALL SIZE

The TrueTriangle solution

for wireless communications

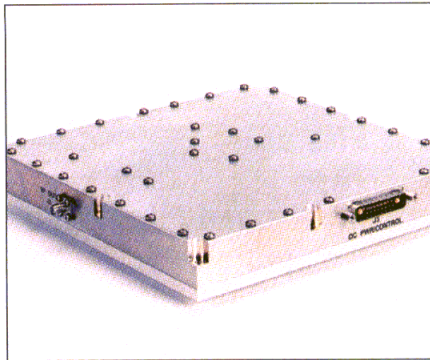


See us at Wireless Symposium, booth #727
and CTIA, booth #8441

Products

15 watt CDMA amplifier

MPD Technologies offers a new 15 watt CDMA power amplifier for the PCS transmit band of 1930 to 1990 MHz. The modular amplifier can be used in base station or tower-top installations, operating with a base plate temperature range of -30 to $+65^{\circ}\text{C}$. A circulator provides protection for transmission into any load mismatch. The



DC power requirement is 24 to 26 volts and the amplifier case measures $8.0 \times 8.0 \times 1.25$ inches. Monitor lines are provided for over-temperature, over-current, VSWR and device failure status.

MPD Technologies, Inc.

Circle #168

1.7 to 2.7 GHz laboratory amplifier

The SM1727-37HR from Stealth Microwave is a compact class A laboratory amplifier covering 1.7 to 2.7 GHz. The unit supplies 5 watts of output power ($P_{1\text{dB}}$) with a typical output IP3 of $+51\text{ dBm}$. Standard features include 33 dB of linear gain, output mismatch protection and internal cooling. Options include 20 dB of linear gain and a digital output power display. The unit includes a power supply for 110 VAC operation and measures $11 \times 8 \times 3.5$ inches in size.

Stealth Microwave

Circle #169

State-of-the-art Quality Crafted, Full Service Cable Manufacturing

Haverhill Cable and Manufacturing Corp.

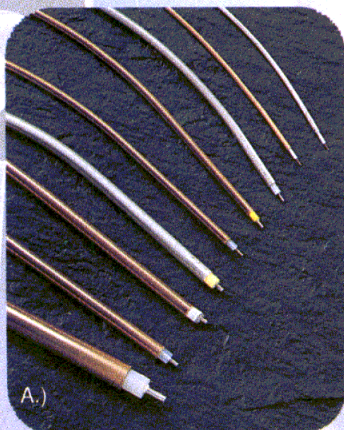


Semi-Rigid Coaxial Cable Specialists

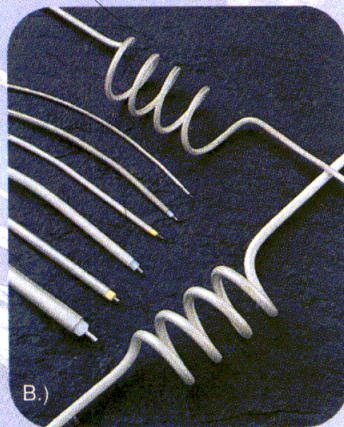
TEL (978) 372-6386 • FAX (978) 373-8024

P. O. BOX 8222, Haverhill, MA 01835

HCMC is a technology leader providing innovative state-of-the-art semi-rigid and flexible coaxial cable designs to the microwave, military and telecommunications industries. Using modern manufacturing techniques **HCMC** has developed a product line of superior semi-rigid hand formable and flexible coaxial cables and components.



A.)



B.)



C.)

A.) Easy Bend semi-rigid cables are fully qualified to MIL-C-17 and space applications. Various impedances and low loss versions also available.

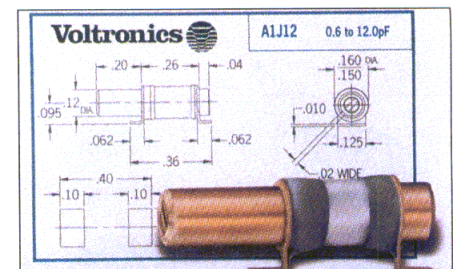
B.) Easy Bend II tinplated aluminum cables can be hand formed with exceptional ease with no spring back. Cables can be reshaped, eliminating the need for costly drawings. In many cases Easy Bend II aluminum cables can be substituted for flexible cables; increasing shielding effectivity, lowering loss, improving performance and lowering cost.

C.) For commercial and telecommunication applications where a flexible cable is required, H-Flex series cables are available offering performance and shielding effectivity greater than standard Flexible RG coaxial cables.

PASSIVE COMPONENTS

New 12 pF trimmer

Voltronics extends the range of the A1 series miniature trimmer capacitors to 12 pF. With 13 turns



of adjustment and positive stops, the model A1_12 is well-suited for tuning applications in amplifiers, filters and oscillators. The A1_12 is offered in PCB and SMT mountings. High voltage and non-magnetic versions are also offered. Q is >1000 at 200 MHz and self-resonance at 12 pF is 1.2 GHz. The A1_12 is \$4.00 in 1,000 quantities.

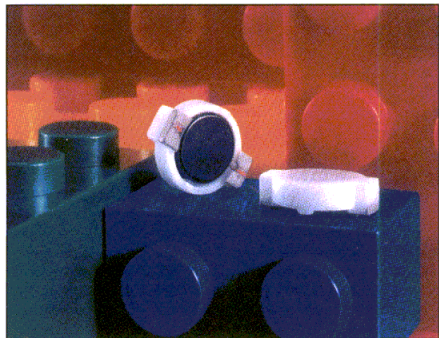
Voltronics Corporation

Circle #170

Products

Low profile inductors

The new DO1606 PowerWafer™ inductors from Coilcraft combine high inductance values with low profile construction. 19 inductance values are offered, from 1 μ H to 1

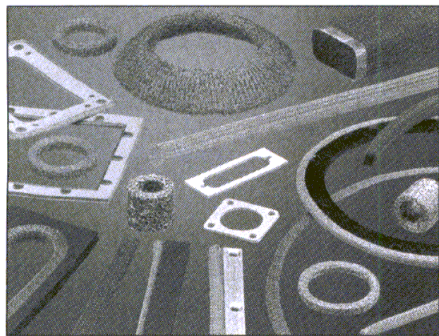


mH, with versions that are capable of handling up to 2.5 amps. The inductors are 2 mm high with a 5.3 \times 6.5 mm footprint. A ceramic cover offers an optimum surface for pick and place handling. The company provides PSPICE models at its web site. A typical inductor costs \$0.60 in quantities of 10,000.

Coilcraft
Circle #171

Wire mesh gaskets

Chomerics offers a broad line of metal-based EMI shielding gaskets



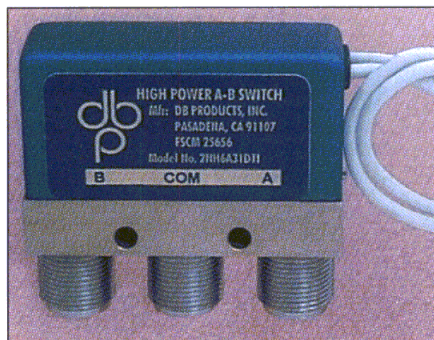
including knitted wire mesh, mesh over an elastomer core, oriented wires in elastomer and metal screen impregnated elastomers. These gaskets typically provide 60 to 100 dB of EMI shielding between 20 MHz and 10 GHz in applications where they are applied to seams and apertures in metal enclosures. Wire mesh prices start below \$0.25 per foot.

Chomerics
Circle #172

SIGNAL PROCESSING

SPDT RF switch handles DC to 3 GHz

DB Products introduces a high power SPDT coaxial switch. This A-B selector switch is rated for DC to

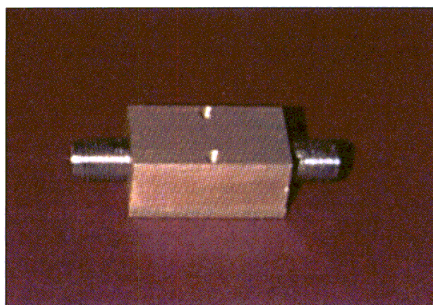


6 GHz with power handling of 1 kW CW at 1 GHz and 600 watts CW at 3 GHz. Specifications at 3 GHz include a maximum insertion loss of 0.15 dB, VSWR of 1.15:1 or better and isolation of at least 90 dB. RF connectors are 50 ohm type N. Coils may be 12, 15, 24 or 28 VDC. Special voltages can be provided, including AC.

DB Products
Circle #173

Small, low loss 2 GHz highpass filter

Sage Laboratories offers a high-pass filter in a package size under



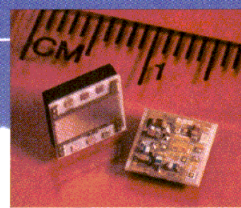
one inch. This selective 2.0 GHz filter has low loss of less than 3.0 dB from 2.0 to 16.0 GHz, VSWR of 2.0:1 maximum and 30 dB rejection at 1.9 GHz. Power handling capability is one watt. The package measures 0.89 \times 0.50 \times 0.39 inches, plus standard SMA connectors.

Sage Laboratories
Circle #174

Introducing the **TrueTriangle™** Celeritek's **NEW** HBT amplifier modules.

HIGHLY INTEGRATED SOLUTION

- ▶ LINEAR EFFICIENT POWER
- ▶ 50 OHM MATCH
- ▶ SINGLE, POSITIVE SUPPLY
- ▶ OPERATION AS LOW AS 3.2V
- ▶ INGaP HBT TECHNOLOGY
- ▶ 6MM SQUARE PACKAGE
- ▶ 1/2 THE BOARD SPACE



Celeritek's TrueTriangle

	CHP0230 Digital/Analog Cellular	CHP1232 Digital PCS
Frequency	824-849 MHz	1.85-1.91 GHz
Output Power	28.5 dBm	28.0 dBm
Linear Efficiency		
Analog	60%	—
Digital	40%	35%
Quiescent Current	50 mA	50 mA
Gain	30 dB	30 dB

CELERITEK

Delivering the solutions to wireless communications.

3236 Scott Boulevard
Santa Clara, CA 95054

Ph: (408) 986-5060 • Fax: (408) 986-5095
e-mail: truetriangle@celeritek.com
www.celeritek.com

We Want to Show You How Quick Circuit Stacks up.

- Accurate Drilling, Milling, Routing
- Plated Through Holes
- Multilayer Capability
- Better Registration and Mechanics

*Sample Boards and Demos
show why we
offer the best solution.



T-TECH, INC.

5591-B New Peachtree Rd. • Atlanta, Georgia 30341 USA
voice: 770.455.0676 fax: 770.455.0970
email: sales@t-tech.com • http://www.t-tech.com

See us at Wireless Symposium, booth #1408

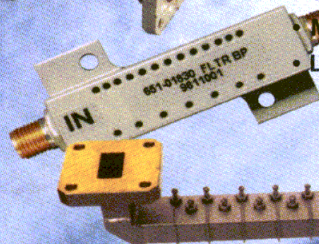
Circle 45

Filters to 50 GHz

Custom Filters Designed to Your Specifications



- Waveguide
- Stripline/Microstrip
- Transmission Line
- Miniature/Subminiature
- Lumped Constant



Foreign
Distributors
Sought

MFC

MICROWAVE FILTER COMPANY, INC.

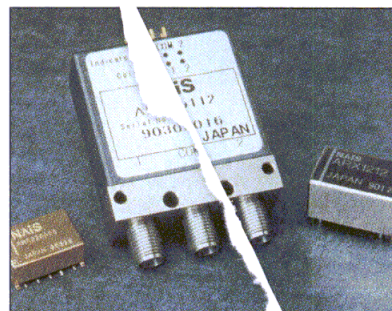
6743 KINNE STREET • EAST SYRACUSE, NY 13057
800-448-1666 • 315-438-4700 • FAX: 315-463-1467
e-mail: mfcsales@microwavefilter.com

Circle 46

Products

RF relays switch signals up to 26.5 GHz

Aromat announces three new NAI's brand relays for switching high frequency 50 ohm signals. The RX small microwave relay covers 300 kHz to 2.5 GHz with 0.2 dB or less insertion loss and 60 or greater isolation. The relay also features 1.2:1 (max.) VSWR. Ultra-small RA relays are used in LAN systems, ADSL, cable modems and many other applications. They include a metal cover for grounding and shielding, and operate with signals up to 1 GHz. Insertion loss is 0.3 dB or less with a minimum isolation of 20 dB. The cost competitive RD coaxial SPDT relay provides stable RF performance and long life. It has a range up to 26.5 GHz with power consumption of 700 mW. Insertion loss is 0.5 dB and isolation is 60 dB at 18 GHz. The RD relays are available in latching, fail safe and TTL drive types, in 12 and 24 VDC.

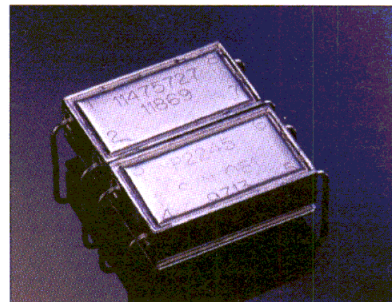


Aromat

Circle #175

High stability filter sets

Model P-2245 from Signal Technology Corporation is a matched set of low loss linear phase diplexer filters for use in I/Q modulation/demodulation systems. They are designed for demanding applications including space systems. Available in the VHF frequency range, the filter sets feature amplitude and delay tracking of ± 0.1 dB and ± 100 ps respectively over a wide temperature range of -40 to $+85^\circ$ C. Insertion loss is ± 0.1 dB, phase linearity is ± 2 degrees and unit isolation is 80 dB minimum. A welded hermetic housing is standard. Pricing is \$480 per set in quantities of 100 to 249.



Signal Technology Corporation

Circle #176

Two watt absorptive solid state switch

American Microwave's model SWN-218-2DT, with Options 0518 and HPR2W, is a SP2T non-reflective switch that will handle 2 watts power from 500 MHz to 18 GHz with 0.85 dB max. insertion loss and 80 dB isolation at 18 GHz, and 95 dB isolation at 500 MHz.

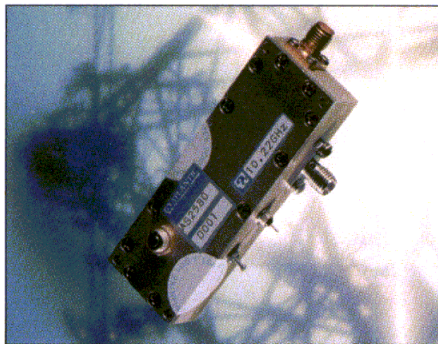
American Microwave

Circle #177

Products

Microwave 6 to 16 GHz frequency converters

Atlantic Microwave's AFC series of frequency converters are designed for use in terrestrial microwave links. A GaAs FET dielectric resonator oscillator is the heart of each unit, feeding a



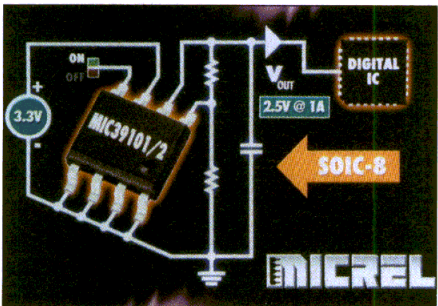
microstrip double balanced mixer that can act as either an up- or downconverter. Units can be mechanically tuned over ± 30 MHz and after being set maintain a frequency stability of ± 120 ppm over -10 to $+60^\circ$ C. A higher performance mixer diode is optional, providing a $+14$ dBm 1 dB compression point and $+24$ dBm input IM3. Another option is electrical tuning or frequency modulation up to ± 3 MHz deviation.

Atlantic Microwave
Circle #178

SEMICONDUCTORS

Ultra low dropout regulator

Low power wireless devices can benefit from a new ultra low dropout regulator from Micrel



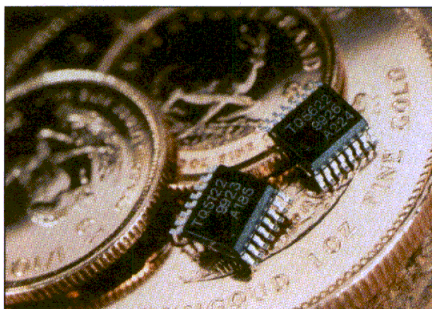
Semiconductor. The regulators convert 3.3 to 2.5 volts, or 2.5 to 1.8 volts, at up to one amp to power low voltage DSP and PLD ICs. The

MIC39101 is a fixed output regulator, while the MIC39102 has an adjustable output voltage down to 1.25 volts. The dropout voltage at full load is 410 mV. These devices are provided in a thermally enhanced SO-8 package and are priced starting at \$1.50 each in 1,000 piece quantities.

Micrel Semiconductor
Circle #179

TDMA receiver ICs

TriQuint Semiconductor now offers the TQ5122 cellular band receiver and TQ5622 PCS band receiver ICs. These complementary



devices are designed for use in IS-136, TDMA or equivalent wireless handsets. The ICs include power down modes to "sleep" at less than $100 \mu\text{A}$ current drain. Conversion gain is 18.5 dB and 17.5 dB for the cellular and PCS models respectively. IIP3 is typically greater than -9 dBm and the noise figure is better than 2.8 dB for each device. Unit price is \$2.43 in quantities of 1,000.

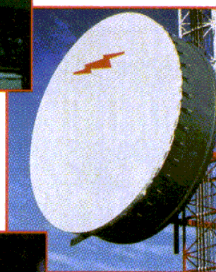
TriQuint Semiconductor
Circle #180

GaAs low noise amplifier

RF Micro Devices has introduced the RF2365, a low noise amplifier with high dynamic range for front end applications in the PCS and 2.4 GHz frequency range. The device features 1.6 dB and 1.75 dB noise figures at 1850 and 2.45 GHz respectively, with 18 dB and 15.5 dB gain at those frequencies. Offered in an extremely small SOT23-5 plastic package, the ICs are priced at \$0.66 each in quantities of 10,000.

RF Micro Devices
Circle #181

Enhance Microwave Performance



Registered
ISO 9001

ECCOSORB®, Emerson & Cuming Microwave Product's complete range of microwave absorbing materials, effective in controlling electromagnetic interferences from 0.6 through 75 GHz. Products Include:

- Cavity damping-surface current absorbing elastomers & foams
- Broadband & tuned specular absorbing elastomers & foams
- Lossy magnetic machinable rod & sheet series for terminations & loads

We specialize in providing custom shaped ECCOSORB® absorbing materials, ECCOSTOCK®, dielectrics and ECCOSHIELD® shielding products.

EMERSON & CUMING
MICROWAVE PRODUCTS

the recognized global leader in microwave absorbing materials.

800-650-5740

28 York Avenue, Randolph, MA 02368
781/961-9600 • fax 781/961-2845

email: sales@emersoncumingmp.com

www.emersoncumingmp.com

Circle 26

See us at Wireless Symposium, booth #839

Products

FREQUENCY CONTROL

VCXO covers telecom frequencies

Connor-Winfield offers an extensive range of 5×7 mm HCMOS surface mount VCXOs specifically designed for telecom applications. The VCXO series is offered in both 3.3 and 5 volts designs, at frequen-

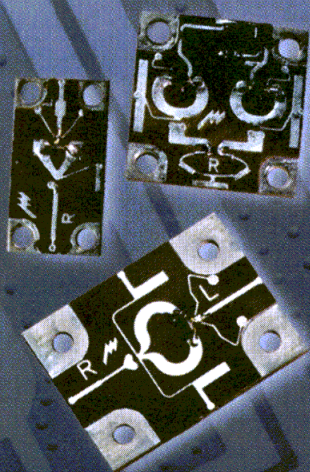


cies from 4 to 45 MHz at 3.3 volts, or 1 to 52 MHz at 5 volts. Standard or extended temperature ranges are offered, with frequency tolerances to 25 ppm and voltage control deviations up to ± 100 ppm. Standard telecom frequencies are available from stock.

Connor-Winfield Corporation
Circle #182

Surface Mount High Performance Microwave Mixers

Choose REMEC Magnum as part of your Total Microwave Solution



Reaching high frequencies with low conversion loss and high isolations is now possible in a series of surface mount mixers from REMEC Magnum. Convert signals up to 20 GHz without connectors, and without manual installation of ribbon leads. These surface mount mixers can be placed atop your circuit and reflow soldered along with all the rest of your surface mount components.

Call us with your application information and we'll match a design to your requirements.

Typical Performance at 25°C

Frequency (GHz)			LO PWR NOM ⁽¹⁾ dBm	CONV LOSS dB	ISOLATION		MODEL NUMBER
RF	LO	IF			LO/RF dB	LO/IF dB	
3.6-4.3	4.7-5.4	DC-1.5	+10	5.2	42	30	MC24SMD-3
5.8-6.5	4.7-8.5	DC-2.0	+10	4.8	43	32	MC34SMD-3
3.5-15.0	3.5-15.0	DC-4.0	+10	5.5	35	30	MC54SMD-7
10.9-12.8	11.8-14.0	DC-2.0	+10	5.5	41	42	MC64SMD-3
13.8-14.7	11.8-14.0	DC-2.0	+10	5.7	36	28	MC74SMD-3

⁽¹⁾ Other LO power levels (+7, +13, +18 dBm) available.

The Total Microwave Solution

Email inquiries to sales@remecmagnum.com
Visit our website at www.remec.com

1-877-66-REMEC

REMEC Magnum, Inc.
1990 Concourse Drive
San Jose, CA 95131
Fax 408.432.1551



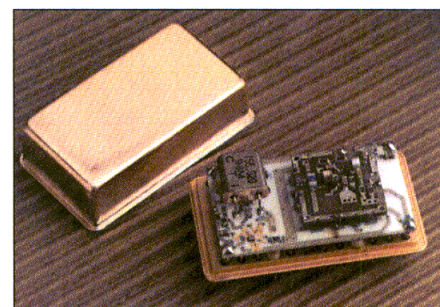
REMEC

Circle 70

Building solutions
through teamwork.

PLL clock modules

Champion Technologies offers custom designed PLL modules for high speed clock, tracking and synchronization applications at fre-

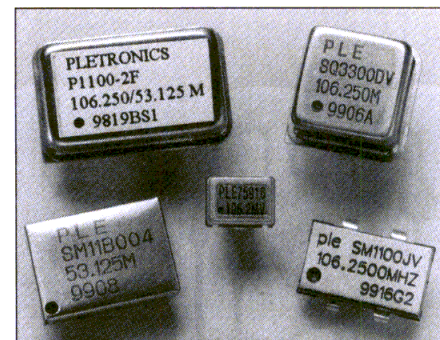


quencies up to 2.488 GHz. A VCXO portion using high frequency inverted-mesa crystals is combined with a low noise microstrip resonator based VCO to obtain the final output frequency.

Champion Technologies
Circle #183

Oscillators for fibre channel

Pletronics offers oscillators in 106.25 MHz and 53.125 MHz frequencies for use in fibre channel



telecom systems. Options include packaging, temperature range and frequency stability. Prices start at \$1.50 each for 10,000 pieces.

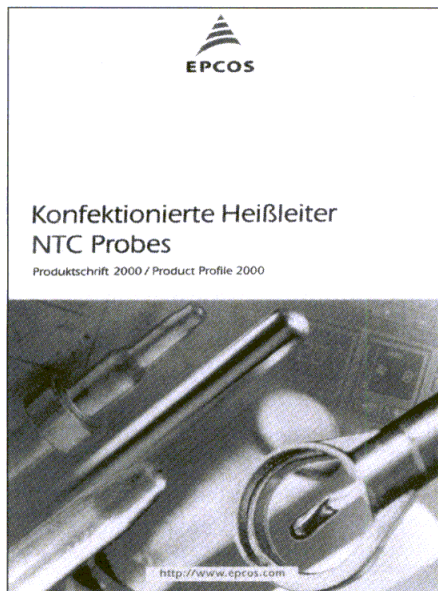
Pletronics, Inc.
Circle #184

Products

LITERATURE

Two new catalogs

EPCOS, Inc. has published two new catalogs, NTC Probes and NTC Thermistor Sensors. Thermistor-controlled electronics are the foundation of many products designed for comfort and convenience. Producers of automobiles, appli-



ances and heating installations rely on the high measuring accuracy of NTC thermistors for exact, energy-saving temperature regulation. The NTC Thermistor Probes catalog provides photographs, schematics and descriptions of 17 devices for home appliance, automotive and heating appliance applications. The NTC Thermistor Sensors catalog provides detailed schematics and technical information about four glass-encapsulated and two ceramic devices for home appliance, automotive, data system and power engineering applications.

EPCOS, Inc.
Circle #185

DSP book

Analog Devices has announced a new DSP book that explains the techniques of digital signal processing (DSP). *The Scientists and Engineers Guide to Digital Signal Processing*, by Steven W. Smith, Ph.D., is directed at scientists and

engineers who need the power of DSP but do not have time to learn the rigorous theory and mathematics. The book covers a wide range of topics, starting with the elementary techniques of convolution, Fourier analysis and analog-to-digital conversion. Advanced chapters describe the methods used in audio and image processing, data compression and neural networks. An extensive

section on digital filters describes how easy-to-use algorithms can solve difficult filtering problems. The author holds advanced degrees in Physics and Electrical Engineering from the University of Utah and has spent the last 15 years directing the development of instrumentation systems.

Analog Devices
Circle #186

RF and Microwave Filters

Choose REMEC as part of your Total Microwave Solution

4-Week Deliveries Available
REMEC offers Quick Reaction Capability (QRC) for low cost, rapid turn around filter prototypes.

Applications

- ▶ Airborne: Radar, Electronic Warfare, Electronic Support Measures, ECCM, CNI, IFF
- ▶ Space: Telemetry, Receivers, Transmitters, IF, Radar
- ▶ Ground Based: Satcom, Transceivers, Communications, Jammers, Radar

Whether you are looking for support on rapid filter prototyping or large volume production, and require standard filter packages or custom designs, REMEC has the solution. REMEC filter designs include:

- Miniature Lumped Element
- Cavity
- Waveguide
- Suspended Substrate
- Interdigital

REMEC filter products offer industry leading quality and performance with competitive pricing. Contact REMEC today for information on products for your RF and Microwave filter requirements.

The Total Microwave Solution

*Email inquiries to sales@remec.com
Visit our website at www.remec.com*

1-877-66-REMEC

REMEC, Inc.
9404 Chesapeake Drive
San Diego, CA 92123
Fax 858.505.3353

Circle 74

REMEC
Building solutions through teamwork.

Products

Specialty wire brochure

A new illustrated brochure describes the full range of specialty wire products from AMETEK Specialty Metal Products, a manufacturer of custom-shaped wire. Specialty wire products are available in a variety of alloys, including aluminum, copper, nickel, stainless steel and custom-engineered alloys. AMETEK offers wire in a broad

range of shapes: round, square, rectangular, half-round, hex, flat, bunched and custom shapes and in sizes from rod size to fine wire. Among the available packaging options are reels, spools, barrels, hex pails, coils, cut-to-length, bundles, and layer level wound reels. AMETEK is a manufacturer of metal powder, strip, wire, and bonded products, holding numer-

ous patents in technically advanced metallurgical products. Its expertise in wrought powder technology enables it to manufacture nickel



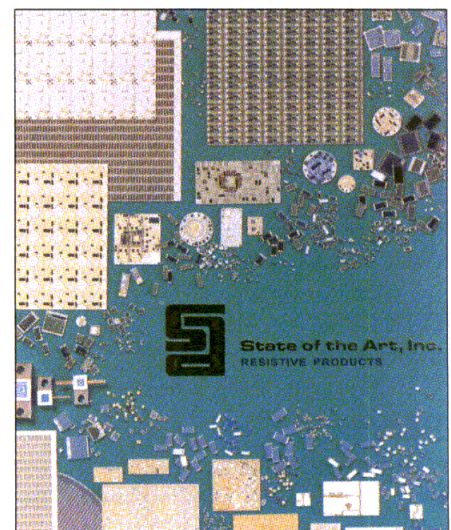
and custom alloy wire with purity, consistency and close compositional control. It uses a variety of forming technologies: drawing, rolling, and shaping; has in-house tooling capabilities; and provides experienced engineering support.

AMETEK

Circle #187

Resistive products catalog

State of the Art, Inc. has published a 28-page catalog covering its entire line of resistive products.



The catalog includes SOTA's high-frequency resistors and chip attenuators, which are designed for RF applications such as base stations

The advertisement for the 'PEAK PERFORMANCE EXCELLENT HARMONICS' amplifier features a central image of a yellow integrated circuit (IC) chip. The chip is labeled 'ARJ109', 'BE0', and 'USA'. Above the chip, the text 'PEAK PERFORMANCE' is written in large, bold, yellow letters, and 'EXCELLENT HARMONICS' is written in blue letters below it. To the right of the chip, the text '0.5 TO 300 MHz' is written in large, bold, yellow letters, and 'Cascadable Amplifier' is written in large, bold, yellow letters below it. The background of the advertisement is a dark blue grid with a yellow lightning bolt graphic.

Specifications are typical.

Frequency:	0.5 - 300 MHz	Reverse Isolation	17 dB
Small Signal Gain	10.8 dB	Voltage	+15 V
Gain Flatness	$\leq \pm 0.2$ dB	Intermodulation	
Noise Figure	4.5 dB	Third Order	+44 dBm
SWR Input	1.5:1	Second Order Two Tone	+75 dBm
SWR Output	1.5:1	Second Order Harmonic	+81 dBm
Power Output		DC Current	235.0 mA
@1dB comp.	+28.5 dBm	Package	10-pin Gullwing



Signal Processing Components & Subsystems

COUGAR
COMPONENTS

408-522-3838 • fax 408-522-3839
email cougar.amps2@cougarcorp.com

384 Santa Trinita Ave • Sunnyvale, CA 94086 • www.cougarcorp.com

See us at Wireless Symposium, booth #1229

Circle 61

Products

and antennas, and in microwave applications for power dividers and power amps, where reduction in an electrical signal is required. Also included is information of SOTA's high-reliability thick and thin film chip resistors, available with TCRs from ± 25 ppm to ± 100 ppm; tolerances to 0.5 percent; and with wire or epoxy bondable, or solderable terminations. Also detailed are SOTA's MIL-PRF-55342 QPL thick and thin film chip resistors, which have established reliability levels of M, P, R, S, and T (space level). The film resistors are designed for use in mission-critical applications, such as manned space flight, life support systems, and human implantable devices. Special application resistors are described, such as high power, high voltage, power moisture, and high value resistors, zero ohm, multi-tap resistors and attenuators. A 5-page section covers both thick and thin film surface mount resistor networks, including SOTA's MIL-PRF-914 QPL.

State of the Art, Inc.
Circle #188

Frequency sources and SAW devices catalog

Micro Networks Corporation has just released a comprehensive 24-page shortform catalog for its wide range of microelectronic products, used in a variety of applications, including network servers, telecommunication systems, instrumentation, and defense electronics. Products include frequency sources (fixed-frequency oscillators, voltage-controlled oscillators, and phase-locked products and synthesizers); Surface Acoustic Wave (SAW) products (filters, correlators, receivers, and delay lines); data conversion products; and custom microelectronics. Engineers will find product descriptions and specifications, along with mechanical package drawings and ordering information.

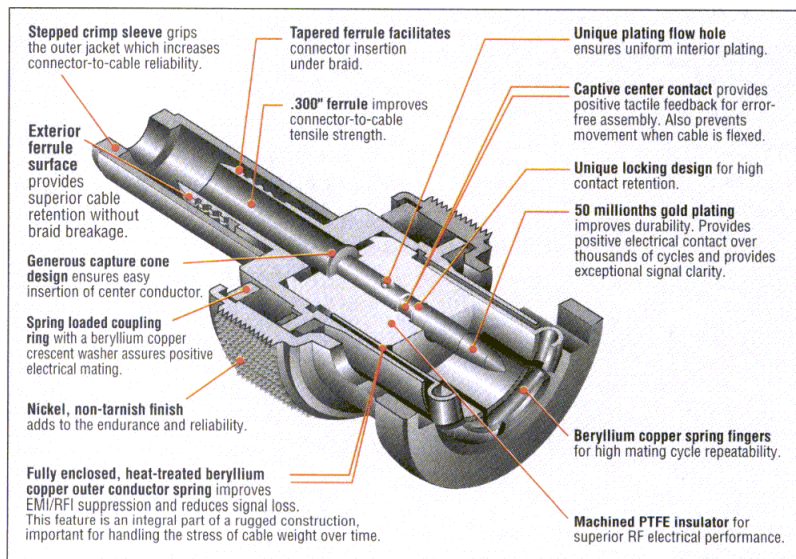
Micro Networks
Circle #189

Wireless communications cables catalog

A new 16-page catalog featuring low loss wireless communications cables, including coaxial antenna feeders, jumper cables and low inductance power cables, is being offered by Montrose/CDT of Auburn, Massachusetts. The *Cables for Wireless Communications*

Systems Catalog describes WCX Series coaxial cables which feature gas-injected foam polyethylene dielectrics for ultra low loss characteristics, and the RGX Series with irradiated dielectrics. These cables provide electrical or cost advantages over conventional 50 ohm types such as RG 8/, 58, 142, 213, 316, and 400, claims the firm. Providing an overview of their

More Reliable For A Reason...



Better yet, make that 16 reasons!

If signal clarity and reliability are essential to your application, here are 16 solid reasons to select Trompeter connectors. Our 35-year commitment to producing dependable connectors, coupled with world class lead times and 99% on-time delivery, has made us the supplier of choice for broad-band, high frequency BNC's.

Need one more reason to choose Trompeter? Visit our website for 24/7, internet-fast service. You can access product information, download drawings, obtain a quote and purchase products that ship next day.

It's all about reliability.



TROMPETER
® ELECTRONICS, INC.

RF SHIELDED CONNECTORS

Circle 63

An ISO 9001 Registered Company

GET QUOTES FAST...VISIT OUR WEBSITE TODAY!

www.trompeter.com or call: 1-800-982-2629



manufacturing capabilities and quality procedures, the 16-page catalog also includes complete product descriptions, specifications and ordering information for both their WCX and RGX Series coaxial cables.

Montrose/CDT
Circle #190

Semiconductor products selection guide

Richardson Electronics, Ltd. announces the release of United Monolithic Semiconductors' new selection guide. Richardson is the worldwide distributor for United Monolithic Semiconductors (UMS). Included in the UMS selection guide are components for point-to-point and point-to-multipoint microwave radios to 60 GHz. Also included are 5.8 GHz ISM band products, amplifiers, switches, frequency generation products, mixers and attenuators for application from DC to 80 GHz. Best known for their work in millimeter wave, UMS designs and produces devices and integrated circuits based on advanced GaAs MMICs in high volume quantities with guaranteed quality. UMS provides key components for mobile communication, automotive radar and point-to-point and point-to-multipoint radio links.

Richardson Electronics, Ltd.
Circle #191

Telecom transformers

Just released by Bel Fuse Inc., a manufacturer of magnetic components for high speed data transmission and networking applications, is a 274-page Telecom Magnetics catalog representing more than 270 Bel components. This comprehen-



sive new literature is designed for easy reference, boasting tabbed sections for devices engineered for high frequency, ISDN, DSL, modem and power applications. To further assist engineers in specifying IC-compatible transformers and magnetic components, a "Product Locator" that indicates part numbers and corresponding data sheets, types of ports supported (single, dual and octal) and cross references to transceiver IC manufacturers, is provided. The Bel telecom transformers featured are available in surface mount and through-hole packages, and are engineered to interface with all major IC manufacturers' chip sets including Globespan, Conexant, Level One, Motorola, Lucent, AMD, Siemens and Analog Devices. Chokes, POTS filters, and inductors are also offered. Moreover, the catalog provides complete electrical specifications, schematics, circuit diagrams and application notes.

Bel Fuse Inc.
Circle #192

Get Your Share of Attention!

Send your company's latest product and literature announcements to *Applied Microwave & Wireless*.

Our editors select dozens of products to feature in each monthly issue — we choose them for their importance to RF/microwave and wireless system designers, to present new companies and new product lines, and to give as many companies as possible their share of attention.

Send press releases to:

Applied Microwave & Wireless
4772 Stone Drive
Tucker, GA 30084
E-mail: amw@amwireless.com

Include a color photograph, if available.

NEW PRODUCTS

RF/IF MICROWAVE COMPONENTS

NO. 67



FROM
\$4.45

RF TRANSFORMERS HAVE

4:1 IMPEDANCE 1.5 TO 600MHz

These broad band TCM4-6T surface mount RF transformers from Mini-Circuits operate in the 1.5 to 600MHz band with 4:1 impedance ratio. Referenced to midband loss (0.6dB typ), insertion loss is 1dB from 3MHz to 350MHz, 2dB in the 2 to 400MHz 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 CATV plus VHF/UHF transmitters and receivers. RF power is 250mW (max.).



FEATURED PRODUCT

BLUE CELL
TECHNOLOGY

FROM
\$8.95

0.07" MIXERS PERFORM IN HIGHER FREQUENCY DESIGNS

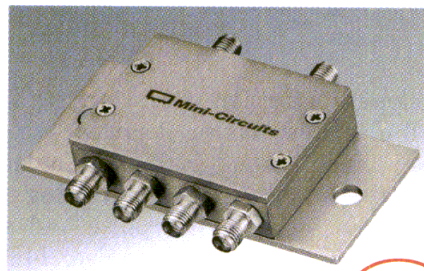
Mini-Circuits patented family of Blue Cell™ mixers deliver a unique combination of low conversion loss, superb temperature stability, thin profile, and low cost to higher frequency designs. This level 7 (LO) MBA-671 model spans 2400MHz to 6700MHz with 36dB L-R, 26dB L-I isolation and low 6.5dB midband conversion loss (all typ). Operating temperature is -40°C to +85°C (max.) and applications include satellite, ISM, and PCMCIA. Available off-the shelf.



FROM
\$6.95

LEVEL 7 (LO) MIXERS IDEAL FOR VHF/UHF RECEIVERS

Mini-Circuits low profile 2500MHz to 3200MHz ADE-32 frequency mixers measure only 0.112" (max.) in height allowing engineers to develop smaller surface mount wireless products. Open case design also allows water wash to drain eliminating the possibility of residue entrapment. Electrically, these mixers typically display low 5.4dB conversion loss, +15dBm IP3 at center band, and good 32dB L-R, 30dB L-I isolation. Maximum RF power rating is 200mW. Patent pending.



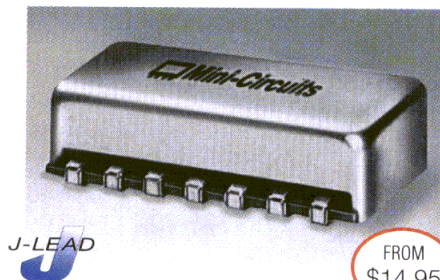
FROM
\$89.95

DC TO 5GHz SPDT SWITCH HAS VERY HIGH ISOLATION

Mini-Circuits ZASW-2-50DR is a DC to 5GHz connectorized single pole double throw (SPDT) reflective switch incorporating a high speed TTL driver for fast 10nsec (typ) switching speed. Typically, isolation is 75dB at 2GHz, 1dB compression is 19dBm at center band, and maximum operating temperature range is -55°C to +100°C. The switch is ideal for transmitter/receiver isolation and automated switching networks. Available from stock.

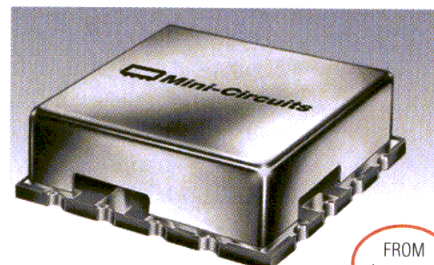
2WAY 150 TO 350MHz SPLITTER FOR SURFACE MOUNT DESIGNS

Mini-Circuits has unveiled the JSPQ-350, a 2way-90° power splitter/combiner operating in the 150 to 350MHz band with 20dB isolation, 0.5dB amplitude and 1 degree phase unbalance, and very good 1.28:1 in/out VSWR (all typ). Insertion loss is 0.5dB typical, which is an average of coupled outputs less 3dB. Package height is 0.250" (max.).



J-LEAD

FROM
\$14.95



FROM
\$12.95

12V VCO PROVIDES 50 TO 100MHz OCTAVE BAND TUNING

Mini-Circuits has introduced a compact, value priced 50 ohm voltage controlled oscillator. Typically, this 12V, 20mA (max. current) ROS-100 model provides 50 to 100MHz octave band tuning, low -105dBc/Hz SSB phase noise at 10kHz offset, and excellent -30dBc harmonic suppression. The miniature 0.5"x0.5"x0.18" size conserves real estate, and applications include test instruments such as signal generators. Maximum operating temperature is -55°C to +85°C.

Mini-Circuits®

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



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

ISO 9001 CERTIFIED

US 84 INT'L 94
CIRCLE READER SERVICE CARD

F 317 Rev. Org.

Unfiltered FQPSK: Another Interpretation and Further Enhancements

Part 1: Transmitter implementation and optimum reception

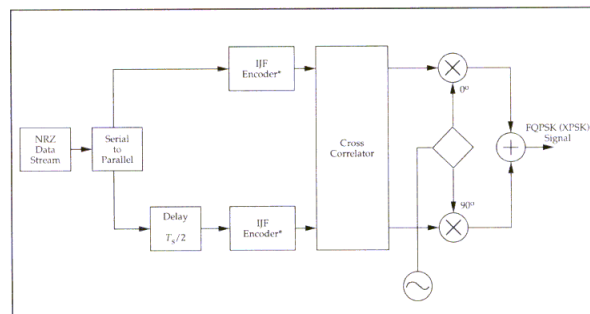
By **Marvin K. Simon** and **Tsun-Yee Yan**
Jet Propulsion Laboratory

A new interpretation of unfiltered Feher-Patented Quadrature Phase-Shift-Keying (FQPSK) is presented, readily identifying a means for spectral enhancement of the transmitted waveform as well as an improved method of reception. The key to these successes is the replacement of the half-symbol by half-symbol mapping, originally used to describe FQPSK by a symbol-by-symbol mapping operation combined with memory. The advantages of such an interpretation are two-fold. In particular, the original FQPSK scheme can be modified so that the potential of a waveform slope discontinuity at the boundary between half symbols is avoided without sacrificing the “constant” envelope property of the transmitted waveform. Also, a memory receiver can be employed to improve error probability performance relative to previously proposed symbol-by-symbol detection methods. The analysis presented in this paper does not include other versions of FQPSK, such as FQPSK-B, which is currently being considered for military applications.

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

Introduction

In its generic form, Feher-Patented Quadrature Phase-Shift-Keying (FQPSK), as patented [1] and reported in the recent literature [2-3], is conceptually the same as the *cross-correlated phase-shift-keying* (XPSK) modulation technique introduced in 1983 by Kato and Feher [4].¹ This technique was in turn a modification of the previously introduced (by Feher et al [6]) *interference and jitter free QPSK* (IJF-QPSK), with the express purpose of reducing



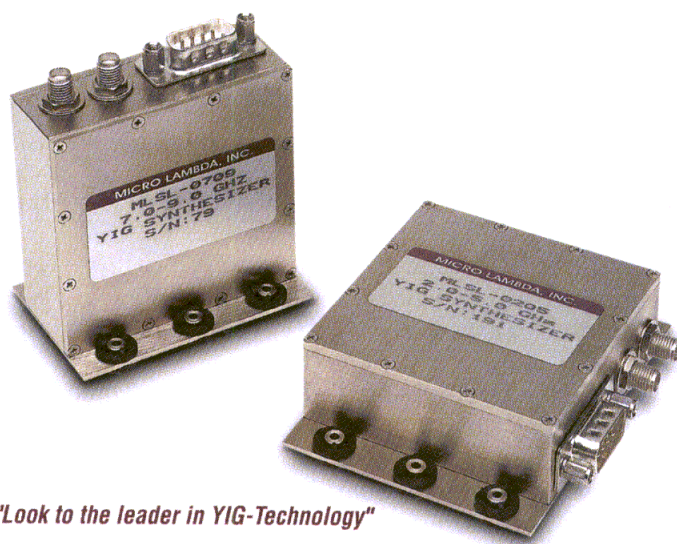
▲ **Figure 1. Conceptual block diagram of FQPSK (XPSK).** Note that what is referred to as an “IJF Encoder” is in fact a mapping function without any error-correcting capability.

the 3 dB envelope fluctuation characteristic of IJF-QPSK to 0 dB, thus making it appear constant envelope², which is beneficial in nonlinear radio systems. (It is further noted that using a constant waveshape for the even pulse and a sinusoidal waveshape for the odd pulse, IJF-QPSK becomes identical to the staggered quadrature overlapped raised cosine (SQORC) scheme introduced by Austin and Chang [7]).

The means by which Kato and Feher achieved their 3 dB envelope reduction was the introduction of an intentional but controlled amount of cross correlation between the inphase (I) and quadrature (Q) channels. This cross correlation operation was applied to the IJF-QPSK (SQORC) baseband signal prior to its modulation onto the I and Q carriers (Figure 1). Specifically, this operation was described by mapping in each half symbol the 16 possible combinations of I and Q channel waveforms present in the SQORC signal into a new³ set of 16 waveform combinations, chosen in such a way



Low Power, Low Noise YIG-Based Synthesizers *for Digital Radios*



"Look to the leader in YIG-Technology"



Micro Lambda, Inc. a leader in the development of next-generation YIG devices now offers YIG-Based Frequency Synthesizers covering the 2-12 GHz frequency range. Designed specifically for Digital Radio ODU's and harsh commercial environments, these synthesizers offer excellent integrated phase noise characteristics over carrier offset frequencies from 10 kHz to 10 MHz.

Tunable bandwidths of either 2 GHz or 3 GHz are available as standard products. This results in fewer numbers of synthesized sources required for a variety of Digital Radio frequency plans. Millimeter-Wave frequencies can easily be obtained using frequency multipliers to obtain output frequencies between 24 GHz through 44 GHz.

Applications include QAM and QPSK modulated Digital Radio's and a multitude of general purpose applications.

Features

- 2 - 12 GHz Frequency Coverage
- Excellent Integrated Phase Noise Characteristics
- Compact Size
- 3-Line Serial Interface
- Low Prime Power
- 500 kHz Step Size
- Internal Memory
(last frequency programmed - recall)

MLSL-Series Synthesizers

This series of synthesizers utilize an external 1 to 50 MHz crystal reference oscillator to generate tunable frequencies covering the 2 - 12 GHz range. Output power levels of +12 dBm to +15 dBm are offered depending on frequency, with a standard tuning step size of 500 kHz. Input tuning commands are via 3-Line Serial interface. The size of these compact units is 2.5" x 2.5" x 1.0" without mounting plate and consume less than 6 watts of prime power. The units have an internal memory capability which "recalls" the last frequency programmed when the prime power is removed and reapplied. Standard models include 2-4 GHz, 4-6 GHz, 5-7 GHz, 7-9 GHz and 9-11 GHz. Specialized frequency ranges are easily implemented utilizing the versatile synthesizer architecture.



48041 Fremont Blvd. Fremont, CA 94538 (510)770-9221 mrolambda@aol.com www.micro-lambda.com

that the cross correlator output is time continuous and has unit (normalized) envelope⁴ at all I and Q uniform sampling instants.

Because the cross correlation mapping is based on a half symbol characterization of the SQORC signal, there is no guarantee that the slope of the cross correlator output waveform is continuous at the half symbol transition points. In fact, we will show that for a random data input sequence, such a discontinuity in slope occurs one quarter of the time.

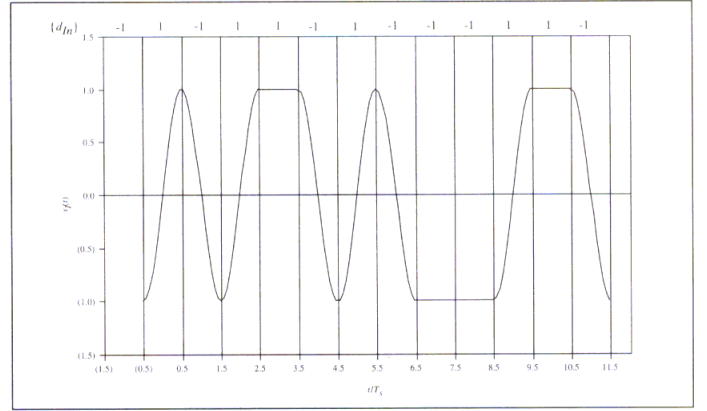
It is well known that the rate at which the side lobes of a modulation's power spectral density (PSD) roll off with frequency is related to the smoothness of the underlying waveforms that generate it. That is, the more derivatives of a waveform that are continuous, the faster its Fourier transform decays with frequency. Thus, since the first derivative of the FQPSK waveform is discontinuous (at half symbol transition instants) on the average one quarter of the time, one can anticipate that an improvement in PSD rolloff could be achieved if the FQPSK cross correlation mapping could be modified so the first derivative is always continuous.

Restructuring the cross correlation mapping into a symbol-by-symbol representation will place the slope discontinuity referred to above in evidence and will be particularly helpful in suggesting a means to eliminate it. This representation also has the advantage that it can be described directly in terms of the data transitions on the I and Q channels. Thus, the combination of IJF encoder and cross correlator can be replaced simply by a single modified cross correlator. The replacement of the conventional FQPSK cross correlator by this modified cross correlator, which eliminates the slope discontinuity, leads to what we shall refer to as *enhanced FQPSK*. We will show that not only does enhanced FQPSK have a better PSD (in the sense of reduced out-of-band energy) than conventional FQPSK, but from a modulation symmetry standpoint, it is a more logical choice.

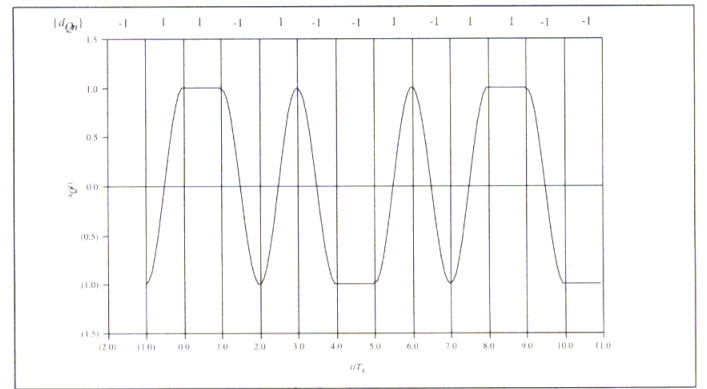
A further and more important advantage of the reformulation as a symbol-by-symbol mapping is the ability to design a receiver of FQPSK or enhanced FQPSK that specifically exploits the correlation introduced into the modulation scheme to significantly improve power efficiency or equivalently, error probability performance. Such a receiver, which takes a form analogous to those used for trellis-coded modulations, will be shown to yield significant performance improvement over receivers that employ symbol-by-symbol detection, thus ignoring the inherent memory of the modulation.

Review of IJF-QPSK and SQORC

The IJF-QPSK scheme (alternately called FQPSK-1) is based on defining waveforms $s_o(t)$ and $s_e(t)$, which are respectively odd and even functions of time over the symbol interval $-T_s/2 \leq t \leq T_s/2$, and then using these and their negatives $-s_o(t)$, $-s_e(t)$ as a 4-ary signal set for



▲ Figure 2a. Inphase IJF encoder output.



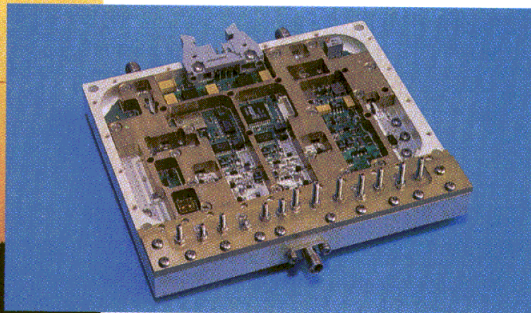
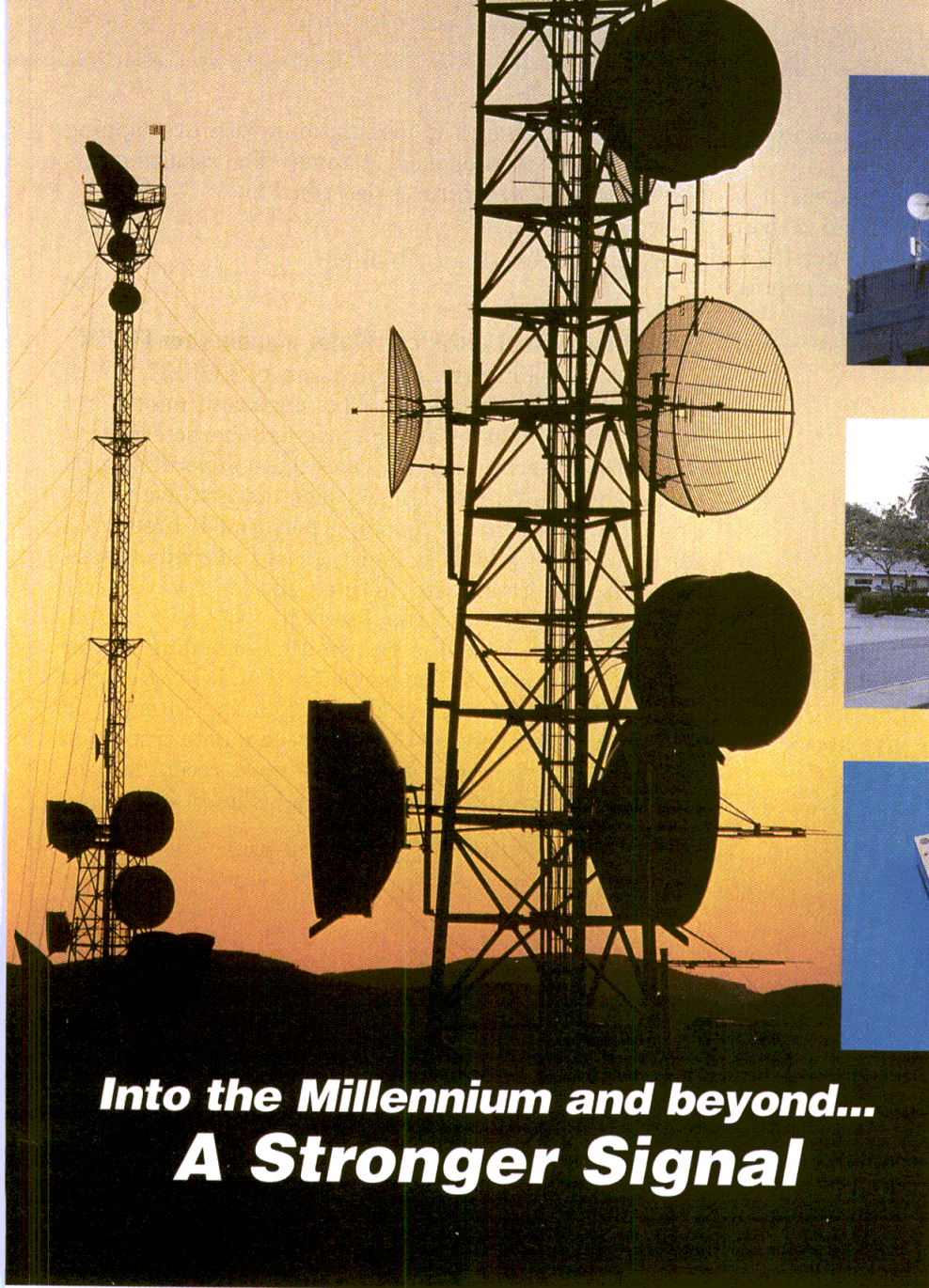
▲ Figure 2b. Quadrature phase IJF encoder output.

transmission in accordance with the values of successive pairs of data symbols in each of the *I* and *Q* arms. Specifically, if $d_{I,n}$ denotes the *I* channel data symbols in the interval, $(n-1/2)T_s \leq t \leq (n+1/2)T_s$, then the transmitted waveform $x_I(t)$ in this same interval would be determined as follows:

$$\begin{aligned} x_I(t) &= s_e(t-nT_s) \triangleq s_0(t-nT_s) \text{ if } d_{I,n-1}=1, d_{I,n}=1 \\ x_I(t) &= -s_e(t-nT_s) \triangleq s_1(t-nT_s) \text{ if } d_{I,n-1}=-1, d_{I,n}=-1 \\ x_I(t) &= s_o(t-nT_s) \triangleq s_2(t-nT_s) \text{ if } d_{I,n-1}=-1, d_{I,n}=1 \\ x_I(t) &= -s_o(t-nT_s) \triangleq s_3(t-nT_s) \text{ if } d_{I,n-1}=1, d_{I,n}=1 \end{aligned} \quad (1)$$

The *Q* channel waveform $x_Q(t)$ would be generated by the same mapping as in (1) using instead the *Q* channel data symbols $\{d_{Q,n}\}$ and then delaying the resulting waveform by one half a symbol. If the odd and even waveforms $s_o(t)$ and $s_e(t)$ are defined by

$$\begin{aligned} s_e(t) &= 1, \quad -T_s/2 \leq t \leq T_s/2 \\ s_o(t) &= \sin \frac{\pi t}{T_s}, \quad -T_s/2 \leq t \leq T_s/2 \end{aligned} \quad (2)$$



**Into the Millennium and beyond...
A Stronger Signal**

SERIES STMS TRANSCEIVERS
*Designed to Convert ISM Band Radios
To License Band Frequency High
Data Rate Wireless Internet Access*

- Dual Digital PLL
- Highly Integrated
- 3.5 and 3.8 GHz Available Now!
- For other bands, call for availability

Taking ISM to Licensed Commercial Bands

Investing in the growing Wireless market, Signal Technology developed a series of low cost, high performance transceivers for Internet access in Wireless Local Loop applications. Series STMS fully integrated transceivers, currently performing in the field are fully ETSI compliant and deliver outstanding phase noise with a high level of reliability. The availability of our small, high performance, low cost STMS series provides the value added WLL designers have been looking for. Series STMS transceivers follow our formula for success, low cost, high performance and product availability! If your requirements dictate something different, we'll be happy to design a custom transceiver to meet your specifications.

At Signal Technology our standard is providing the industry with the products it needs, when it needs them.

**To learn more about our low cost, high performance, transceivers, visit our website at
www.sigtech.com or call (408) 730-6300.**

SIGNAL
TECHNOLOGY CORPORATION

975 BENECIA AVENUE • SUNNYVALE, CA 94086 • TEL. 408.730.6300 • FAX 408.733.0254

Circle 28

See us at Wireless Symposium, booth #733

then typical waveforms for the I and Q IJF encoder outputs are illustrated in Figure 2.

An identical modulation to $x_I(t)$ (and likewise for $x_Q(t)$) generated from the combination of (1) and (2) can be obtained directly from the binary data sequence $\{d_{In}\}$ itself, without the need for defining a 4-ary mapping based on the transition properties of the sequence. In particular, if we define the two-symbol wide raised cosine pulse shape

$$p(t) = \sin^2\left(\frac{\pi(t + T_s/2)}{2T_s}\right), \quad -T_s/2 \leq t \leq 3T_s/2 \quad (3)$$

then the I modulation

$$x_I(t) = \sum_{n=-\infty}^{\infty} d_{In} p(t - nT_s) \quad (4)$$

will be identical to that generated by the above IJF scheme. Similarly,

$$x_Q(t) = \sum_{n=-\infty}^{\infty} d_{Qn} p(t - \left(n + \frac{1}{2}\right)T_s) \quad (5)$$

would also be identical to that generated by the above IJF scheme. A quadrature modulation scheme formed from $x_I(t)$ of (4) and $x_Q(t)$ of (5) is precisely what Austin and Chang [7] referred to as SQORC modulation, name-

ly, independent I and Q modulations with overlapping raised cosine pulses on each channel. The resulting carrier modulated waveform is described by

$$x(t) = x_I(t) \cos \omega_c t + x_Q(t) \sin \omega_c t \quad (6)$$

Symbol-by-symbol cross correlator mapping for FQPSK

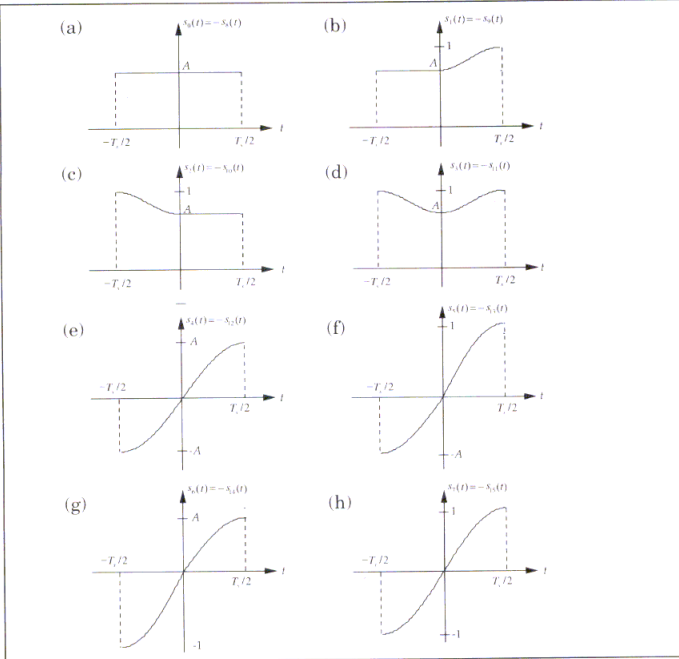
Before revealing the modification of FQPSK, which results in a transmitted signal having a continuous first derivative, we first recast the original characterization of FQPSK in terms of a cross correlation operation performed on the pair of IJF encoder outputs every half symbol interval into a mapping performed directly on the input I and Q data sequences every full symbol interval. To do this, we define sixteen waveforms $s_i(t); i=0,1,2,\dots,15$ over the interval $-T_s/2 \leq t \leq T_s/2$, which collectively form a transmitted signaling set for the I and Q channels. The particular I and Q waveforms chosen for any particular T_s -sec signaling interval on each channel depends on the most recent data transition on that channel as well as the two most recent successive transitions on the other channel (Figure 3).

$$\begin{aligned} s_0(t) &= A, \quad -T_s/2 \leq t \leq T_s/2, \quad s_8(t) = -s_0(t) \\ s_1(t) &= \begin{cases} A, & -T_s/2 \leq t \leq 0 \\ 1 - (1-A) \cos^2 \frac{\pi t}{T_s}, & 0 \leq t \leq T_s/2 \end{cases}, \\ s_9(t) &= -s_1(t) \end{aligned} \quad (7a)$$

$$\begin{aligned} s_2(t) &= \begin{cases} 1 - (1-A) \cos^2 \frac{\pi t}{T_s}, & -T_s/2 \leq t \leq 0 \\ A, & 0 \leq t \leq T_s/2 \end{cases}, \\ s_{10}(t) &= -s_2(t) \\ s_3(t) &= 1 - (1-A) \cos^2 \frac{\pi t}{T_s}, \quad -T_s/2 \leq t \leq T_s/2, \\ s_{11}(t) &= -s_3(t) \end{aligned}$$

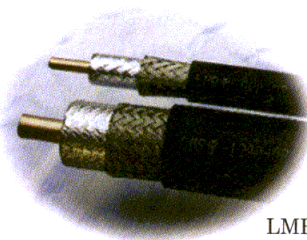
$$\begin{aligned} s_4(t) &= A \sin \frac{\pi t}{T_s}, \quad -T_s/2 \leq t \leq T_s/2, \\ s_{12}(t) &= -s_4(t) \\ s_5(t) &= \begin{cases} A \sin \frac{\pi t}{T_s}, & -T_s/2 \leq t \leq 0 \\ \sin \frac{\pi t}{T_s}, & 0 \leq t \leq T_s/2 \end{cases}, \\ s_{13}(t) &= -s_5(t) \\ s_6(t) &= \begin{cases} \sin \frac{\pi t}{T_s}, & -T_s/2 \leq t \leq 0 \\ A \sin \frac{\pi t}{T_s}, & 0 \leq t \leq T_s/2 \end{cases}, \\ s_{14}(t) &= -s_6(t) \end{aligned} \quad (7b)$$

$$\begin{aligned} s_7(t) &= \sin \frac{\pi t}{T_s}, \quad -T_s/2 \leq t \leq T_s/2, \\ s_{15}(t) &= -s_7(t) \end{aligned}$$

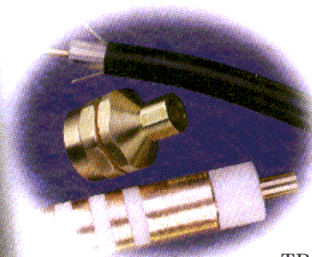


▲ **Figure 3. FQPSK full-symbol waveforms:** (a) $s_0(t) = -s_8(t)$ vs. t ; (b) $s_1(t) = -s_9(t)$ vs. t ; (c) $s_2(t) = -s_{10}(t)$ vs. t ; (d) $s_3(t) = -s_{11}(t)$ vs. t ; (e) $s_4(t) = -s_{12}(t)$ vs. t ; (f) $s_5(t) = -s_{13}(t)$ vs. t ; (g) $s_6(t) = -s_{14}(t)$; and (h) $s_7(t) = -s_{15}(t)$ vs. t .

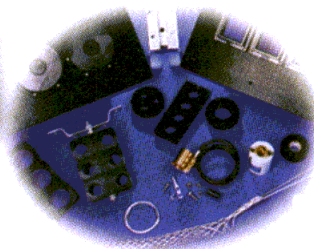
Flexible Coax Solutions... They're All Right Here



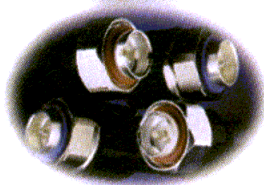
LMR® - DB Flexible
Watertight Coaxial Cables



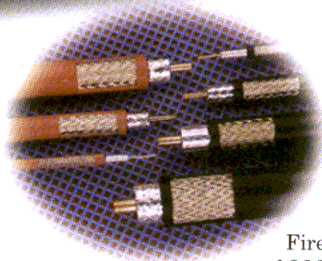
nu-TRAC® and Nu-RAD
Radiating Cables



A Complete Family of Hardware
Accessories and Installation Tools



A Comprehensive Line
of Connectors



Fire-Retardant LMR® - LLPL Plenum
and LMR® - FR Riser Coaxial Cables

*A Full Line of Coaxial Cables, Connectors, Hardware Accessories and Tools
Plus 50 Years of Experience. Visit our web site for your free catalog today!*

Distributed by...

MICROWAVE
COMPONENTS

3171 S.E. Dominica Terrace
Stuart, Florida 34997-5994

Phone: (888) 591-4455 or (561) 286-4455

Fax: (561) 286-4496

E-Mail: admin@microwavecomponentsinc.com

www.microwavecomponentsinc.com

Circle 18



1-800-591-4455

Note that for any value of A other than unity, $s_6(t)$ and $s_7(t)$ as well as their negatives $s_{13}(t)$ and $s_{14}(t)$, will have a discontinuous slope at their midpoints (i.e., at $t=0$), whereas the remaining twelve waveforms all have a continuous slope throughout their defining interval. Also, all 16 waveforms have zero slope at their endpoints, and thus concatenation

of any pair of these will not result in a slope discontinuity.

Next, we define the mapping function for the baseband I-channel transmitted waveform $y_I(t)=s_I(t)$ in the n th signaling interval $(n-1/2)T_s \leq t \leq (n+1/2)T_s$, in terms of the transition properties of the I and Q data symbol sequences $\{d_{I,n}\}$ and $\{d_{Q,n}\}$, respectively.

8a

I. If $d_{I,n-1}=1$, $d_{I,n}=1$ (no transition on the I sequence, both data bits positive), then

A. $y_I(t)=s_0(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in no transition and $d_{Q,n-1}, d_{Q,n}$ results in no transition.

B. $y_I(t)=s_1(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in no transition and $d_{Q,n-1}, d_{Q,n}$ results in a transition (positive or negative).

C. $y_I(t)=s_2(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in a transition (positive or negative) and $d_{Q,n-1}, d_{Q,n}$ results in no transition.

D. $y_I(t)=s_3(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in a transition (positive or negative) and $d_{Q,n-1}, d_{Q,n}$ results in a transition (positive or negative).

8b

II. If $d_{I,n-1}=-1$, $d_{I,n}=1$ (a positive going transition on the I sequence), then

A. $y_I(t)=s_4(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in no transition and $d_{Q,n-1}, d_{Q,n}$ results in no transition.

B. $y_I(t)=s_5(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in no transition and $d_{Q,n-1}, d_{Q,n}$ results in a transition (positive or negative).

C. $y_I(t)=s_6(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in a transition (positive or negative) and $d_{Q,n-1}, d_{Q,n}$ results in no transition.

D. $y_I(t)=s_7(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in a transition (positive or negative) and $d_{Q,n-1}, d_{Q,n}$ results in a transition (positive or negative).

8c

III. If $d_{I,n-1}=-1$, $d_{I,n}=-1$ (no transition on the I sequence, both data bits negative), then

A. $y_I(t)=s_8(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in no transition and $d_{Q,n-1}, d_{Q,n}$ results in no transition.

B. $y_I(t)=s_9(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in no transition and $d_{Q,n-1}, d_{Q,n}$ results in a transition (positive or negative).

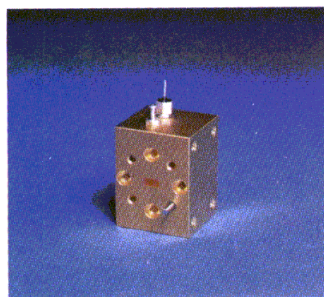
C. $y_I(t)=s_{10}(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in a transition (positive or negative) and $d_{Q,n-1}, d_{Q,n}$ results in no transition.

D. $y_I(t)=s_{11}(t-nT_s)$ if $d_{Q,n-2},$

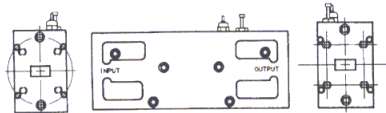
MILLIMETER WAVE AMPLIFIERS

FROM 23 GHz TO 100 GHz

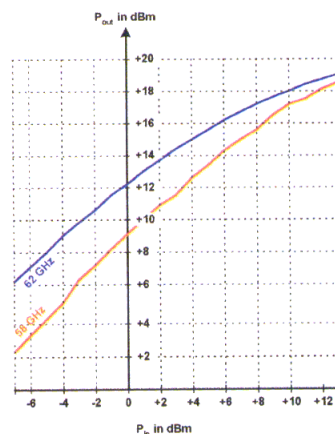
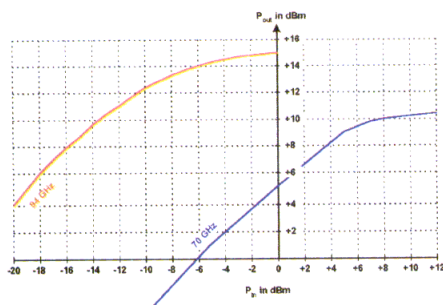
Millitech Corporation manufactures a line of MMIC based low noise power amplifiers from 23 GHz to 100 GHz. These amplifiers can be incorporated into the upconverter or downconverter modules, or into special packages. Contact sales engineering for additional information.



W-Band LNA



Inline Waveguide Package



MILLIMETER-WAVE PRODUCTS

Millitech Corporation

20 Industrial Drive East

Post Office Box 109

South Deerfield, MA 01373-0109

Tel: (413)665-8551 Fax: (413)665-2536

E-mail: info@millitech.com

www.millitech.com

$d_{Q,n-1}$ results in a transition (positive or negative) and $d_{Q,n-1}, d_{Q,n}$ results in a transition (positive or negative).

8d

IV. If $d_{I,n-1}=1, d_{I,n}=-1$ (a negative going transition on the I sequence), then

A. $y_I(t)=s_{12}(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in no transition and $d_{Q,n-1}, d_{Q,n}$ results in no transition.

B. $y_I(t)=s_{13}(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in no transition and $d_{Q,n-1}, d_{Q,n}$ results in a transition (positive or negative).

C. $y_I(t)=s_{14}(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in a transition (positive or negative) and $d_{Q,n-1}, d_{Q,n}$ results in no transition.

D. $y_I(t)=s_{15}(t-nT_s)$ if $d_{Q,n-2}, d_{Q,n-1}$ results in a transition (positive or negative) and $d_{Q,n-1}, d_{Q,n}$ results in a transition (positive or negative).

Making use of the signal properties in (7a) and (7b), the mapping conditions in (8a-8d) for the I channel baseband output can be summarized in a concise form (Table 1). A similar construction for the baseband Q-channel transmitted waveform $y_Q(t) = s_Q(t-T_s/2)$ in the n th signaling interval $nT_s \leq t \leq (n+1)T_s$ in terms of the transition properties of the I and Q data symbol sequences $\{d_{in}\}$ and $\{d_{Qn}\}$, respectively, can be obtained analogous to (8a-d). The results are summarized in Table 2. *Note that the subscript i of the transmitted signal $s_i(t-nT_s)$ or $s_i(t-(n+1/2)T_s)$ as appropriate is the binary coded decimal (BCD) equivalent of the three transitions.*

Applying the mappings in Tables 1 and 2 to the I and Q data sequences of Figure 2 produces the identical I and Q baseband transmitted signals to those that would be produced by passing the I and Q encoder outputs of this filter through the cross-correlator (half symbol mapping) of the FQPSK (XPSK) scheme as described in [4] (Figure 4). Thus, we conclude that for arbitrary I and Q data sequences,

FQPSK can alternately be generated by the symbol-by-symbol mappings of Tables 1 and 2 as applied to these sequences.

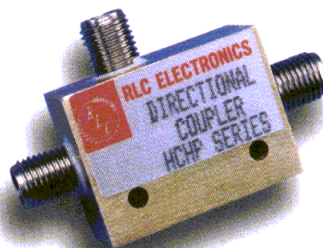
A new and improved FQPSK

As discussed above, the symbol-by-symbol mapping representation of FQPSK identifies the fact that four out of the sixteen possible

transmitted waveforms, namely $s_5(t), s_6(t), s_{13}(t)$ and $s_{14}(t)$ have a slope discontinuity at their midpoint. Thus, for random I and Q data symbol sequences, on the average the transmitted FQPSK waveform will likewise have a slope discontinuity at one quarter of the uniform sampling time instants. To prevent this from occurring, we now redefine

Presenting...

Couplers



High Frequency... High Power
12 to 40 GHz... 60 to 100 W

- Accurate Coupling Value
 - Low Insertion Loss
 - Small Package Size
 - ± 1.5 dB Accuracy
 - 20 or 30 dB Coupling
- Connectors: 12 to 26.5 GHz SMA (F)
26.5 to 40 GHz 2.9 mm (F)

APPLICATIONS

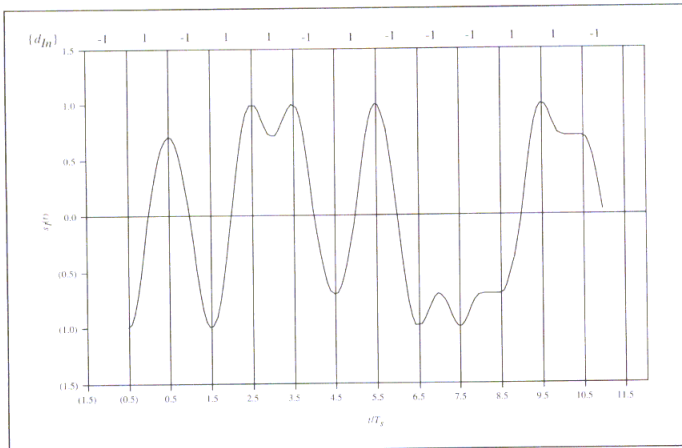
- Power Sampling Measurements
 - Continuous Frequency Measurements
 - Reflectometer to monitor antenna power
- Call, fax or e-mail your requirements.



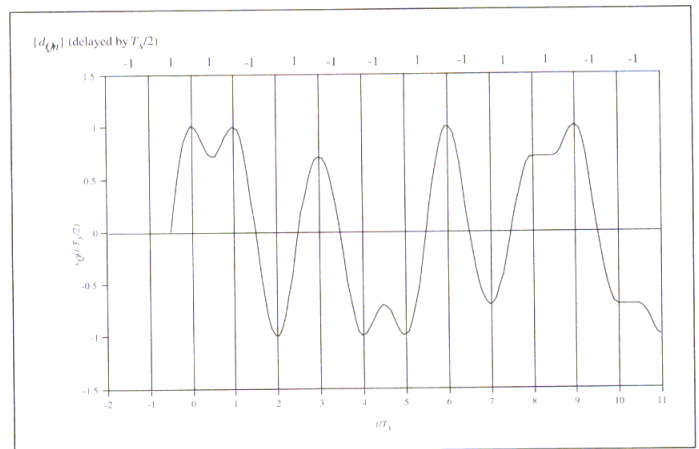
RLC ELECTRONICS, INC.

83 Radio Circle, Mount Kisco, New York 10549 • Telephone: 914-241-1334 • Fax: 914-241-1753
e-mail: sales@rlcelectronics.com • www.rlcelectronics.com

RLC is your complete Microwave Component source...
Switches, Filters, Power Dividers, Couplers, Terminations, Attenuators, DC Blocks, Bias Tees & Detectors.



▲ Figure 4a. Inphase FQPSK (XPSK) output.



▲ Figure 4b. Quadrature phase FQPSK (XPSK) output.

these four transmitted signals in a manner analogous to $s_1(t)$, $s_2(t)$, $s_9(t)$ and $s_{10}(t)$, namely,

$$s_5(t) = \begin{cases} \sin \frac{\pi t}{T_s} + (1-A) \sin^2 \frac{\pi t}{T_s}, & -T_s/2 \leq t \leq 0 \\ \sin \frac{\pi t}{T_s}, & 0 \leq t \leq T_s/2 \end{cases},$$

$$s_{13}(t) = -s_5(t)$$

$$s_6(t) = \begin{cases} \sin \frac{\pi t}{T_s}, & -T_s/2 \leq t \leq 0 \\ \sin \frac{\pi t}{T_s} - (1-A) \sin^2 \frac{\pi t}{T_s}, & 0 \leq t \leq T_s/2 \end{cases},$$

$$s_{14}(t) = -s_6(t)$$

Note that the signals $s_5(t)$, $s_6(t)$, $s_{13}(t)$ and $s_{14}(t)$ as defined in (9) do not have a slope discontinuity at their midpoint nor, for that matter, anywhere else in the defining interval. Also, the zero slope at their endpoints

$\left \frac{d_{I_n} - d_{I_{n-1}}}{2} \right $	$\left \frac{d_{Q_{n-1}} - d_{Q_{n-2}}}{2} \right $	$\left \frac{d_{Q_n} - d_{Q_{n-1}}}{2} \right $	$s_I(t)$
0	0	0	$d_{I_n} s_0(t - nT_s)$
0	0	1	$d_{I_n} s_1(t - nT_s)$
0	1	0	$d_{I_n} s_2(t - nT_s)$
0	1	1	$d_{I_n} s_3(t - nT_s)$
1	0	0	$d_{I_n} s_4(t - nT_s)$
1	0	1	$d_{I_n} s_5(t - nT_s)$
1	1	0	$d_{I_n} s_6(t - nT_s)$
1	1	1	$d_{I_n} s_7(t - nT_s)$

▲ Table 1. Mapping for inphase (I)-channel baseband signal $y_i(t)$ in the interval $(n-1/2)T_s \leq t \leq (n+1/2)T_s$.

has been preserved. Thus, using (9) in place of the corresponding signals of (7b) will result in a modified FQPSK signal that has no slope discontinuity anywhere in time *regardless of the value of A*. Figure 5 illustrates a comparison of the signal $s_6(t)$ of (9) with that of (7b) for a value of $A=1\sqrt{2}$. Figure 6 illustrates the power spectral density of conventional FQPSK and its enhancement obtained by using the waveforms of (9) as replacements for those in (7b). The significant improvement in spectral rolloff rate is clear from a comparison of the two.

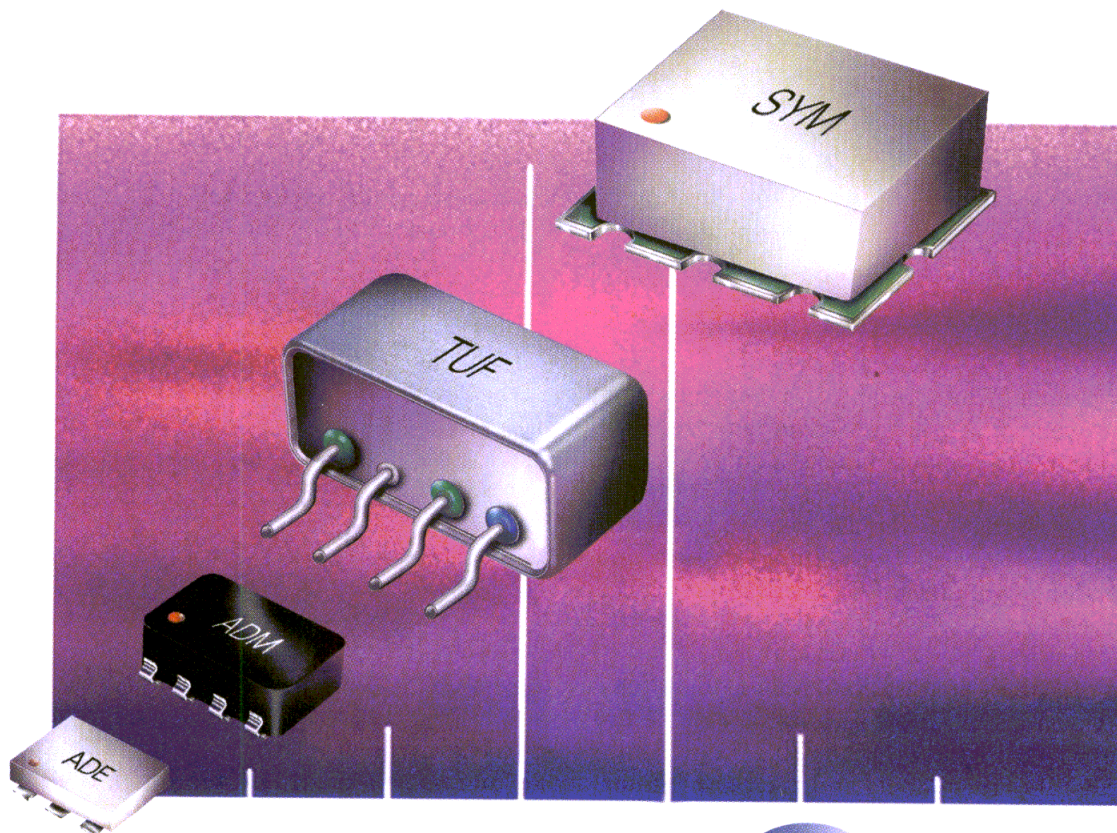
As it currently stands, the signal set chosen for enhanced FQPSK has a symmetry property for $s_0(t)$, $s_1(t)$, $s_2(t)$ and $s_3(t)$ that is not present for $s_4(t)$, $s_5(t)$, $s_6(t)$ and $s_7(t)$. In particular, $s_1(t)$ and $s_2(t)$ are each composed of one half of $s_0(t)$ and one half of $s_3(t)$, i.e., the portion of $s_1(t)$ from $t = -T_s/2$ to $t = 0$ is the same as that of $s_0(t)$, whereas the portion of $s_1(t)$ from $t = 0$ to $t = T_s/2$ is the same as that of $s_3(t)$, and vice versa for $s_2(t)$. To achieve the same symmetry property for $s_4(t) - s_7(t)$, one would have to reassign $s_4(t)$ as

$\left \frac{d_{Qn} - d_{Q,n-1}}{2} \right $	$\left \frac{d_{I,n} - d_{I,n-1}}{2} \right $	$\left \frac{d_{I,n+1} - d_{I,n}}{2} \right $	$s_I(t)$
0	0	0	$d_{Qn}s_0(t-nT_s)$
0	0	1	$d_{Qn}s_1(t-nT_s)$
0	1	0	$d_{Qn}s_2(t-nT_s)$
0	1	1	$d_{Qn}s_3(t-nT_s)$
1	0	0	$d_{Qn}s_4(t-nT_s)$
1	0	1	$d_{Qn}s_5(t-nT_s)$
1	1	0	$d_{Qn}s_6(t-nT_s)$
1	1	1	$d_{Qn}s_7(t-nT_s)$

▲ Table 2. Mapping for quadrature (Q)-channel baseband signal $y_Q(t)$ in the interval $nT_s \leq t \leq (n+1)T_s$.

HIGH IP3 MIXERS

suppress noisy intermods



+30dBm IP3 5 to 2200MHz from **\$7⁹⁵** **WOW!**
(10-49 qty.)

The popularity of wireless communication services is soaring, but when signal overcrowding creates intermodulation distortion... Mini-Circuits has the solution! Our full range of low distortion high IP3 mixers provide the muscle it takes to **suppress noisy intermods** and clear the air of unwanted signals. At the same time, these affordable surface mount and plug-in solutions achieve low conversion loss and excellent L-R, L-I isolation. Developed for both analog and digital use, applications include airphone, cellular and cordless phones, radar, satellite, FM Broadcast, ISM, PCS, and PCN. Achieve the high performance your customers expect. Specify low loss, high IP3 mixers from Mini-Circuits. It's the *clear* choice!

Mini-Circuits...we're redefining what VALUE is all about!

TYPICAL SPECIFICATIONS: LO = +17dBm except SYM-15VH LO = +23dBm

Model	Freq. (MHz)	IP3 Midband (dBm)	Isolation (dB) L-R L-I	Conv.Loss Midband (dB)	Price \$ea. Qty. 1-9
*ADE-10H	400 -1000	30	39 25	7.0	7.95**
*ADE-12H	500 -1200	28	34 28	6.7	8.95**
SYM-18H	5 -1800	30	45 40	5.75	17.95
SYM-15VH	10 -1500	31	45 35	6.5	29.95
SYM-14H	100-1370	30	36 30	6.5	16.95
SYM-10DH	800 -1000	31	45 29	7.6	18.95
SYM-22H	1500 -2200	30	33 38	5.6	19.95
SYM-20DH	1700-2000	32	35 34	6.7	16.95
•TUF-18DHSM	100 -1800	27	41 33	7.3	21.95
*ADM-10DH	800 -1000	30	35 37	6.0	15.95

IT Innovative Technology
(Patent Pending)

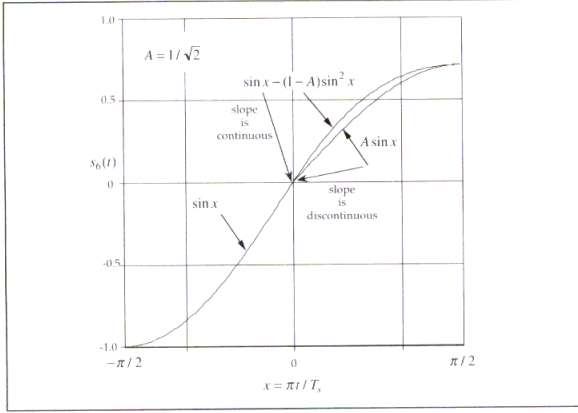
**Quantity 10 to 49. All models are surface mount and available in tape and reel.
•Plug-in version available, specify TUF-18DH

Mini-Circuits®

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE
The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: <http://www.minicircuits.com>

ISO 9001 CERTIFIED

F 270 Rev D



▲ Figure 5. Original and new FQPSK shapes.

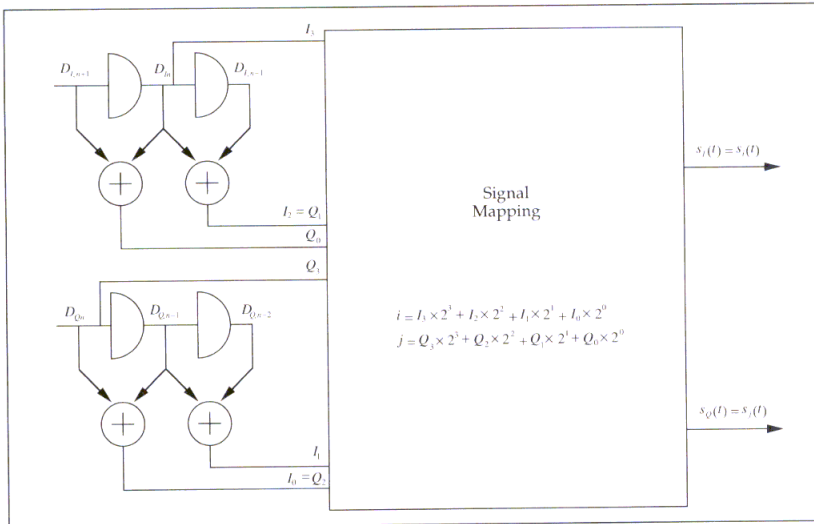
$$s_4(t) = \begin{cases} \sin \frac{\pi t}{T_s} + (1-A) \sin^2 \frac{\pi t}{T_s}, & -T_s/2 \leq t \leq 0 \\ \sin \frac{\pi t}{T_s} - (1-A) \sin^2 \frac{\pi t}{T_s}, & 0 \leq t \leq T_s/2 \end{cases}, \quad (10)$$

$$s_{12}(t) = -s_4(t)$$

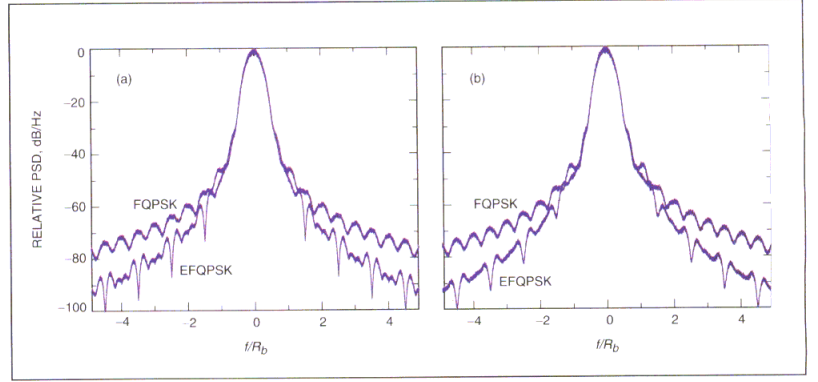
This minor change, which produces a complete symmetry in the waveform set, has an advantage from the standpoint of hardware implementation and produces a negligible change in spectral properties of the transmitted waveform. Nevertheless, for the remainder of the discussion, we shall ignore this minor change and assume the version of enhanced FQPSK first introduced in this section.

Interpretation of FQPSK as a trellis-coded modulation

The I and Q mappings given in Tables 1 and 2 are alternately described in terms of the (0,1) representation of the I and Q data symbols and their transitions. Specifically, define



▲ Figure 7. Alternate implementation of FQPSK baseband signals.



▲ Figure 6. Power spectra of conventional and enhanced FQPSK: (a) without SSPA; and (b) with SSPA.

$$D_{In} \triangleq (1-d_{In})/2, D_{Qn} \triangleq (1-d_{Qn})/2 \quad (11)$$

which both range on the set (0,1). Then, defining the BCD representation of the indices i and j by

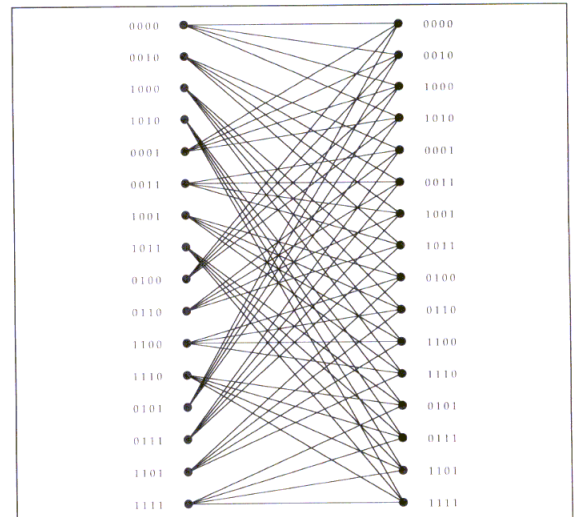
$$i = I_3 \times 2^3 + I_2 \times 2^2 + I_1 \times 2^1 + I_0 \times 2^0 \quad (12)$$

$$j = Q_3 \times 2^3 + Q_2 \times 2^2 + Q_1 \times 2^1 + Q_0 \times 2^0$$

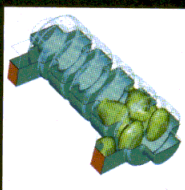
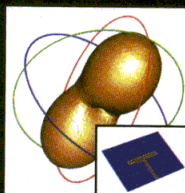
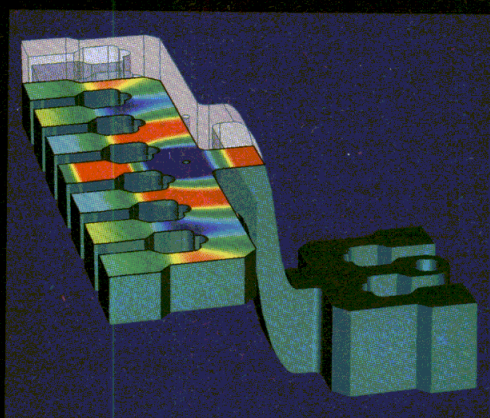
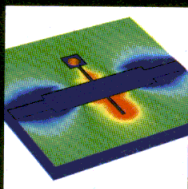
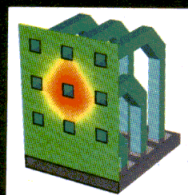
with

$$\begin{aligned} I_0 &= D_{Qn} \oplus D_{Q,n-1}, Q_0 = D_{I,n+1} \oplus D_{In} \\ I_1 &= D_{Q,n-1} \oplus D_{Q,n-2}, Q_1 = D_{In} \oplus D_{I,n-1} = I_2 \\ I_2 &= D_{In} \oplus D_{I,n-1}, Q_2 = D_{Qn} \oplus D_{Q,n-1} = I_0 \\ I_3 &= D_{In}, Q_3 = D_{Qn} \end{aligned} \quad (13)$$

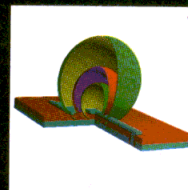
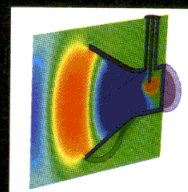
we have $y_I(t) = s_i(t - nT_s)$ and $y_Q(t) = s_j(t - (n + 1/2)T_s)$. That is, in each symbol interval $((n - 1/2)T_s \leq t \leq (n + 1/2)T_s$ for $y_I(t)$ and $nT_s \leq t \leq (n + 1)T_s$ for $y_Q(t)$), the I and Q channel baseband signals are each chosen from a set of 16



▲ Figure 8. 16-state trellis diagram for FQPSK.



All kind of S-parameter and antenna problems
e.g. waveguides, filters, connectors, couplers,
planar structures and *any* antennas.



The Company whose products have
been in existence for over ten years and has
been providing the U.S. industry
leaders with the German engineered
MAFIA Simulation Software, announces:

CST MICROWAVE STUDIO

**“Changing the standards
for 3D EM Simulation”**

■ A **NEW** product using a **NEW** technique
“Perfect Boundary Approximation” combined
with a powerful optimization tool.

Discover the applications and the new
technologies now available and reserve a
seat at one of CST’s free training seminars
being held in the following locations:

Houston

Boston

Seattle

San Francisco

San Diego

Atlanta

Toronto

CST
COMPUTER SIMULATION
TECHNOLOGY



CST OF AMERICA

124
Mount Auburn Street
Suite 200N
Cambridge, MA 02138

Phone:
(617) 576 - 5857

Fax:
(617) 576 - 5702

CST_America
@compuserve.com

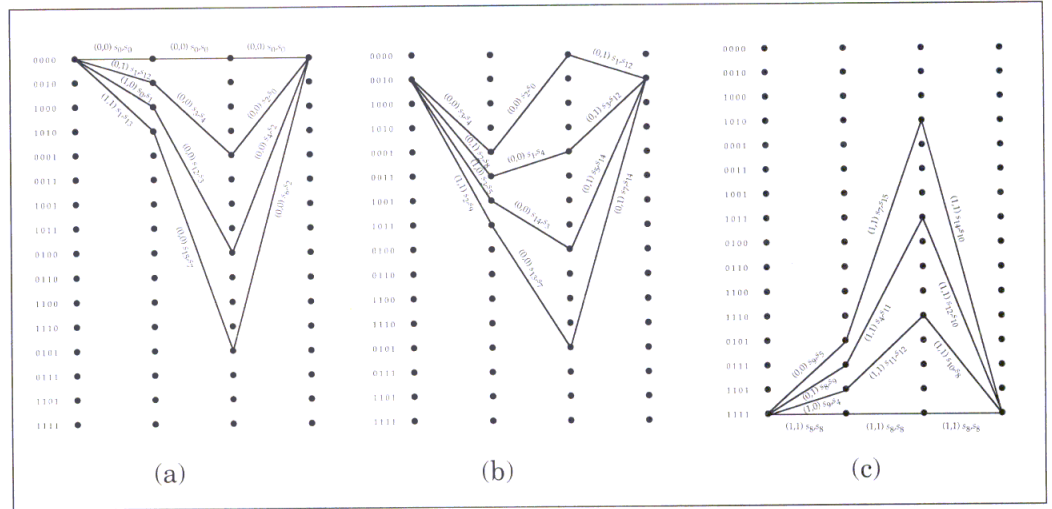
Website:
www.cst.de

signals, $s_i(t)$, $i=0,1,\dots,15$, in accordance with the 4-bit BCD representations of their indices defined by (12) together with (13). A graphical illustration of the implementation of this mapping is given in Figure 7.

Another interpretation of the mapping in Figure 7 is as a 16-state trellis code with two binary (0,1) inputs $D_{I,n+1}$, $D_{Q,n}$, and two waveform outputs $s_i(t)$, $s_j(t)$, where the state is defined by the 4-bit sequence $D_{I,n}$, $D_{I,n-1}$, $D_{Q,n-1}$, $D_{Q,n-2}$. The trellis is illustrated in Figure 8, and the transition mapping is given in Appendix 1. In this table, the entries in the column labeled "input" correspond to the values of the two input bits that result in the transition, while the entries in the column "output" correspond to the subscripts i and j of the pair of symbol waveforms $s_i(t)$, $s_j(t)$ that are outputted.

To compute the performance of this trellis coded modulation (TCM), we need to determine the minimum Euclidean distance between pairs of error event paths that leave a given state and first return to that or another state a number of branches later. The smallest length error event for which there are at least two paths that start in one state and remerge in the same or another state is three branches. For each of the 16 starting states, there are exactly four such error event paths that remerge in each of the 16 end states. Figures 9a and 9b are examples of these error event paths corresponding to the first two states, respectively, for the case where the start and end states are the same. The remaining length three error event paths for states 9-16 are the mirror images of the ones for states 1-8 (for example, Figure 9c, which should be compared with Figure 9a). Also, the paths for states 9-16 will have identical Euclidean distance properties to those for states 1-8, since the output symbols along their branches will be the negatives of those along their mirror images. Figures 10a and 10b are examples of the groups of four error event paths that start in a given state and remerge in another state. A similar mirror image symmetry exists for these groups of paths and thus once again it is sufficient to consider only the first eight starting states.

It is important to note that the trellis code defined by the mapping in Appendix 1 is not uniform, e.g., it is not sufficient to consider only the all zeros path as the transmitted path in computing the minimum

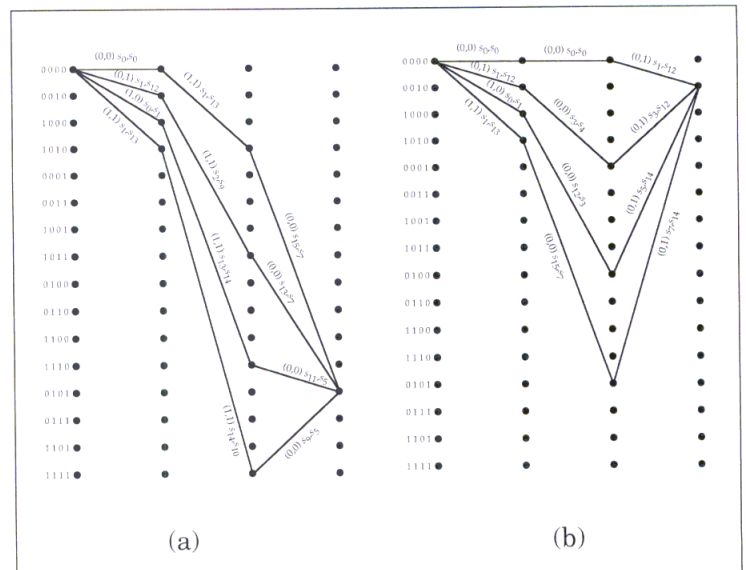


▲ Figure 9. (a) Paths of length 3 branches starting and ending in State 1; (b) paths of length 3 branches starting and ending in State 2; and (c) paths of length 3 branches starting and ending in State 16.

Euclidean distance. Rather, one must consider all possible pairs of error event paths starting from each of the 16 states (eight states is sufficient in view of the above-mentioned distance symmetry properties) and ending in each of the 16 states. This determines the pair having the minimum Euclidean distance.

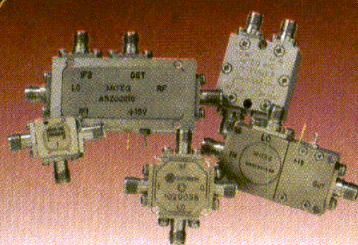
The following example illustrates the procedure for the groups of paths that start and end in the same state.

Upon examination of the squared Euclidean distance between all pairs of paths in the above-mentioned figures, it can be shown that the minimum of this distance, for example, d_{\min}^2 , occurs between the first and third paths of Figure 9b. Thus, based on the output symbols



▲ Figure 10. (a) Paths of length 3 branches starting in state 1 and ending in State 13; (b) paths of length 3 branches starting in State 1 and ending in State 2.

MITEQ FROM COMPONENTS TO SYSTEMS

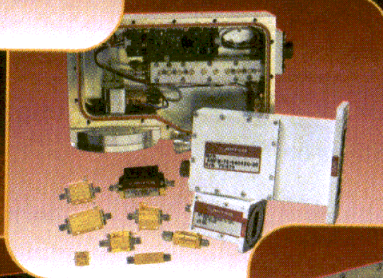


MIXERS TO 60 GHz

- Single-, double-, and triple-balanced
- Image rejection and I/Q
- Single-sideband, BPSK and QPSK modulators
- High dynamic range
- Active and passive frequency multipliers

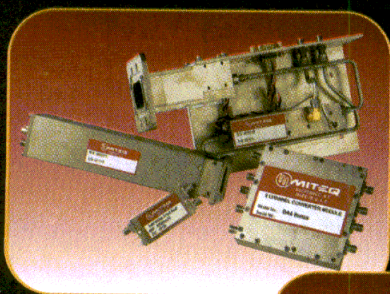
AMPLIFIERS TO 60 GHz

- Octave to ultra-broadband
- Noise figures from 0.35 dB
- Power to 10 watts
- Temperature compensated
- Cryogenic



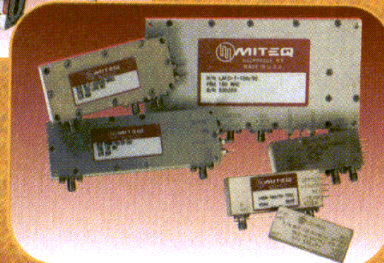
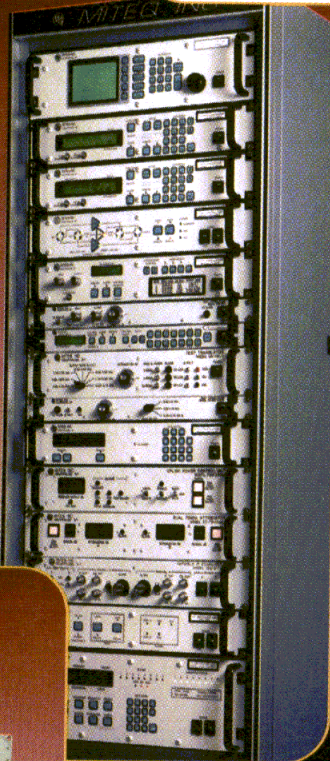
INTEGRATED SUBASSEMBLIES TO 60 GHz

- Integrated up/downconverters
- Monopulse receiver front ends
- PIN diode switches
- Ultra-miniature switch matrices
- Missile receiver front ends
- Switched amplifier/filter assemblies



FREQUENCY SOURCES TO 40 GHz

- Free-running VCOs/DROs
- Phase-locked cavity oscillators
- Phase-locked coaxial resonators
- Synthesizers for SATCOM
- Fast-tuning communication synthesizers



IF AND VIDEO SIGNAL PROCESSING

- Logarithmic amplifiers
- Constant phase-limiting amplifiers
- Frequency discriminators
- AGC/VGC amplifiers
- I/Q processors
- Digital DLVAs

SATCOM EARTH STATION EQUIPMENT TO Ka-BAND

- Synthesized up/downconverters
- Test translators
- LNA systems
- 1:N redundancy units
- INMARSAT products
- FM modems

Circle 14


MITEQ

TEL: (516) 436-7400

FAX: (516) 436-7430

100 Davids Drive, Hauppauge, NY 11788

www.miteq.com

AS OF NOVEMBER 1999, OUR NEW AREA CODE WILL BE 631

See us at Wireless Symposium booth #1227

that occur along this pair of paths, we have

$$d_{\min}^2 = \int_{-T_s/2}^{T_s/2} [(s_3(t) - s_3(t))^2 + (s_4(t) - s_5(t))^2 + (s_2(t) - s_{14}(t))^2 + (s_0(t) - s_3(t))^2 + (s_1(t) - s_5(t))^2 + (s_{12}(t) - s_{14}(t))^2] dt \quad (14)$$

Evaluation of the squared Euclidean distances between the pairs of waveforms required in (14) using (7a) and (7b) for their definition results after much algebra in

$$d_{\min}^2 = \left[\frac{7}{4} - \frac{8}{3\pi} - A \left(\frac{3}{2} + \frac{4}{3\pi} \right) + A^2 \left(\frac{11}{4} + \frac{4}{\pi} \right) \right] T_s = 1.552T_s \quad (15)$$

The average signal (I+Q) energy is obtained from

$$E_{av} = \frac{1}{256} \sum_{i=0}^{15} \sum_{j=0}^{15} \int_{-T_s/2}^{T_s/2} [s_i^2(t) + s_j^2(t)] dt = 2 \left[\frac{1}{16} \sum_{i=0}^{15} \int_{-T_s/2}^{T_s/2} s_i^2(t) dt \right] = \frac{1}{4} \sum_{i=0}^7 \int_{-T_s/2}^{T_s/2} s_i^2(t) dt \quad (16)$$

which again using (7a) and (7b) evaluates to

$$E_{av} = \left(\frac{7 + 2A + 15A^2}{16} \right) T_s = 0.9946T_s \quad (17)$$

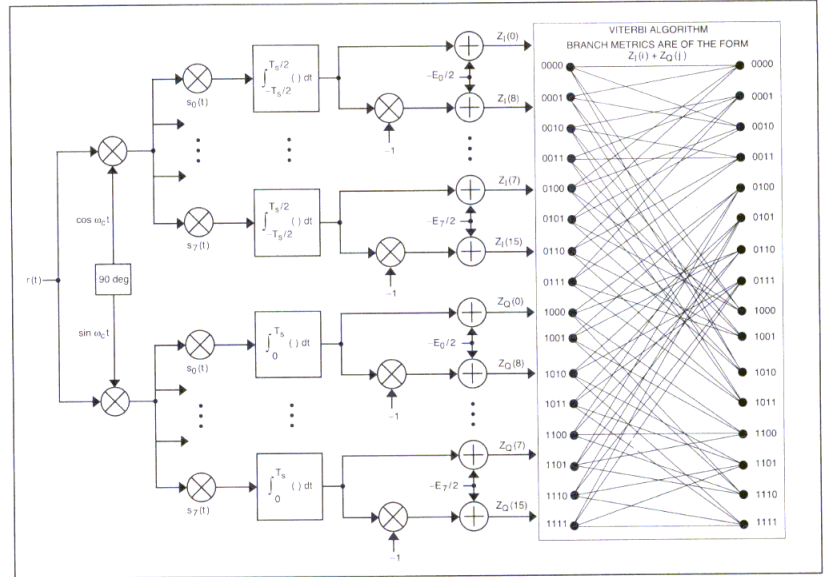
Since the average signal (symbol) energy is twice the average energy per bit, then the normalized minimum squared Euclidean distance for the paths corresponding to starting and ending in the same state is

$$\frac{d_{\min}^2}{2E_b} = \frac{16 \left[\frac{7}{4} - \frac{8}{3\pi} - A \left(\frac{3}{2} + \frac{4}{3\pi} \right) + A^2 \left(\frac{11}{4} + \frac{4}{\pi} \right) \right]}{(7 + 2A + 15A^2)} = 1.56 \quad (18)$$

Upon examination of all length 3 error event paths that begin in one state and end in another, e.g., Figures 10a and 10b, no pair of paths with smaller normalized minimum squared Euclidean distance was found.

Furthermore, by exhaustive search, it can be shown that the minimum squared Euclidean distance of (18) is the smallest over all pairs of paths that start in any state and end in any state regardless of the length of the path. Thus, the normalized minimum squared Euclidean distance for the FQPSK scheme is given by (18).

For the spectrally enhanced FQPSK using the wave-



▲ Figure 11. The optimum trellis-coded receiver for FQPSK.

forms of (9) as replacements for their equivalents in (7b), the minimum squared Euclidean distance over all length 3 trellis paths occurs, for example, between the first and second paths, starting and ending in state "0000" and is given by (see Figure 9a)

$$d_{\min}^2 = \int_{-T_s/2}^{T_s/2} [(s_0(t) - s_1(t))^2 + (s_0(t) - s_{12}(t))^2 + (s_0(t) - s_3(t))^2 + (s_0(t) - s_4(t))^2 + (s_0(t) - s_2(t))^2 + (s_0(t) - s_0(t))^2] dt \quad (19)$$

Once again, evaluation of the squared Euclidean distances between the pairs of waveforms required in (19) using (7a) and (7b) together (now with (9) for their definition) results after much algebra in

$$d_{\min}^2 = \left[\frac{3 - 6A + 15A^2}{4} \right] T_s = 1.564T_s \quad (20)$$

Likewise, the average signal energy is now

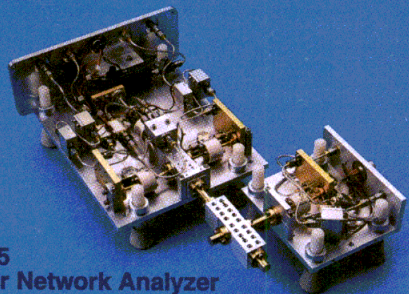
$$E_{av} = \left(\frac{21}{8} - \frac{8}{3\pi} - A \left(\frac{1}{4} - \frac{8}{3\pi} \right) + \frac{29}{8} A^2 \right) T_s = 1.003T_s \quad (21)$$

Thus, the normalized minimum squared Euclidean distance is

$$\frac{d_{\min}^2}{2E_b} = \frac{(3 - 6A + 15A^2)}{21 - \frac{8}{3\pi} - A \left(\frac{1}{4} - \frac{8}{3\pi} \right) + \frac{29}{8} A^2} = 1.56 \quad (22)$$

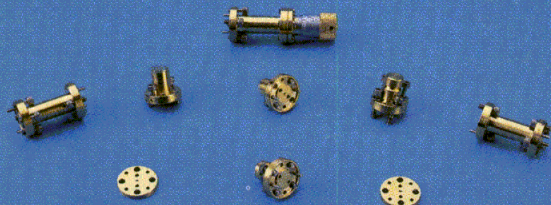
mmW Test Equipment

Vector Network Analysis Systems Use with popular microwave VNA equipment to achieve millimeter wave vector/amplitude measurement capability. Can be used in either the forward direction only (S11 & S21) with one T/R module or in the forward and reverse direction (S11, S21, S22, S12) with two T/R modules. Systems are available for all waveguide bands from WR-22 to WR-05.

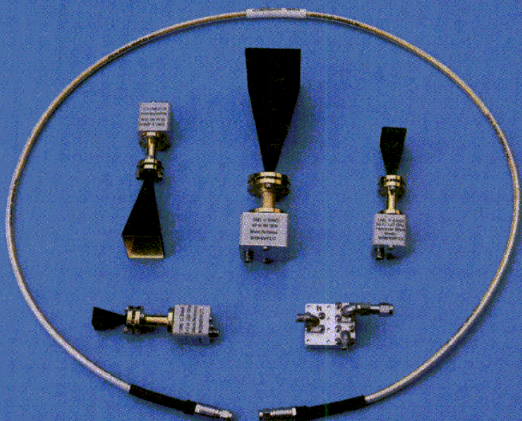


**WR-05
Vector Network Analyzer**

Waveguide VNA Calibration Kits for calibration of the above Vector Network Analysis Systems. Contains all of the components necessary to achieve any of the popular calibration methodologies.



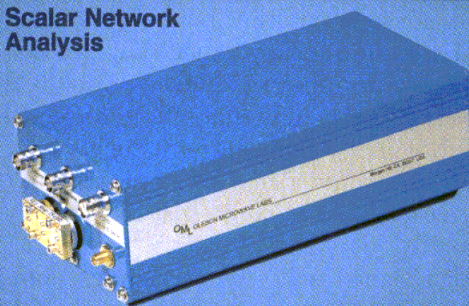
WR-05 VNA Calibration Kits



FCC Spurious and Harmonic Test Kit

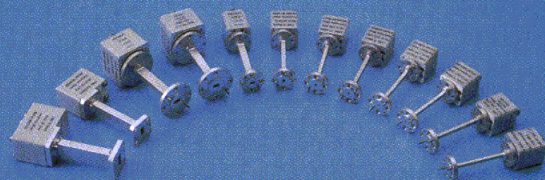
FCC Spurious and Harmonic Test Kit for use with popular Spectrum Analyzers. Each kit contains four mixers providing continuous coverage from 40 to 220 GHz. Each mixer is equipped with an appropriate horn antenna for accomplishing the FCC desired radiated spurious level measurement. Shown with optional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

Scalar Network Analysis

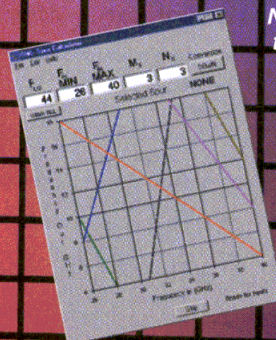


Scalar Network Analysis (SNA) Systems and Multiplier Sources Complete SNA systems containing filtered multipliers with -50 dBc spurs and harmonics. Included are a dual directional coupler and detectors for reference, reflection and transmission. Available for WR-22 through WR-10. Filtered Multiplier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

Harmonic Mixers



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



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

Also contained on the Web Site are complete specifications for all of the above millimeter wave frequency extension products as well as technical papers addressing many of the more common millimeter wave testing problems.

Contained in these papers are many useful millimeter wave charts and graphs not found elsewhere.

OML Oleson Microwave Labs

Visit us at www.oml-mmw.com

355 Woodview Drive, Suite 300 • Morgan Hill, CA 95037 • Tel: (408) 779-2698 • Fax: (408) 778-0491

FQPSK ENHANCEMENTS

which coincidentally is identical to that for FQPSK.

Again there is no other pair of paths starting in any state and ending in any other that produces a smaller normalized minimum squared Euclidean distance. Thus, we shall conclude that *the enhancement of FQPSK provided by using the waveforms of (9) as replacements for their equivalents in (7b) is significantly beneficial from a spectral standpoint with no penalty in receiver performance.*

In accordance with the foregoing representation of FQPSK as a trellis coded modulation with 16 states, the optimum receiver (employing a Viterbi algorithm) for FQPSK is illustrated in Figure 11.

In later sections of this article, we shall illustrate average bit error probability (BEP) results obtained from a simulation of this receiver. For the moment, we shall just compare its asymptotic (limit of infinite energy-to-noise ratio) performance with that of the optimum receiver for conventional uncoded offset QPSK (OQPSK).

Since for the latter, $d_{\min}^2 / 2\bar{E}_b = 2$, which is the same as that for BPSK [8], we see that as a trade against the significantly improved power spectrum afforded by FQPSK and its enhanced version relative to that of

OQPSK, an asymptotic loss of only $10 \log(2/1.56) = 1.07$ dB is experienced.⁶

Symbol-by-symbol FQPSK detection

In the second part of this article, which will be published in the March issue of *Applied Microwave & Wireless*, we will examine the performance of FQPSK when the detector makes decisions on a symbol-by-symbol basis — that is, the inherent memory introduced by the trellis coding is ignored at the receiver. Signal representation, suboptimum receivers and average bit error probability performance will also be covered in the conclusion to this article. ■

End notes

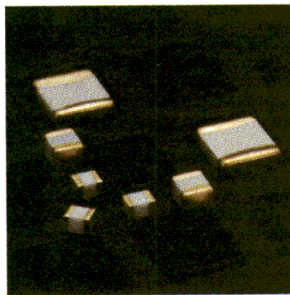
[1] Other versions of FQPSK, referred to as FQPSK-B [5], include proprietary designed filtering for additional spectrum containment. Such filtering is not germane to our discussions in this paper and will not be considered.

[2] The reduction of the envelope from 3 dB to 0 dB occurs only at the uniform sampling instants on the inphase (I) and quadrature (Q) channels. It is for this reason that XPSK is referred to as being “pseudo” or

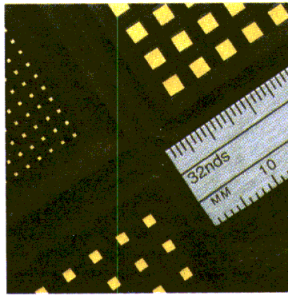
HIGH PERFORMANCE RF CAPACITORS



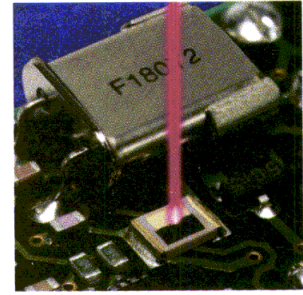
High Frequency Ceramic Capacitors



Porcelain NPO Ceramic Capacitors



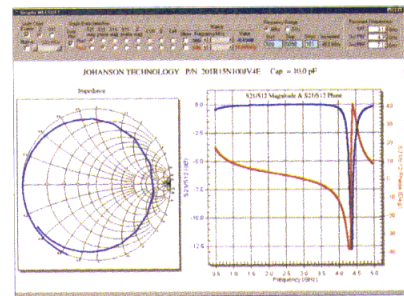
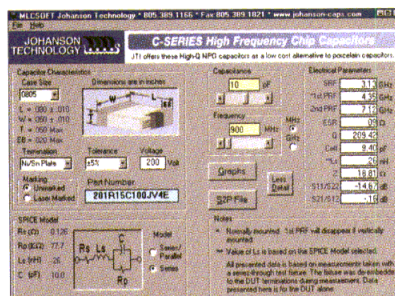
Single Layer Microwave Capacitors



Laser Adjustable Ceramic Capacitors



Capacitor Proto-typing Kits



... NOW COMPLIMENTED WITH MLCSoft®, ADVANCED SPICE AND S-PARAMETER MODELING SOFTWARE

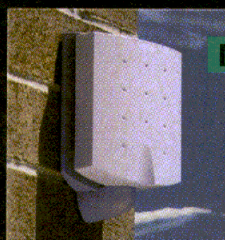
JOHANSON TECHNOLOGY

DOWNLOAD MLCSoft® AT: www.johansontechnology.com
931 VIA ALONDRA • CAMARILLO, CALIFORNIA • (805) 389 1166

Circle 38

See us at Wireless Symposium, booth #1401

High Performance Antennas For AMPS/SMR, PCS/DCS & ISM



DirectLink™ Series

Articulating wall mount version, linearly polarized with 7.5 dBi gain.



Dual Linear Antenna

Linearly polarized dual patch antenna, 7 dBi gain, one feed for horizontal and one feed for vertical polarization, slant 45 degree also available.



"SQUINT" Omni Antenna

Low profile, omnidirectional with a 3.5 dBi dipole like pattern shape.



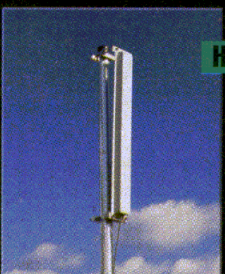
Dual Patch Array

Linearly polarized dual patch antenna provides 12 dBi gain.



Directional Yagi

Linearly polarized, 15 dBi gain.



High Gain Patch Array

Linearly polarized directional antenna, 12 dBi gain, nominal 90 by 10 degree half power beamwidth.



High Gain Dish Antenna

2.4-2.5 GHz, 23.5 dBi gain, parabolic reflector.

Housed in rugged, low profile, UV protected radomes, this selection of AMPS/SMR, PCS/DCS & ISM band antennas facilitates installation with an array of versatile mounting options including wall, mast or ceiling mounts for both indoor and outdoor applications. Each Cushcraft patch antenna is engineered with our patented MicroAir technology to insure superior electrical performance.

- ▶ Low Profile, Aesthetically Pleasing Designs
- ▶ Rugged Construction for Indoor/Outdoor Use
- ▶ Versatile Mounting Options for All Models
- ▶ MicroAir™ Technology in All Panel Antennas

Cushcraft has been designing innovative antenna solutions for more than four decades. Cushcraft's commitment to providing quality antennas gives our customers the competitive edge needed in today's demanding marketplace.

Contact Cushcraft today. Our experienced staff will provide the antenna solution you need.

Telephone: 1-800-258-3860

Fax: 1-800-258-3868



CUSHCRAFT
COMMUNICATIONS ANTENNAS

48 Perimeter Road, Manchester NH 03103 USA

Telephone: 603-627-7877 • Fax: 603-627-1764

E-mail: sales@cushcraft.com

Web Site: <http://www.cushcraft.com>

International - Tel: +1-603-627-7877 • Fax: +1-603-627-1764

FQPSK ENHANCEMENTS

“quasi” constant envelope, i.e., its envelope has a small amount of fluctuation between the uniform sampling instants.

[3] Of the 16 possible cross correlator output combinations, only 12 of them are in fact new, i.e., for four of the input I and Q combinations, the cross correlator outputs the identical combination.

[4] Actually, in its generic form, Kato and Feher allow (through the introduction of a transition parameter $k = 1-A$) for a controlled amount of envelope fluctuation. For quasi-constant envelope, one should choose $A = 1/\sqrt{2}$.

[5] This also occurs between several other pairs of paths starting and ending in the same state.

[6] Needless to say, at smaller (finite) SNRs, the loss between uncoded OQPSK and trellis decoded FQPSK will be even less.

Acknowledgment

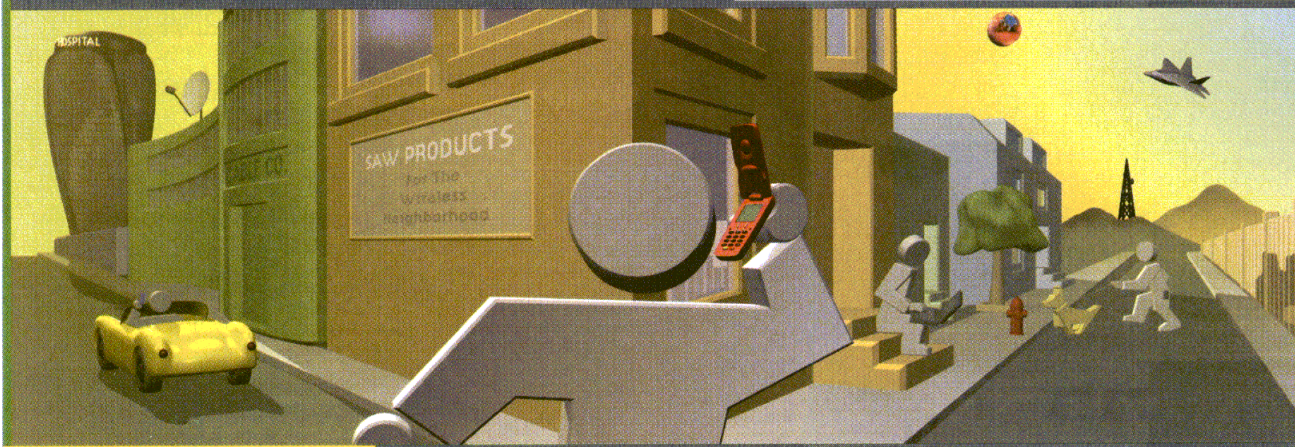
The authors wish to gratefully acknowledge Meera Srinivasan for simulating the optimum trellis-coded receiver of FQPSK (Figure 11). Additional thanks is also due Meera for having spent considerable time independently verifying much of what is presented here, which

is immeasurably important in establishing the credence of our results.

References

1. K. Feher and S. Kato, US Patent 4,567,602; K. Feher, U. S. Patent 5,491,457, and K. Feher, U. S. Patent 5,784,402.
2. K. Feher, *Wireless Digital Communications: Modulation and Spread Spectrum Applications*, Prentice-Hall, Englewood Cliffs, NJ, 1995.
3. K. Feher, “FQPSK doubles spectral efficiency of operational telemetry systems,” European Telemetry Conference, ETC '98, Garmish-Patternk, Germany, May 5-8, 1998.
4. S. Kato and K. Feher, “XPSK: A new cross-correlated phase-shift-keying modulation technique,” *IEEE Trans. on Communications*, Vol. 31, No. 5, May 1983.
5. W. L. Martin, T-Y. Yan, L. V. Lam, “CCSDS-SFCG: Efficient Modulation Methods Study at NASA/JPL, Phase 3: End-to-end performance,” SFCG Meeting, Galveston, TX, September 1997.
6. T. Le-Ngoc, K. Feher and H. Pham Van, “New modulation techniques for low-cost power and bandwidth efficient satellite earth stations,” *IEEE Trans. on*

Brighter Wireless Futures Begin With Sawtek...



What's the future of wireless? EDGE? 3G? WLAN? Wireless Internet? Rely on Sawtek for all your wireless design needs. **We've set a new standard with low-cost, high-performance RF filters for CDMA, GSM, TDMA and AMPS.** Our IF base station and handset SAW filters continue to set the quality and performance standard for 2G, 3G, Wireless Internet, WLL, WLAN, plus other commercial and military applications.



Call us today or visit our NEW website.

www.sawtek.com

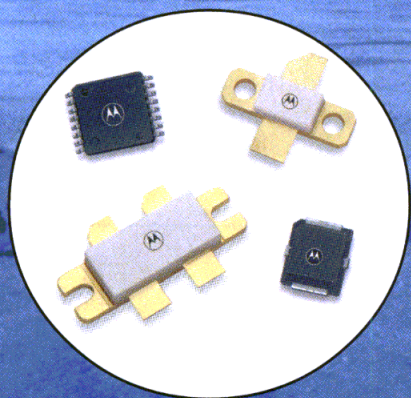
When you look to the future, look to Sawtek... We're leading the way!

Phone (407) 886-8860
Fax (407) 886-7061

Visit Sawtek at booth #1133 at the Wireless Symposium, February 21-25, 2000, in San Jose, California.

No Matter Where You Are In The World

Richardson is Focused on your Motorola RF Power Transistor and RFIC Needs



As part of an ongoing focus to meet customer needs, two stars in the RF arena — Richardson and Motorola — have joined forces to provide you the best in RF technology. Richardson Electronics is now authorized worldwide to sell Motorola wireless RF and IF components.

From RF transistors...to power amplifier modules to RF/IF components including PAs and LNAs, mixers, small signal transistors and phase-locked loops... you now have access to product and service capabilities that are unsurpassed in the industry.

Motorola, recognized as the market leader in RF Power Transistors and RFICs, will continue to introduce innovative, state-of-the-art RF products. Through its worldwide network, Richardson Electronics will provide technical and logistical support for new and existing Motorola RF and wireless customers around the globe.

The combination of our resources and expertise means you can count on getting the best...from the best. All with one goal in mind – to provide timely, efficient and well-focused solutions to your RF needs worldwide.

Motorola and Richardson Electronics - A World of Difference



MOTOROLA



**Richardson
Electronics**
Engineered Solutions

More than 60 locations worldwide to serve you. Email: ssc@rell.com, Internet: www.rfpower.net, Toll Free: 800-RF Power or 800-737-6937 (U.S. & Canada), Mexico: Mexico City +52 (5) 674-2228, Guadalajara +52 (3) 645-4641, Brazil: São Paulo +55 (11) 820-6199, Colombia: Santa Fe de Bogota, DC (57-1) 636-1028, France: Colombes Cedex +33 1.55.66.00.30, Germany: Puchheim +49 (89) 890 214-0, Italy: Agrate (MI) +39 (039) 653 145, Roma +39 (06) 41.73.37.51, Sesto Fiorentino (FI) +39 (055) 42.08.31, Spain: Barcelona +34 (93) 415 83 03, Madrid +34 (91) 528-3700, Sweden: Stockholm +48 8 564 705 90, Turkey: Istanbul +90 212 2643721, The Netherlands: Amsterdam +31 20 446 7070, United Kingdom: Slough +44 (01753) 733010, Australia: Castle Hill ACN 069 808 108 +61 (2) 9894-7288, Bayswater ACN 069 808 108, +61 (3) 9738-0733, China: Shanghai +86 (21) 6440-0807, Japan: Osaka +81 (6) 314-5557, Tokyo +81 (3) 5215-1577, Korea: Seoul +82 (2) 539-4731, Singapore +65 487-5995, Taiwan: Taipei +886 (2) 86915238, Thailand: Bangkok +66 (2) 749-4402, Vietnam: Ho Chi Minh City +84 8.811.1919, Corporate Headquarters: LaFox, IL (630) 208-2200, for other international inquiries call (630) 208-2200, Fax (630) 208-2550. ©1999 Richardson Electronics, Ltd. MK0342



For more
information visit

www.rfpower.net/motorola.asp
or our Online catalog at catalog.rell.com

Communications, Vol. 30, No. 1, January 1982.

7. M. C. Austin and M. V. Chang, "Quadrature overlapped raised-cosine modulation," *IEEE Trans. on Communications*, Vol. 29, No. 3, March 1981.

8. J. B. Anderson, T. Aulin, and C. E. Sundberg, *Digital Phase Modulation*, Plenum Press, New York, NY, 1986.

Author information

Dr. Marvin K. Simon is a Senior Research Engineer at the Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena, CA. For the last 31 years, he has performed research as applied to the design of NASA's deep-space and near-earth missions, resulting in the issuance of 9 patents and 23 NASA Tech Briefs. Dr. Simon is particularly well-versed in the subject of digital communications, with emphasis in several disciplines of modulation and demodulation, synchronization techniques for space, and satellite and radio communications. He has published more than 140

papers on the above subjects and is co-author of several textbooks. He is a Fellow of the IEEE and of the IAE, winner of a NASA Exceptional Service Medal and a NASA Exception Engineering Achievement Medal, and most recently winner of the IEEE Edwin H. Armstrong Achievement Award. Dr. Simon may be reached via e-mail at marvin.k.simon@jpl.nasa.gov.

Dr. Tsun-Yee Yan is the Technical Group Supervisor of the Digital Signal Processing Research Group, Communications Systems Research Section, at the Jet Propulsion Laboratory, Pasadena, CA. He is also the area program manager for Spacecraft Communications of the Technology and Applications Program Office at JPL, managing a sizable research and development effort in the high rate data communications area. He received the B.Sc. degree in electronics from the Chinese University of Hong Kong, and the M.Sc. and Ph.D. degrees in Electrical Engineering from the University of California, Los Angeles. Dr. Yan has published more than 60 journal and conference papers.

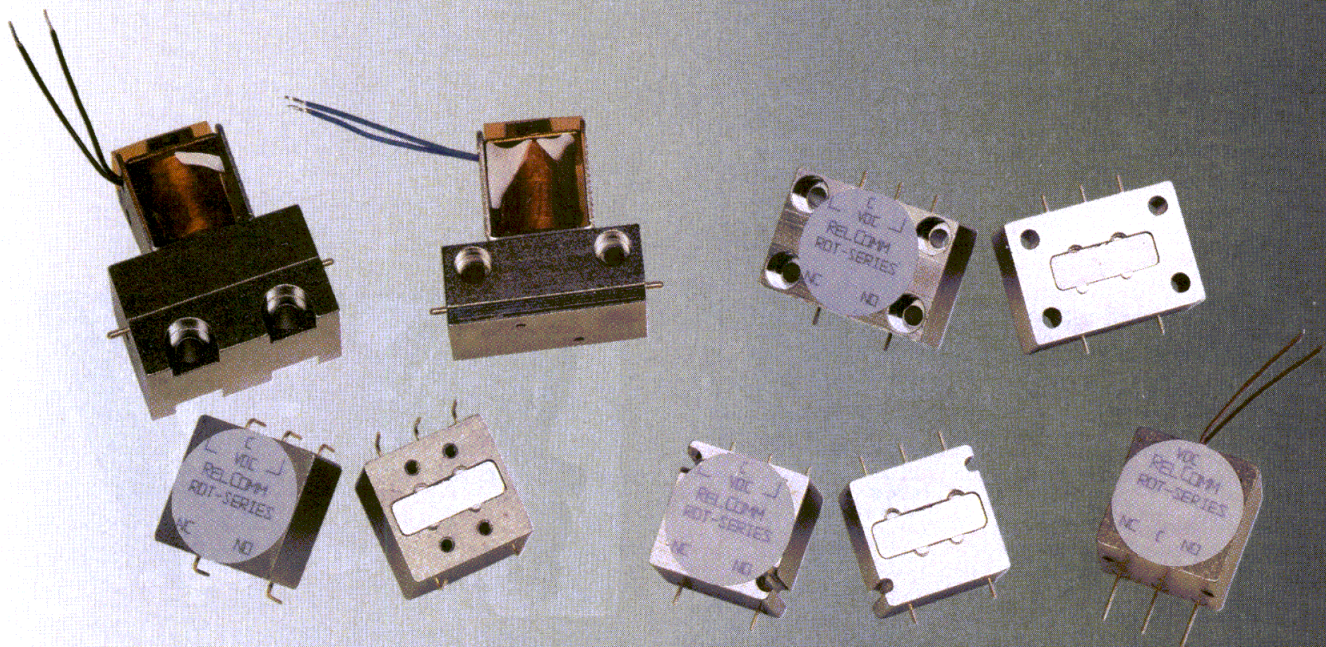
Appendix 1. Trellis state transitions.

current state	input	output	next state	current state	input	output	next state
0000	00	0 0	0000	0100	00	4 2	0000
0000	01	1 12	0010	0100	01	5 14	0010
0000	10	0 1	1000	0100	10	4 3	1000
0000	11	1 13	1010	0100	11	5 15	1010
0010	00	3 4	0001	0110	00	7 6	0001
0010	01	2 8	0011	0110	01	6 10	0011
0010	10	3 5	1001	0110	10	7 7	1001
0010	11	2 9	1011	0110	11	6 11	1011
1000	00	12 3	0100	1100	00	8 1	0100
1000	01	13 15	0110	1100	01	9 13	0110
1000	10	12 2	1100	1100	10	8 0	1100
1000	11	13 14	1110	1100	11	9 12	1110
1010	00	15 7	0101	1110	00	11 5	0101
1010	01	14 11	0111	1110	01	10 9	0111
1010	10	15 6	1101	1110	10	11 4	1101
1010	11	14 10	1111	1110	11	10 8	1111
0001	00	2 0	0000	0101	00	6 2	0000
0001	01	3 12	0010	0101	01	7 14	0010
0001	10	2 1	1000	0101	10	6 3	1000
0001	11	3 13	1010	0101	11	7 15	1010
0011	00	1 4	0001	0111	00	5 6	0001
0011	01	0 8	0011	0111	01	4 10	0011
0011	10	1 5	1001	0111	10	5 7	1001
0011	11	0 9	1011	0111	11	4 11	1011
1001	00	14 3	0100	1101	00	10 1	0100
1001	01	15 15	0110	1101	01	11 13	0110
1001	10	14 2	1100	1101	10	10 0	1100
1001	11	15 14	1110	1101	11	11 12	1110
1011	00	13 7	0101	1111	00	9 5	0101
1011	01	12 11	0111	1111	01	8 9	0111
1011	10	13 6	1101	1111	10	9 4	1101
1011	11	12 10	1111	1111	11	8 8	1111

Design Enhanced Application Specific

SMT COAXIAL RELAYS

Now Very Affordable



*Typical Insertion Loss is 0.07dB at 900MHz, 0.12dB at 1900 MHz
Typical Isolation is 85dB at 900MHz; 75dB at 1900MHz
Designs available up to 8GHz*

RELCOMM
TECHNOLOGIES, INC.

Circle 53

See us at Wireless Symposium, booth #1334

**COMMITMENT TO SERVE THE CHANGING NEEDS
OF THE CUSTOMER BY DESIGN**

610 Beam Street, Salisbury, Maryland 21801 Sales Office...410-749-4488; Fax...410-860-2327

EXCELLENCE BY DESIGN

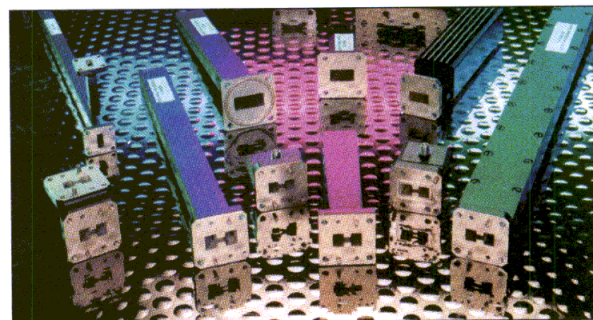
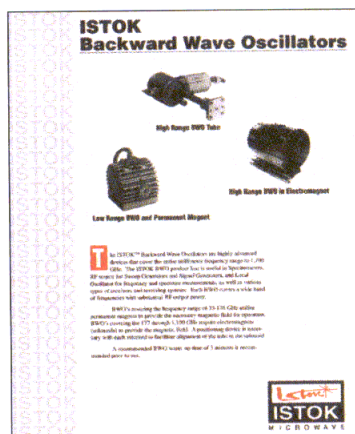
Product Focus — Components for mm-Wave Systems

Backward wave oscillators are available for frequencies from 33 to 1100 GHz

A series of backward wave oscillators are now available from ISTOK Microwave, covering 33 to 1100 GHz in overlapping ranges. Power output of 6 to 20 mW is available at lower frequency ranges, while high range units provide a minimum 1 mW output. Permanent magnet oscillators cover 33 GHz to 178 GHz with five models. They require 0.9 to 1.2 volts at 2.5

amps (max.) for the BWO tube filament, and 350 to 1500 volts at 40 mA for the slow wave structure. For higher frequencies, a single electromagnet can be used with seven BWO tubes to cover 177 GHz to 1100 GHz. The electromagnet requires 300 volts at 14.5 amps (max.) to create an 11 Tesla field. BWO filaments require 5.5 to 7.5 volts at 1.4 to 2.0 amps, along with 1.0 to 6 kV at 45 mA for the slow wave structure. Power supplies for the BWO units and electromagnet assembly are offered, along with an optional positioner to facilitate the alignment of the BWO tube into the electromagnet solenoid. Applications include university, government and industrial research labs, providing signals for signal generators, spectrum analyzers, spectrometers and receiving systems.

ISTOK Microwave
Circle #193



Waveguide products cover up to 40 GHz

Advanced Microtek has introduced a wide range of high-performance waveguide products designed to address both commercial and military microwave applications up to 40 GHz. Available in either rectangular or double-ridge configurations, the products range from standard items such as adapters, transitions, terminations, attenuators and couplers, as well as a variety of bends, twist/straight sections and flexible waveguide sections. Specialized designs can be manufactured, including pressure windows, TEM transmission cells, harmonic filters, horn antennas, mismatches and water-cooled loads. Standard waveguide products are offered in aluminum with matte black paint, or they can be specified in traditional materials of brass or copper. Custom design services are offered for requirements that cannot be met with the standard product line.

Advanced Microtek Ltd.
Circle #194

Broadband K- and Ka-band amplifiers

QuinStar offers the QGU series of ultra-broadband PHEMT based general purpose power amplifiers for applications across the entire K- or Ka-band frequency range. The

SV MICROWAVETM

RF Connectors • Cable Assemblies • Resistive Products

HAS YOUR RF CONNECTOR SUPPLIER...

- a) Been swallowed up by a huge conglomerate?
- b) Moved to a new location and lost the recipe?
- c) Changed names and forgotten yours?

If so, SV Microwave can solve your problems by providing:

- An accessible engineering staff
- A supportive and helpful sales team
- Quick responses
- Short lead times
- Direct equivalents
- An array of Mil Qualified items

Tired of being treated like a number? Feeling misplaced in the confusion? Being turned away on special design projects? Give us a call. We haven't lost the personal touch!

Visit our new website:
www.svmicrowave.com

3301 Electronics Way, West Palm Beach, Florida 33407
Tel: 561-840-1800 • Fax: 561-844-8551 • E-mail: sales@svmicro.com

Circle 27

See us at Wireless Symposium, booth #1027

amplifiers are offered with 20 dB or 40 dB gain, with a nominal power output of +17 dBm. Each amplifier has internal bias circuitry that generates gate control voltages and provides proper voltage sequencing and reverse/overvoltage protection using a single external 8 to 12 volt supply. The standard amplifier is provided with K-female connector input and output ports, although standard rectangular waveguide (K- and Ka-bands) and double-ridge waveguide (18 to 40 GHz) are also available. Waveguide input and output ports are arranged in line for simplified installation.

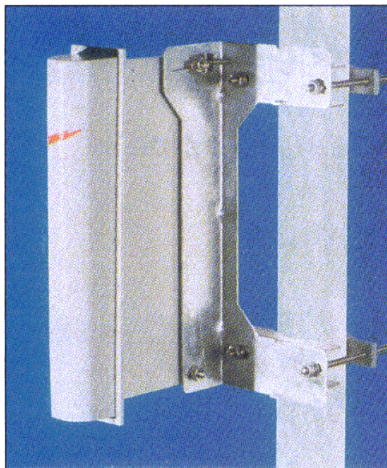
QuinStar Technology, Inc.

Circle #195

Sector antennas for broadband services

Andrew Corporation now offers three new models in its Broadband Communications Antenna (BCA) series.

The High Gain Sector Antenna covers the 24.25 to 26.5 GHz band, delivering 20.5 dBi gain with 90 degree azimuth coverage. Coverage of 45 or 90 degrees is available in either vertical or horizontal polarization, and the vertical pattern is contoured to avoid nulls in the coverage area. Two models of the BCA



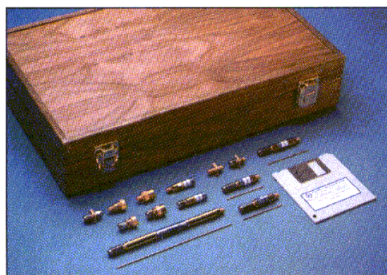
Series Mark II give enhanced pattern performance in the 27.35 to 28.5 GHz and 37.0 to 40.0 GHz bands, with 21 dBi and 22 dBi gain respectively at 90 degree sector coverage. Azimuth patterns and cross-polarization rejection are improved over earlier models for better rejection outside the desired sector.

Andrew Corporation

Circle #196

3.5 mm coaxial calibration kits

Maury Microwave has announced the 8060A series of coaxial TRL/LRL (Through-Reflect-Line, Line-Reflect-Line) 3.5 mm calibration kits. The kit is designed to work with Hewlett Packard (Agilent) vector network analyzers at frequencies up to 34 GHz. They are provided with either 3.5 mm in-series phase matched adapters or 2.4 to 3.5 mm phase matched adapters. A full 2-port calibration can be made over the entire bandwidth. In addition, 1-port or 2-port



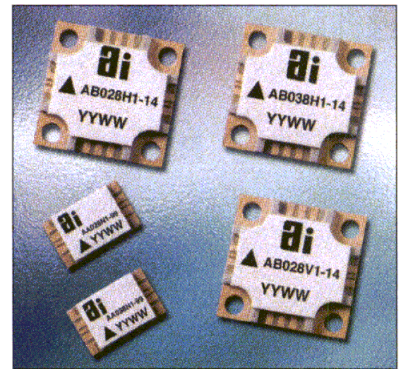
SOLT (Short-Open-Load-through) fixed load calibration can be performed, and a 1-port Short-Open (airline plus load) calibration can be performed for gated measurements. Recommended options include the A034B and A034E push-on and thread-on connector gages and the 8799A1 8 in/lbs torque wrench.

Maury Microwave Inc.

Circle #197

Packaged broadband mm-wave amplifiers

Alpha Industries has added five packaged amplifiers to its product line, supporting mm-wave sensor and communications applications. The AB028H1-14 is a high gain amplifier for 23 to 30 GHz, with 36 dB gain, +16 dBm power output and 3 dB noise figure. The AB038H1-14 offers 30 dB gain, +16 dBm power output and 4 dB noise figure. Both of these amplifiers operate from a single supply. The AB028V1-14 is a variable gain amplifier covering 23 to 30 GHz. It features 30 dB available gain, 30 dB attenuation range, +16 dBm power output and 3 dB noise figure. Two new low noise amplifiers, the AA028N1-99 and AA038N1-99, cover 23 to 30 GHz and 26 to 42 GHz respectively. The lower frequency model has 3 dB noise figure, 18 dB gain and +9 dBm output power, while the high frequency version has 3.8 dB noise figure, 18 dB gain and +5 dBm power output. The AA028N1-99 is priced at \$30.98 in quantities of 10,000.

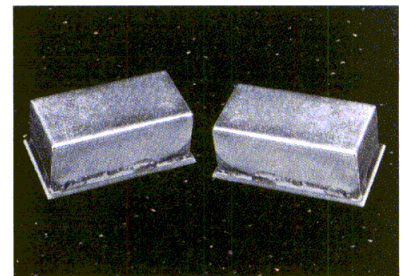


Alpha Industries

Circle #198

IF filters are designed for LMDS

Piezo Technology, Inc. (PTI) offers the 8600 series of LC filters for IF and tuner applications in LMDS/MMDS wireless network equipment. Transmit path filters feature center frequencies in the 450 to 650 MHz range, with receive path filters operating in the 1200 to 1500 MHz range. At 1 dB, passband responses are generally 75 MHz and 375 MHz for the transmit and receive paths respectively. The filters are provided in hermetically sealed packages on tape and reel for automated manufacturing.



Piezo Technology, Inc.

Circle #199

CHIP INDUCTOR KITS

NEW! 0402CS Series
1.0 nH - 40 nH, 5% tolerance
21 values (10 each) Kit C128 \$60

NEW! 0603CS Series
1.6 nH - 270 nH, 5% tolerance
37 values (10 each) Kit C124 \$80
Kit C124-2 (2% tolerance) \$100

0805CS Series
3.3 nH - 820 nH, 5% tolerance
26 values (10 each) Kit C103 \$60
Kit C103-2 (2% tolerance) \$85

NEW! 0805HQ High Q Series
2.5 nH - 51 nH, 5% tolerance
12 values (10 each) Kit C125 \$60

1008CS Series
10 nH - 4.7 μ H, 5% tolerance
36 values (10 each) Kit C100 \$100
Kit C100-2 (2% tolerance) \$120

NEW! 1008HQ High Q Series
3.0 nH - 100 nH, 5% + 10% tolerance
14 values (10 each) Kit C123 \$60
Kit C123-2 (2% tolerance) \$80

AIR CORE INDUCTOR KITS

"Micro Spring" Series
Inductance: 1.65 nH - 12.54 nH
9 values (12 each) Kit C108 \$50

"Mini Spring" Series
Inductance: 2.5 nH - 43 nH
10 values (12 each) Kit C102 \$60

"Midi Spring" Series
Inductance: 22 nH - 120 nH
10 values (12 each) Kit C118 \$60

LOW PROFILE POWER INDUCTORS

NEW! LP02506 Power Wafers™
4.7 μ H - 1000 μ H, 0.16 - 1.9 Amps
15 values (3 each) Kit C132 (In-board versions) \$60
Kit C133 (On-board versions) \$60

NEW! LPT3305 Shielded Power Wafers™
1 μ H - 47 μ H, 0.6 - 1.6 Amps
11 values (3 each) Kit C130 \$60

D03308 Series
10 μ H - 1000 μ H, 0.05 - 2 Amps
13 values (3 each) Kit C109 \$60

POWER INDUCTOR KITS

DS1608 Shielded Series
1 μ H - 10,000 μ H, 0.02 - 3 Amps
25 values (3 each) Kit C115 \$80

NEW! D01813HC High Current Series
0.56 μ H - 48.1 μ H, 0.72 - 6 Amps
9 values (3 each) Kit C131 \$60

DS3316 Shielded Series
1 μ H - 47 μ H, 0.8 - 5 Amps
11 values (3 each) Kit C116 \$60

NEW! D03316HC High Current Series
0.33 μ H - 3.3 μ H, 6.4 - 16 Amps
7 values (3 each) Kit C126 \$45

D01608/3316 Series
1 μ H - 1000 μ H, 0.07 - 6.8 Amps
38 values (3 each) Kit C105 \$90

DT1608/3316 Shielded Series
1 μ H - 1000 μ H, 0.8 - 5 Amps
38 values (3 each) Kit C104 \$95

DS5022 Shielded Series
10 μ H - 1000 μ H, 0.53 - 3.9 Amps
13 values (3 each) Kit C117 \$60

D05022 Series
1 μ H - 1000 μ H, 0.56 - 8.6 Amps
17 values (3 each) Kit C111 \$60

D05022HC High Current Series
0.78 μ H - 10 μ H, 6.0 - 15 Amps
9 values (3 each) Kit C113 \$60

FOR EVEN MORE KITS VISIT
[HTTP://ORDER.COILCRAFT.COM](http://ORDER.COILCRAFT.COM)

Coilcraft
**DESIGNER'S
KIT**

Coilcraft

**DESIGNER'S
KIT**

Coilcraft

**DESIGNER'S
KIT**

Coilcraft

**DESIGNER'S
KIT**

Coilcraft

**DESIGNER'S
KIT**

Coilcraft

**DESIGNER'S
KIT**

Coilcraft

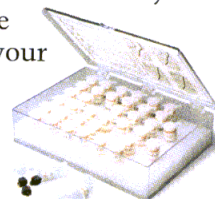
**DESIGNER'S
KIT**



The longest line
of magnetics kits is
now available on-line

Pull up our web site. Pull out your credit card. And within minutes the kits you need will be on their way.

No one offers more prototyping kits for your RF, EMI and power magnetics. And no one makes it so easy to order, even on nights and weekends.



Of course you can still pick up the phone and call us at 800-322-2645.

Either way, we'll put the right magnetics right at your fingertips.

Coilcraft™

Cary, IL 60013 800/322-2645 www.coilcraft.com

Test Systems Enhance RF Component and Power Amplifier IC Testing

Agilent Technologies, Inc. has announced new test instrumentation for RF component and RFIC production. The Agilent 87050E multiport test set can greatly improve throughput and accuracy in high volume production of 50 ohm components, while the Agilent 84000 Series Model A20e addresses high volume RFIC testing by providing a complete solution for power amplifier ICs.

The 87050E multiport test set works with the Agilent 8712E series network analyzers to characterize devices operating up to 3 GHz with as many as 12 ports. All transmission paths and port reflection characteristics can be measured with a single set of connections.

Calibration time is reduced with two types of calibration. Periodic full calibration using short, open and load standards is simplified by requiring only one connection at each port while the unit calibrates all measurement paths. In addition, a self calibration routine uses the unit's internal standards to correct for system drift. A full calibration may not be needed for as long as a month. The unit is priced from \$8,250 to \$14,250, depending on the configuration.

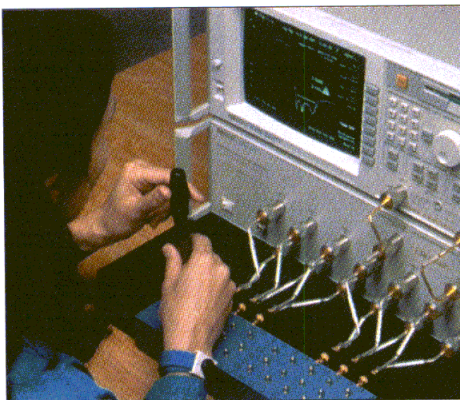
The Model A20e expands the Agilent 84000 RFIC series with the capability for complete testing of power amplifier RFICs. The system performs 2-port

tests, with vector measurements from 750 MHz to 3 GHz and scalar measurements up to 8 GHz. The product is compliant with CDMA, NADC, PDC, PHS, GSM, DECT and TETRA. Measurements include input/output power, gain, ACPR, harmonics, *s*-parameters, current and voltage. The base price is under \$400,000. ■

For more information, contact:

Agilent Technologies, Inc.
(A subsidiary of Hewlett-Packard Company)
5301 Steven Creek Blvd. – MS 54LAK
Santa Clara, CA 95052
Tel: 800-452-4844 ext. 6849 (87050E)
ext. 6866 (Model A20e)
Internet: <http://www.agilent.com>

**Or circle Reader Service #201 (Agilent 87050E)
or #202 (Agilent 84000 Series Model A20e)**



▲ Agilent introduces new production test equipment, the Agilent 87050E multiport test set (above) and the 84000 Series Model A20e RFIC power amplifier test system (right).



NEW ERA AMPLIFIERS

WOW! DC to 8GHz **\$1¹⁹**
(up to +18.5dBm output) From (1000 qty.)

Mini-Circuits ushers-in a new era of technology and economy with ERA monolithic GaAs amplifiers. Just check the specs! These surface mount and drop-in amplifiers cover your applications to 8GHz with higher gain, more output, and flatter response. Characterized with S-parameter data, these amplifiers are very easy to use. Simply sketch an interconnect layout, and the design is done. And ERA's are engineered with wider bandwidths to eliminate your need for costly compensation networks and extra gain stages. So, review your present design and replace with Mini-Circuits new ERA technology. Lower overall cost, wide bandwidth, and lots to...gain!

Mini-Circuits...we're redefining what VALUE is all about!

Model	*Freq. (MHz)	Gain (dB)	Max. Power Out (dBm, @ 1dB Comp)	Dynamic Range NF(dB)	IP3(dBm)	@Device Current(mA)	①Price \$ ea. (10 Qty.)
ERA-1	DC-8000	11.8	11.7	5.3	26.0	40	1.80
ERA-1SM	DC-8000	11.8	11.3	5.5	26.0	40	1.85
ERA-2	DC-6000	15.6	12.8	4.7	26.0	40	1.95
ERA-2SM	DC-6000	15.2	12.4	4.6	26.0	40	2.00
ERA-3	DC-3000	20.8	12.1	3.8	23.0	35	2.10
ERA-3SM	DC-3000	20.2	11.5	3.8	23.0	35	2.15
ERA-4	DC-4000	13.5	▲17.0	5.5	▲32.5	65	4.15
ERA-4SM	DC-4000	13.5	▲16.8	5.2	▲33.0	65	4.20
ERA-5	DC-4000	18.8	▲18.4	4.5	▲33.0	65	4.15
ERA-5SM	DC-4000	18.5	▲18.4	4.3	▲32.5	65	4.20
ERA-6	DC-4000	11.3	▲18.5	8.4	▲36.5	70	4.15
ERA-6SM	DC-4000	11.3	▲17.9	8.4	▲36.0	70	4.20

Note: Specs typical at 2GHz, 25°C. Exception: ▲ indicates typ. numbers tested at 1GHz.

* Low frequency cutoff determined by external coupling capacitors.

① Price (ea.) Qty.1000: ERA-1 \$1.19, -2 \$1.33, -3 \$1.48, -4, -5 or -6 \$2.95. SM option same price.

DESIGNER'S AMPLIFIER KITS:

K1-ERA: 10 of each ERA-1, -2, -3 (30 pieces) only \$49.95

K1-ERASM: 10 of each ERA-1SM, -2SM, -3SM (30 pieces) only \$49.95

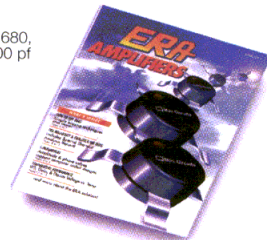
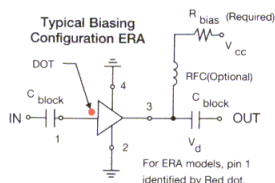
K2-ERA: 10 of each ERA-4, -5 (20 pieces) only \$69.95

K2-ERASM: 10 each ERA-4SM, -5SM (20 pieces) only \$69.95

K3-ERASM: 10 each ERA-4SM, -5SM, -6SM (30 pieces) only \$99.95

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

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



Free User Guide!
Packed with comprehensive technical support. Shipped with order, or call for your free copy today.

Mini-Circuits®

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661 **INTERNET** <http://www.minicircuits.com>
For detailed specs on all Mini-Circuits products refer to • 760- pg. HANDBOOK • INTERNET • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM

ISO 9001 CERTIFIED

US **89** INT'L **99**
CIRCLE READER SERVICE CARD

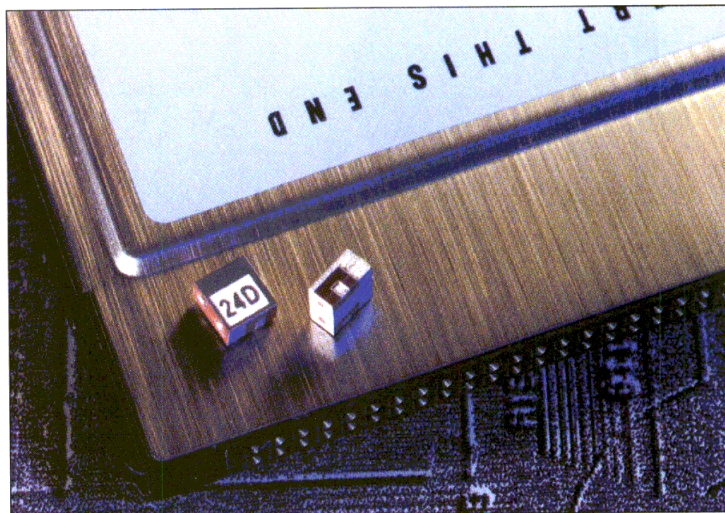
F 214 Rev F

Miniature 2.45 GHz Dielectric Filter Targets PCMCIA Card Applications

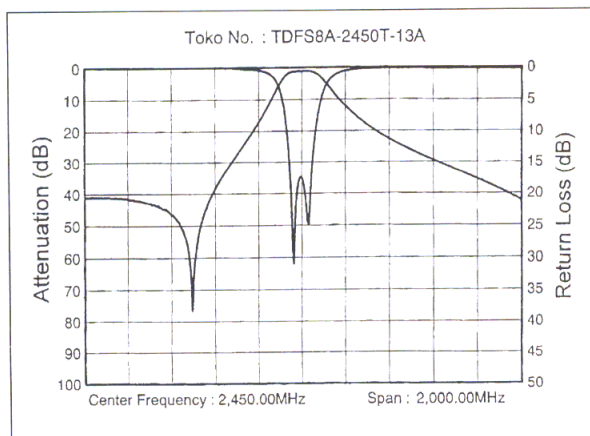
Toko announces a new dielectric bandpass filter for 2.45 GHz wireless local area networking designs using PCMCIA card for factors. The TDFS8A-2450T-13A has a footprint of 3.2×3.0 mm and a low profile of only 1.8 mm.

The TDFS8A-2450T-13A is a bandpass filter with an insertion loss of <2.0 dB and an average minimum attenuation of 40 dB at 1950 MHz. The filter's center frequency is 2450.0 MHz and it has a passband of $f_0 \pm 50.0$ MHz. Passband amplitude ripple is 0.7 dB maximum and VSWR in the passband is 2.0:1 maximum. The filter is designed for 50 ohm input and output impedances. Figure 1 shows a plot of the filter's frequency response and return loss.

The filter is manufactured using Toko's proprietary dielectric material and process. It is



▲ Toko announces the TDFS8A-2450T-13A, a miniature band-pass filter for 2.45 GHz PCMCIA card applications.



▲ Figure 1. Frequency response and return loss of the miniature 2.45 GHz filter.

provided on 2000-piece tape and reel in for automated circuit assembly. Pricing in 10,000 unit quantities is less than \$1.00 each. Other Toko products include miniature inductors, integrated circuits, DC-DC converters, imaging products and electronic component assemblies. ■

For more information, contact:

Toko America, Inc.
125 Feehanville Drive
Mount Prospect, IL 60056
Tel: 847-297-0070
Fax: 847-699-7864
E-mail: info@tokoam.com
Internet: <http://www.tokoam.com>

Or circle Reader Service #203



Committed to:

Service & Support
Rapid Response

With:

Standard Product Solutions
Custom "Application Specific Designs"

For:

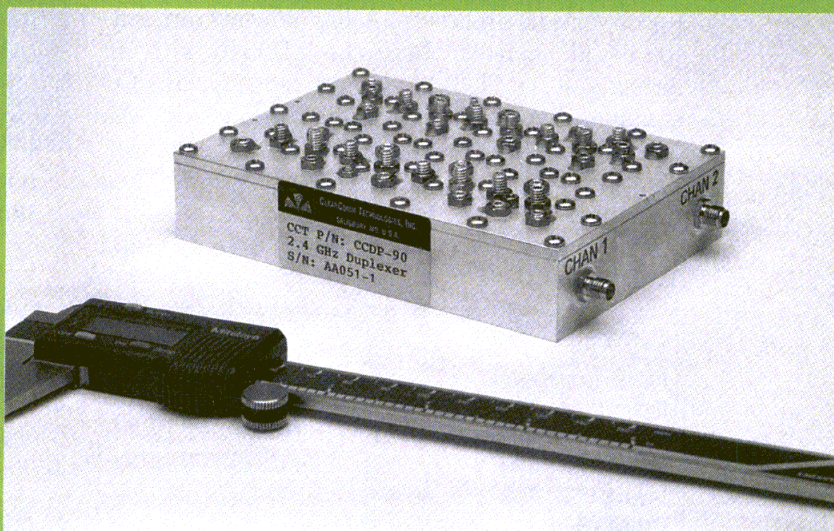
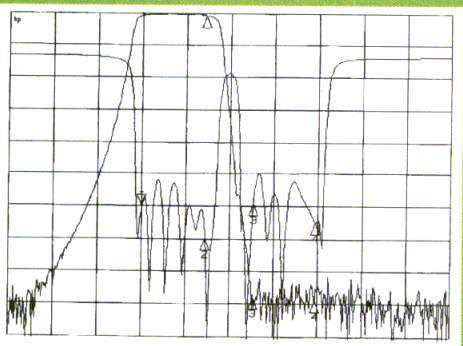
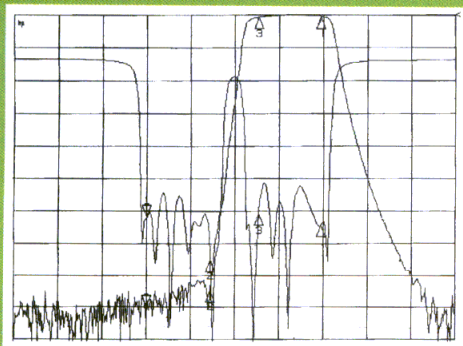
High Volume, Wireless
Telecommunication Requirements

Excellence in Wireless Filter Technology

ClearComm Technologies offers a variety of filter products targeted at the wireless/telecommunications market.

Applications include:

- Standard base station filters/duplexers
- Custom performance enhancing base station assemblies
- Delay filters for feed-forward amplifiers
- Cosite interference solutions
- Duplexers for 2.4-5.8GHz radios
- Custom products up to 40GHz



Designed for Wireless Modem applications ClearComm Technologies' CCDP-90, 2.4GHz Duplexer achieves 100dB of isolation between channels with less than 2.5dB of loss in the passband. Clearcomm's design techniques allow this performance to be achieved in a minimal package size. Standard as well as custom 2.4 and 5.8GHz designs are available.

1918C Northwood Drive
Salisbury, Maryland 21801
Web: clearcommtech.com



Circle 62

Tel: 410-860-0500
Fax: 410-860-9005
E-mail: clearcom@dmv.com

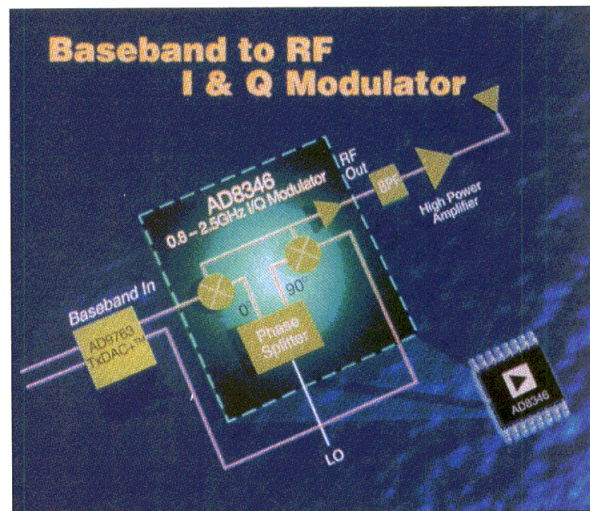
See us at Wireless Symposium, booth #1336

Quadrature Modulator IC Operates up to 2.5 GHz

A new RF integrated circuit for wireless communications has been introduced by Analog Devices. The AD8346 is a direct quadrature (I/Q) modulator with high phase accuracy and amplitude balance over its rated frequency range of 800 to 2500 MHz.

Quadrature modulation is used in many modern communications systems, including GSM, CDMA and W-CDMA. The AD8346 provides quadrature modulation directly at the transmitter output frequency, eliminating IF stages and upconversion processes. A low power transmitter could be built using the AD8346 with an AD97xx series TxDAC and an appropriate LO signal source (e.g. frequency synthesizer). An external amplifier can be used for higher power. Key specifications of the device are summarized in Table 1.

Packaging for the AD8346 is a 16-lead TSSOP and it is specified for operation over a



▲ Analog Devices' new AD8346 offers direct quadrature modulation up to 2.5 GHz.

Parameter	Specification
Output frequency	0.8 to 2.5 GHz
Quadrature phase error	1 degree
I/Q amplitude balance	0.2 dB
Output power (typ)	-10 dBm
Output VSWR (typ)	1.25:1
Output P _{1dB} (typ)	-3 dBm
Carrier feedthrough (typ)	-42 dBm
Sideband suppression (typ)	-36 dBc
IM3 suppression (typ)	-60 dBc
Output noise floor (typ)	-147 dBm/Hz
LO input drive level (min/max)	-12 dBm/-6 dBm
LO input VSWR (typ)	1.9:1
Supply voltage (min/max)	2.7 V/5.5 V
Supply current (min/max)	35 mA/55 mA

▲ Table 1. AD8346 key specifications (for operation at 1900 MHz).

temperature range of -40 to +85° C. Its 2.7 to 5.5 volt supply range is suitable for today's typical design requirements. The IC is fabricated using Analog Devices' 2.5 GHz bipolar silicon process. The device is priced at \$4.96 each in 1000-piece quantities. ■

For more information, contact:

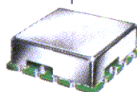
Analog Devices, Inc.
Ray Stata Technology Center
804 Woburn Street
Wilmington, MA 01887
Tel: 800-ANALOGD (800-262-5643)
Fax: 781-937-1021
Internet: <http://www.analog.com>

Or circle Reader Service #204

ROS
50MHz to 1600MHz

MINIATURE SURFACE MOUNT VCO's **\$12⁹⁵** from **12⁹⁵** (qty. 5-49)

The big news is Mini-Circuits miniature family of **50 to 1600MHz** ROS voltage controlled oscillators! Each unit is housed in a shielded 0.5"x0.5"x0.18" non-hermetic industry standard package for highly efficient wash-thru capability, reliability, and cost effectiveness. Models with "PV" suffix typically operate from a 5 volt power supply and require 5V tuning voltage to cover the frequency range. This makes them ideal for integration with monolithic PLL chips and commercial synthesizers working within the 245 to 1600MHz band. The series also features wide band 12V models optimized for 50 to 1410MHz linear tuning, up to one octave band widths, and low phase noise. Support your customers demands for smaller size and better performance, switch to ROS VCO's today!



ACTUAL SIZE

Mini-Circuits...we're redefining what **VALUE** is all about!

ROS SPECIFICATIONS:

Model	Freq. Range (MHz)	V _{tune} (V) Max.	Phase Noise* Typ.	Harmonics** (dBc) Typ.	Voltage V	Current (mA) Max.	Price \$ea. (5-49)
ROS-285PV	245-285	5	-100	-20	5	20	17.95
ROS-900PV	810-900	5	-102	-25	4.5	12	19.95
ROS-960PV	890-960	5	-102	-27	5	12	19.95
ROS-1000PV	900-1000	5	-104	-33	5	22	19.95
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
ROS-765	485-765	16	-95	-27	12	22	15.95
ROS-1410	850-1410	11	-99	-8	12	25	19.95

*Phase Noise: SSB at 10kHz offset, dBc/Hz. **Specified to fourth.

Mini-Circuits®

US **80** INT'L **90**
CIRCLE READER SERVICE CARD

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 INTERNET <http://www.minicircuits.com>

For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE • EEM • MICROWAVE PRODUCT DATA DIRECTORY • WWW.RFGLOBALNET.COM

ISO 9001 CERTIFIED

F 295 Rev 0rg

High Speed VCXOs and Master Clock Oscillators Operate at 3.3 Volts

Micro Networks/Andersen Laboratories has introduced new low voltage (3.3 V) oscillator products for high speed, high performance computing and telecommunications equipment. Applications include network servers, instrumentation, base stations, datacom/telecommunication transmission, defense and ATE systems.

Master Clock Oscillators

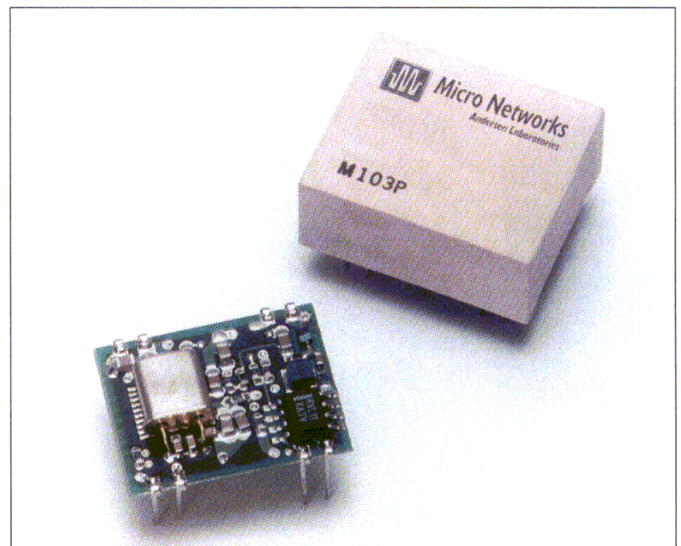
The M103 series of Master Clock Oscillators features 2 ps phase jitter for timing applications at frequencies up to 800 MHz. The oscillators provide a precise, stable clock source in either a SMT or DIP package for state-of-the-art or first generation products.

PECL logic is used in the M103, operating at 3.3 volts. Optimum jitter is obtained in a 50 ohm environment. temperature stability is maintained within <30 ppm variation from 0 to 70° C at frequencies up to 800 MHz. Any application requiring high frequency and precise timing can benefit from the M103 performance. OEM delivery is from stock to 18 weeks.

High performance, high speed VCXOs

The expanded line of Micro Networks' products includes the M303 series of 3.3 volt VCXOs. Originally designed for SONET applications, the M303 series has been expanded to include frequencies from 100 to 800 MHz. With 3 ps jitter in a 50 ohm environment, these VCXOs are suited for any high speed clock application.

The M303 series is available in either SMT or DIP packaging, operating from 3.3 volts with a



▲ Micro Networks has developed a series of low voltage Master Clock Oscillators for high performance computer and telecommunications systems.

temperature stability specification of <30 ppm over the range of 0 to 70° C. OEM delivery is from stock to 12 weeks.

Micro Networks is ISO-9001 registered and certified to MIL-PRF-38534. ■

For more information, contact:

Micro Networks/Andersen Laboratories
324 Clark Street
Worcester, MA 01606
Tel: 508-852-5400 ext. 3110
Fax: 508-853-8296
E-mail: sales@mnc.com

Or circle Reader Service #205

A Stronger Signal

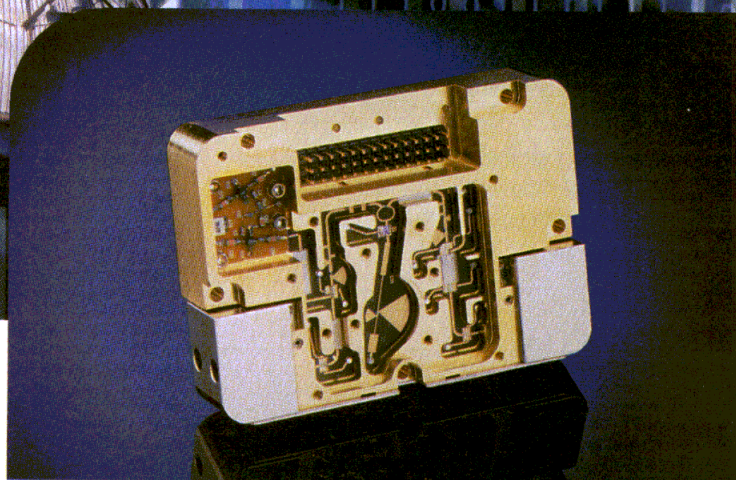
**Integrated T/R Modules.
Singular in Nature,
Multiple in Functionality.**

From low to medium capacity FSK and QPSK radio platforms, to high data rate QAM radios, Signal has a solution for integrating your transmit and receive functions into a single module.



Building on the core
technology of AFP
(acquired Dec. 1999),

we can deliver the exact module for the job. A strong design library of Transmitters, Receivers, Mixers, Multipliers, Power Amps, and LNAs allow us to go from prototype to production in a flash. And we can also design-in other critical features of your radio (VCOs, prescalers, etc.) to create a customized package that suits your architecture perfectly. These devices are ideal for your latest Digital point-to-point and point-to-multipoint designs. For more information visit our T/R Module web page at www.sigtech.com/afp/trm1.



38 GHz T/R Modules w/Internal VCO & Prescaler

Frequency Range:	37 to 40 GHz (ETSI and FCC versions available)
Rx Gain:	30 dB typ.
Rx Noise Figure:	5 dB typ.
Tx Output Power:	20 dBm typ.
Tx Gain:	15 dB min.
Tx Output Phase Noise:	-84 dBc/Hz @ 100 kHz typ.
LO Multiplication Factor:	VCO x 9
Prescaler Output:	VCO/4

www.sigtech.com/afp/trm1

SIGNAL
TECHNOLOGY CORPORATION
WIRELESS GROUP

28 Tozer Road, Beverly, MA 01915 • 978-922-0019 • Fax 978-927-9328
www.sigtech.com

Circle 42

Engineers and Designers: Find **SOLUTIONS** at Wireless/Portable 2000

SOLUTIONS

For over nine years, **Wireless Symposium/Portable by Design** has been the most comprehensive, market-focused event designed specifically for wireless and portable engineers and designers.

AN EXCLUSIVE MIX OF

- ◆ Over 75 powerful conference sessions
- ◆ An exhibition featuring over 400 industry-leading hardware, software, testing, and quality-control vendors
- ◆ Plus popular networking/workshop functions makes Wireless/Portable 2000 the center of industry convergence

SOLUTIONS

If you can't find solutions to your engineering, design, test, or quality-control challenges at Wireless/Portable 2000, they probably don't exist.

Register on-line for a **FREE Exhibit Hall pass**, which includes access to popular networking sessions.

✓ **On-Line Conference Registration is now discounted!**

Register on-line today for the renowned conference program using code **AMW2**, and **save 40%** off the on-site prices. **Log on now to** www.WirelessPortable.com

Call 1-888-WireReg to receive a conference brochure. Don't delay, seating is limited.



EXHIBITION: February 22 - 24, 2000

CONFERENCE: February 22 - 25, 2000

San Jose Convention Center

San Jose, CA, USA

Platinum Sponsor:



Gold Sponsors:



Sponsoring Publications:

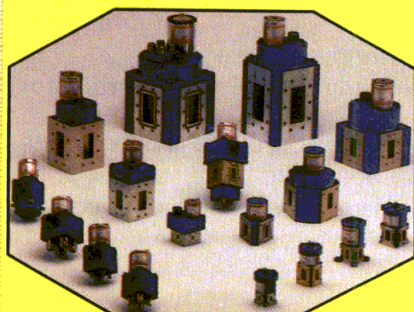


Produced By:



Product Spotlight

WAVEGUIDE & COAXIAL SWITCH SPECIALISTS



SWITCH OVER TO:



SECTOR MICROWAVE INDUSTRIES, INC.

999 Grand Blvd., Deer Park, New York 11729
(516)242-2300 · Fax: 516-242-8158

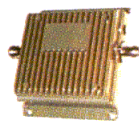
Request your "R-F Switch slide Guide" today!

Circle 101

Don't You Wish You Had Longer Range or more power

GO FARTHER with SMARTAMPS

The low cost, patent pending bi-directional SmartAMPs can automatically boost and maintain power to assure optimum performance of your system for long range applications.



- Automatic Wide Range Input Adapting
- 900 MHz, 2.4 GHz, 5.8 GHz
- Direct Sequence or Frequency Hopping.
- Wireless Internet/LAN/Modems/Local Loops
- OEM Military & International Applications



Teletronics International, Inc.
1803 Research Blvd. Suite 404
Rockville, MD 20850

Call: 301-309-8500
Fax: 301-309-8851
sales@teletronics.com
www.teletronics.com

Circle 102



Personal Probe Station

**Very Low Cost
High Function**

A compact full featured, modestly priced, manually operated probe station developed for engineers and scientists. Measure Microwave, RF and DC parameters of Semiconductor Devices, Packages and Assemblies with NIST traceability.

- Benchtop Size (<1ft³) • Vacuum chuck • X-Y-Z stage •
- X-Y-Z probe positioners • Top Plate Z-lift • Vacuum Accessory Manifold •
- 7X-40X Stereo Zoom Microscope • Adjustable Halogen Illuminator •
- Vacuum Accessories • Compatible with 40GHz+ probes •
- Accessories for Thermal Chucks and Probe Cards •
- Test wafers, microstrip packages and surface mount components •



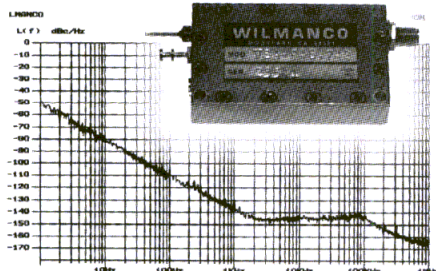
JmicroTechnology

3744 NW Bluegrass Pl
Portland, OR 97229
(503) 614-3869
(503) 531-9328 (FAX)
www.jmicrotechnology.com

A Probe Station On Every Bench

Circle 103

HYBRID FREQUENCY SOURCE CRYSTAL OSCILLATOR- MULTIPLIERS

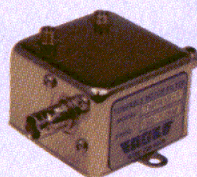


Typical measured phase noise of (2) model
VSA-100 MHz Freq. Source.

FREQ. RANGE: 10 MHz to
FREQ. STABILITY: ± 5 ppm, 0°C to $+50^\circ\text{C}$
POWER OUT: +8 dBm to +15 dBm

Wilmanco 5350 Kazuko Court, Moorpark, Ca. 93021
(805) 523-2390 Fax: (805) 523-0065

Circle 104



SUPER NARROW NOTCH

Our TNF400 tuneable filters provide $<0.7\%$ notch width with notch depths of >30 dB. Frequencies available are 10 to 500 Mhz. Units will pass up to 1.0 GHz. Package size is 2"x2." Call for FREE application note!



More Info? Phone: 520.204.2597

Circle 105

WAVEGUIDE DESIGN AND ANALYSIS SOFTWARE

Windows 95/NT/Alpha
Full EM Field Modeling Based

Filters:

Lowpass, Bandpass, Bandstop,
Evanescent, Dual Mode, Finline

Diplexers & Multiplexers

E/H-Plane, Bifurcated, T, L and Coaxial
Line Common Ports

Transformers

E-Plane, H-Plane & EH-Plane

Power Dividers & Couplers

Hybrids and N-Way

OMT-Polarizers & Horn

Antennas

Consulting services for all types of
filter design including planar

POLAR WAVES CONSULTING

6-425 Pinehouse Drive
Saskatoon, SK S7K5K2

Tel: (306) 934-6688 Fax: (306) 931-4694
e-mail: pramanick@sk.sympatico.ca
http://www.polarwaves.com

Circle 106

How to place Product Spotlight and Classified ads

Our Product Spotlight section allows you to show off your company's products or services in an economical 1/9 page color ad. Ads may be sent camera ready, or we'll make up an ad for you! All you'll need to provide is a product photo, company logo and a description of the product or service you want to advertise.

Our Classifieds section is the place to advertise career opportunities, consulting services, used test equipment and just about anything else. Special Classifieds rates are available and are agency-commissionable if material is sup-

plied. Or, if you prefer, our staff can make up the ad for you.

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

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

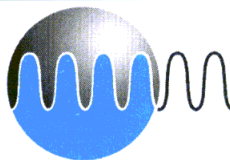
Classifieds

EAGLEWARE RF and Microwave Design Software

Eagleware Corporation is seeking experienced engineers, software developers, and sales professionals to accommodate the company's rapid growth. Positions available include:

- Application/Testing Engineer
- Electromagnetic Simulation Developer
- Windows Developer
- Model Engineer
- System Simulation Developer
- International Sales Coordinator

We offer a competitive salary and exceptional benefits. Eagleware, founded in 1985, is a successful, entrepreneurial software firm that develops, distributes, and supports RF and microwave design software. Complete job descriptions are available on our web site, www.eagleware.com; or, send a resume to jobs@eagleware.com.



Click Here:

<http://www.rfglobalnet.com>

Read application notes and practical articles

Find RF/MW and Wireless product information

Look for new jobs in our career center

Save 15-25% on 2,000 technical books in our bookstore

Ask questions in expert-hosted technical forums

RF Globalnet

info@rfglobalnet.com

303-415-9233

OUR INDUSTRY'S #1 WEB SITE

Circle 65

Applied

MICROWAVE & WIRELESS

Author's Guidelines

Applied Microwave & Wireless does not use a detailed author's guide! We don't want to make your job of writing any more difficult. We're editors, and it's our job to make sure your efforts are presented to our readers in a professional manner. We want your expertise, not your grammatical skills.

To submit an article for publication in *Applied Microwave & Wireless* magazine, send a proposal or abstract to Gary Breed, Publisher, at the address below. Please be sure to include a contact name, telephone and fax numbers, and e-mail address.

We will notify you if we want to publish your work and will ask you to submit the final article. We'll need to receive your article at least eight weeks before the date of publication. You may consult our Editorial Calendar and indicate a topic on your proposal, although we cannot guarantee publication in a specific issue.

Submit article proposals to:

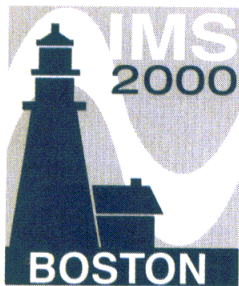
Applied Microwave & Wireless

4772 Stone Drive
Tucker, GA 30084

Tel: 770-908-2320

Fax: 770-939-0157

amw@amwireless.com



International Microwave Symposium

Boston, Massachusetts

IEEE Microwave Theory and Techniques Society

June 11–16, 2000

MARK YOUR CALENDAR NOW TO ATTEND THE

**2000 IEEE MTT-S International
Microwave Symposium & Exhibition**
June 11–16, 2000

John B. Hynes Veterans Memorial Convention Center

Featuring Technical Sessions and Workshops for Wireless, Commercial and Military Applications.

- | | |
|--|--|
| ■ ICs for Wireless Communications | ■ Transistor Power Amplification |
| ■ Microwave Vehicular Technology | ■ Nonlinear Modeling and Analysis |
| ■ CAD Design Methodology | ■ Measurement Theory and Techniques |
| ■ Power Devices and MMICs | ■ High Power Sources and Control |
| ■ Wireless Communication Systems and Technologies | ■ Low Noise Receivers |
| ■ Power Amplifiers for Wireless Applications | ■ Manufacturing, Production and Packaging |
| ■ Subsystems for Commercial Communications | ■ Advances in Hybrid Technology |
| ■ Biological Effects and Medical Applications | ■ Millimeter and Submillimeter Wave Technology |
| ■ Signal Generation, Frequency Conversion and Control Circuits | ■ Monolithic Technology |
| ■ Filters and Multiplexers | ■ Active and Quasi-optic Arrays |
| ■ Ferrite Components | ■ Lightwave Technology and Techniques |
| ■ Guided Waves and Propagation Characteristics | ■ Superconductivity Technology |
| | ■ Microwave Digital Processing |
| | ■ Full Guest Program — Bring the Family! |

In addition to the outstanding Symposium, visit the World's Largest Microwave Exhibition, featuring more than 400 industry innovators displaying their newest wireless and commercial products and services. Once again this year, industry representatives will be presenting application and marketing seminars on the exhibition floor which will be open to all attendees.

☐ Yes, I would like additional information on attending MTT-S '00. Please send it to:

Name _____ Title _____

Organization _____

Address _____

City _____ State _____ Zip Code _____

Country _____ Telephone _____

Microwave Journal®, 685 Canton St., Norwood, MA 02062 ■ FAX: 781-769-5037

AMW

Access MTT-S On-Line at *Microwave Journal*® via <http://www.mwjjournal.com>.

Advertiser Index

Advertiser and FAX number	Page No.	Advertiser and FAX number	Page No.
Agilent Technologies 1-800-452-4844 (tel.)		Microwave Filter Company 315-463-1467	
Signal analyzer	11	Filters	64
Alpha Industries 508-894-1904 (tel.)		Millitech 413-665-2536	
Wireless products	43	Amplifiers	82
American Technical Ceramics 516-622-4748		MITEQ 516-436-7430	
Capacitors	33	Microwave components and satellite communications equipment	89
Amplifier Research 215-723-5688		Noble Publishing 770-908-2320 (tel.)	
Amplifiers	53	Books for wireless engineers	49
Anritsu 1-800-ANRITSU (267-4878) (tel.)		Oleson Microwave Labs 408-778-0491	
Measurement system	40-41	Millimeter-wave test equipment	91
Ansoft 412-471-9427		Quasar + 44 1 626 832994	
Design software	51	Waveguide components	14
Besser Associates 650-949-4400		Rakon + 64 9 573 5559	
Training courses	16	TCXOs	24
C.W. Swift 818-989-4784		RelComm 410-860-2327	
Components	C2	SMT coaxial relays	97
California Eastern Labs 408-988-3500 (tel.)		REMEC Inc. 1-877-66-REMEC (667-3632) (tel.)	
Bipolar transistors	55	Microwave mixers	70
Celeritek 408-986-5095		Microwave filters	71
Amplifier modules	61, 63	RF Globalnet 303-415-9233 (tel.)	
Clearcomm 410-860-9005		Training courses	112
Filter products	105	RF Micro-Devices 336-664-0454	
Coilcraft 847-639-1469		RF components	28-29
Inductors	101	Richardson 1-800-RF POWER (737-6937) (tel.)	
Cougar Components 408-522-3839		Distribution for Motorola	95
Amplifiers	72	RLC Electronics 914-241-1753	
CST 617-576-5702		Couplers	83
EM simulation software	87	Sawtek 407-886-8860 (tel.)	
Cushcraft 1-800-258-3868		Filters	94
Antennas	93	Signal Technology 408-730-6300 (tel.)	
Eagleware 770-939-0157		Transceivers	79
GENESYS design suite	20-21	Signal Technology 978-927-9328	
Emerson & Cuming 781-961-2845		T/R modules	109
Microwave absorbing materials	69	Stanford Microdevices 408-496-4767	
Ericsson 408-779-3108		SGA 6000 amplifiers	4
Power transistors	15	SGA-2000 amplifiers	5
Filtron Solid State 408-970-9950		InGaP HBTs	115
pHEMTs	31	Stellex 650-813-2030	
Harbour Industries 802-985-9354		Mixers	13
Flexible coaxial cables	60	SV Microwave 561-844-8551	
Haverhill 978-373-8024		Interconnectors	99
Flexible coaxial cables	62	Synergy Microwave 973-881-8361	
Huber + Suhner 802-878-9880		Synthesizers	35
Cable assemblies	19	Times Microwave 203-949-8423	
JCA Technology 805-987-6990		Coaxial assemblies	C4
RF and microwave amplifiers and subsystems	9	Toko 847-699-1194	
Johanson Manufacturing 973-334-2954		EL drivers	23
Trimmers	1	Trompeter 1-800-982-2629 (tel.)	
Johanson Technology 805-389-1166 (tel.)		BNC connectors	73
Capacitors	92	T-Tech 770-455-0970	
M/A-Com 1-800-618-8883		Circuit board milling machines	64
RF and microwave components and subsystems	C3	Vari-L 303-371-0845	
Micrel Semiconductor 1-800-401-9572 (tel.)		Signal sources and processing	45
RF receivers	17	Vector Fields 630-851-2106	
Micro Lambda 510-770-9213		Electromagnetic design software	18
Synthesizers	77	Vitcom 619-452-6649	
Microwave Components 561-286-4496		Synthesizers	10
Cable distribution for Times	81	Voltronics International 973-586-3404	
Mini-Circuits 718-332-4661		Trimmer capacitors	25
Power splitters/combiners	2-3	Watkins-Johnson 650-813-2447	
Mixers	6, 85	Amplifiers	39
Couplers	27	Werlatone 914-279-7404	
VCOs	37, 107	Couplers, combiners, dividers, hybrids	57
Transformers	37	Xemod 408-733-7229 (tel.)	
New products	75	Amplifier components	58
Amplifiers	103		

Applied Microwave & Wireless (USPS 011-596) (ISSN 1075-0207), printed in the U.S.A., is published monthly by Noble Publishing Corporation, 4772 Stone Drive, Tucker, GA 30084. February 2000. Twelve issues are mailed in the United States for \$30, outside the U.S. for \$60, or provided free, with a completed and signed subscription form, to qualified professionals engaged in electronics engineering at 1 MHz to lightwave frequencies. Single issues, when available, are \$7 in the U.S. and \$12 outside the U.S. The material contained in this magazine is believed to be true and correct; however, the responsibility for the contents of articles and advertisements rests with the respective authors and advertisers. Periodical Rate postage paid at Tucker, GA 30084 and additional mailing offices.

Postmaster: Send address corrections to *Applied Microwave & Wireless*, 4772 Stone Drive, Tucker, GA 30084-6647.

Copyright © 2000 by Noble Publishing Corporation. All rights reserved. Reproduction in whole or in part of any text, photograph or illustration without written permission from the publisher is strictly prohibited.

NEW! InGaP HBT

Innovative
technology from
**Stanford
Microdevices**



High MTTF
High Linearity
Broadband Performance

A new generation of HBT MMIC Amplifiers

Using Gallium Indium Phosphide/Gallium Arsenide Technology

As low as
\$3.09
in quantity

NGA-489 DC-8 GHz

Designed with InGaP process technology for greater reliability, this Darlington configured, high gain, heterojunction bipolar transistor MMIC amplifier offers value and performance for all wireless and broadband communication applications. Outstanding features are:

- Cascadable 50Ω: 1.5:1 VSWR
- Low positive voltage supply
- Low thermal resistance package
- High linearity

SPECIFICATION MATRIX

	NGA-489	NGA-589
Frequency (GHz)	DC-8.0	DC-6.0
Gain (dB)	14.5	19.0
TOIP (dBm)	38.5	38.0
N.F. (dB)	4.5	4.5
P1dB (dBm)	17.5	19.0
Supply Voltage	4.2	5.0
Supply Current	80	80

All data measured at 900MHz and is typical.
MTTF @ 150C T_j = 2 million hrs. (R_{TH} = 110 C/W typ.)

NGA-589 DC-6 GHz

High gain and high output make this heterojunction bipolar transistor MMIC amplifier ideal for use in all wireless applications. InGaP HBT technology improves the reliability and performance and minimizes leakage current between junctions. Other features include:

- Cascadable 50Ω: 1.5:1 VSWR
- Low thermal resistance package
- High linearity
- High gain
- High P1dB

Stanford Microdevices is a world leader in meeting the need for high performance components at market leading prices. Fabless technology allows us to manufacture over 200 different products covering the following: Cellular, PCS, Wireless LAN, Wireless Internet, GSM and ISM. InGaP represents the latest in design and innovation for swiftly growing wireless communication technologies. Founded in 1992, Stanford Microdevices has grown to become the favorite of OEMs worldwide.

 **Stanford
Microdevices**

1-800-764-6642

Dept. NGAM1

Visit our web site at

<http://www.stanfordmicro.com>

©1999 Stanford Microdevices. All company and/or product names are trademarks and/or registered trademarks of their respective owners.

The Wireless Industry Gathers for Business and Technology

Two major trade shows are scheduled for the end of this month. First, the Wireless Symposium will be held February 22-24 in San Jose, CA, then CTIA's Wireless 2000 event will take place in New Orleans, LA, February 28 to March 1. The first show covers components, technical forums and design matters. The CTIA show emphasizes the business of wireless and the overall technologies that drive the industry.

Wireless Symposium

The Eighth Wireless Symposium includes an exhibition with 400 companies displaying their products and services for wireless design engineers and system developers. In addition, some 75 technical papers describe new products and engineering techniques useful for the design, testing and manufacture of wireless products.

A significant part of this event is a series of workshops, providing concentrated technical instruction. These courses include:

Wireless Made Simple — Instructor: Al Scott, Besser Associates, Part I, Tuesday February 22; Part II, Wednesday, February 23.

RF Fundamentals — Instructor: Rick Fornes, Besser Associates, Part I, Tuesday February 22; Part II, Wednesday, February 23.

Topical Issues in RF Power Amplifier Design — Instructor: Steve Cripps, Besser Associates, Part I, Tuesday February 22; Part II, Wednesday, February 23.

Measuring Wireless — Instructor: Morris Engleson, JMS, Tuesday, February 22.

Fundamentals in CDMA Technology for PCS — Instructor: Darryl Schick, Linear Lightwave, Wednesday, February 23.

DSP Made Simple — Instructor: Rick Lyons, Besser Associates, Part I, Thursday, February 24; Part II, Friday, February 25.

Digital Modulation — Instructor: Joe Boccuzzi, Besser Associates, Part I, Thursday, February 24; Part II, Friday, February 25.

Oscillator Design — Instructor: Randy Rhea, Eagleware, Thursday, February 24.

3G Wideband CDMA Technology — Instructor: Darryl Schick, Linear Lightwave, Thursday, February 24.

Antennas and Propagation for Wireless Communications — Instructor: Steven Best, Cushcraft Corp., Friday, February 25.

Phase Locked Loops — Instructor: Eric Drucker, PLL

Consultants, Friday, February 25.

RF Wireless System Fundamentals — Instructor: Rick Fornes, Besser Associates, Friday, February 25.

For more information on the Wireless Symposium, or to register, call 1-888-WireReg or go online to www.WirelessPortable.com.

CTIA Wireless 2000

New Orleans is a very good venue for a business-to-business trade show, with an excellent convention center and plenty to do after show hours. Following the theme "Wireless Today & Tomorrow," Wireless 2000 includes both a large exhibition and informational seminars. Instructional meetings covering business and technology topics include:

Wireless Data University, presented by Andrew Seybold and Alan Reiter, Sunday, February 27. Register by calling 831-338-7701.

CTIA's Latin American Conference, held on Wednesday, March 1.

Panel sessions, held Monday, February 28, and Tuesday, February 29 — *Management Issues in Business, Marketing Issues in Wireless, Technology Issues in Wireless Data, Wireless Data Consumer Products and Marketing, Distribution, Borderless Wireless and Public Policy*.

A highlight of the event will be the three keynotes featuring industry and government leaders:

International Roundtable — Monday, February 28, with Chris Gent, Chief Executive of Vodaphone AirTouch plc, Keiji Tachikawa, President of NTT Mobile Communications Network, and Anthony S.K. Wong, Director-General of Telecommunications Authority, OFTA.

Internet Anywhere — Tuesday, February 28.

A Conversation with Nelson Mandela — Wednesday, March 1, the former President of the Republic of South Africa will discuss issues of importance in a world where technology and social change continue to play major roles in our lives.

For information and registration for CTIA's Wireless 2000, call 1-800-421-6338 or 1-415-979-2250. On the Internet, show information can be found at the event's comprehensive Web site: www.ctiashow.com.

Applied Microwave & Wireless will be attending both events to learn about issues that affect our readers and advertisers, and to stay abreast of technical and business developments. ■

We're Shaping the Future of Wireless

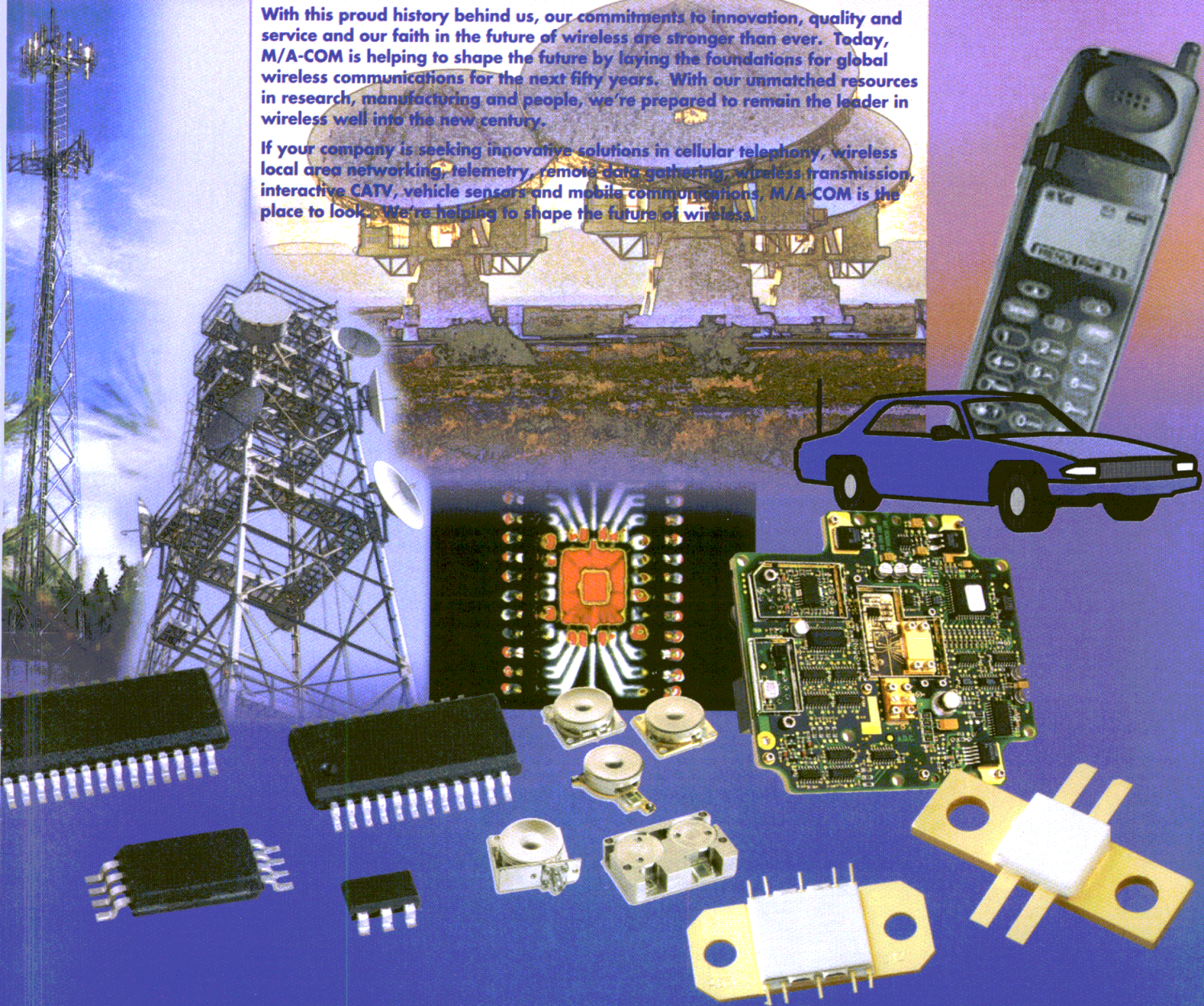
Since its founding in 1950 M/A-COM has led the world in developing and manufacturing RF and microwave devices, components and subsystems for wireless communications.

The M/A-COM years have been an era of explosive growth and change in communications technologies. Yet, through these changing times, M/A-COM has remained at the cutting edge, offering its customers innovative and creative products that help them to keep pace with the communications revolution.

We've held our lead by investing substantially in research and development of new products, and by employing the industry's most advanced manufacturing techniques. We've learned that just developing and marketing products that set the industry standard for quality and innovation isn't enough. You've also got to offer great customer service, backed by design and manufacturing support.

With this proud history behind us, our commitments to innovation, quality and service and our faith in the future of wireless are stronger than ever. Today, M/A-COM is helping to shape the future by laying the foundations for global wireless communications for the next fifty years. With our unmatched resources in research, manufacturing and people, we're prepared to remain the leader in wireless well into the new century.

If your company is seeking innovative solutions in cellular telephony, wireless local area networking, telemetry, remote data gathering, wireless transmission, interactive CATV, vehicle sensors and mobile communications, M/A-COM is the place to look. We're helping to shape the future of wireless.



M/A-COM, headquartered in Lowell, MA, is a leading supplier of radio frequency (RF), microwave and millimeter wave semiconductors, components and IP Networks to the wireless telecommunications and defense-related industries. M/A-COM's products include semiconductor devices, RF integrated circuits, passive control devices, antennas, subsystems and systems. Employing more than 2,800 people, M/A-COM has offices and manufacturing facilities worldwide.

Circle 43

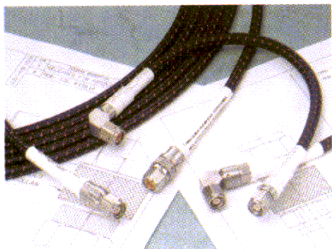
www.macom.com

tyco / Electronics / **M/A-COM**

Expertise

Our Expertise — Coaxial Assembly Technology.

We have been supplying RF and microwave interconnection



solutions for the most sophisticated airborne military electronic systems in the harshest environments for more than 50 years. With our unmatched engineering and production capabilities we can

also provide the most cost effective coaxial assemblies for commercial applications. Get the benefit of our expertise, call us with your application at 1-800-TMS-COAX or visit our web site at www.timesmicrowave.com.



TIMES MICROWAVE SYSTEMS

A Smiths Industries company



World Headquarters: 358 Hall Avenue, Wallingford, CT 06492 • 203-949-8400, 1-800-867-2629 FAX: 203-949-8423
International Sales: 4 School Brae, Dysart, Kirkcaldy, Fife, Scotland KY1 2XB UK • +44(0)1592655428 FAX: +44(0)1592653162
www.timesmicrowave.com