

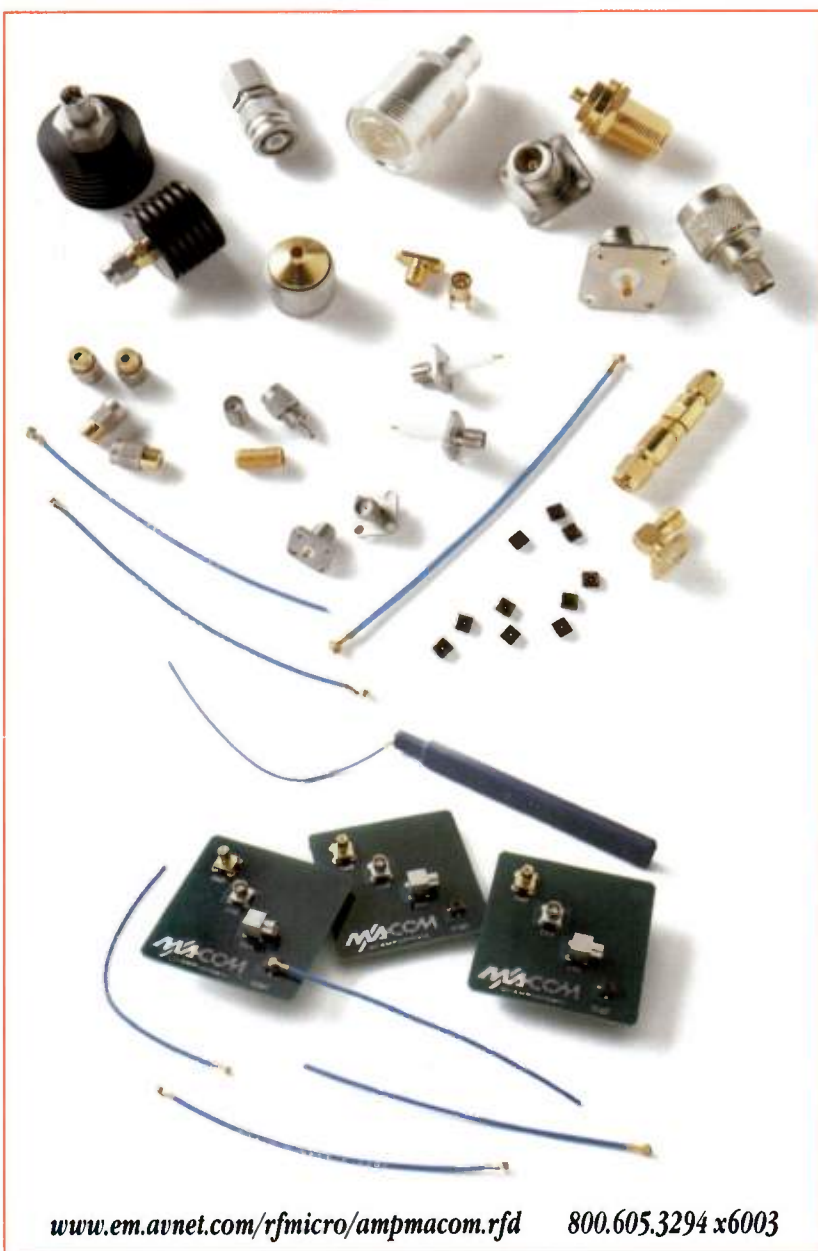


**SAR advances  
data acquisition**

**Free software  
calculates field strength**

**New techniques  
help measure multipath**

# AMP and M/A-COM have the largest selection of RF Interconnect and Avnet Electronics Marketing can get you connected.



[www.em.avnet.com/rfmicro/ampmacom.rfd](http://www.em.avnet.com/rfmicro/ampmacom.rfd)

800.605.3294 x6003

M/A-COM Interconnects has been integrated into AMP to give you more RF interconnect choices than ever before. AMP now has more varieties of RF, coax and antenna interconnects than any other manufacturer. And Avnet Electronics Marketing gives you access to the largest RF Interconnect inventory in the world, as well as the most experienced RF team in the industry.



For your free copy of the latest AMP Product Selection Guide, visit our Web site at [www.em.avnet.com/rfmicro/ampmacom.rfd](http://www.em.avnet.com/rfmicro/ampmacom.rfd) or call 800-605-3294 x6003.

All trademarks property of their respective owners. Limited time offer while supplies last. Third party software included is for evaluation purposes only and may be time or function limited. AMP and Connecting at a HIGHER level are trademarks.



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



But Shep Said Yes.

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

But here's wisdom: things are changing so fast in the wireless world, there's little logic in manufacturing or buying anything that meets only immediate needs. Only a brain donor would bank on an amp with a really narrow band. A more righteous approach gives you room at the top—extra band you're gonna be glad you have in the test room, where performance counts. And tomorrow, when the rules are rewritten.

Shep knows this. He knew it all along. That's why he insisted AR "S" Series amplifiers each offer bandwidth from 0.8 to 4.2 GHz and power from 1 to 100 watts, in increments just right for your application. With low harmonics. And other extras, like IEEE 488 and RS 232 interfaces for remote operation.

For frequency response to 40 GHz, ask about our other brainchild—"T" Series amplifiers—0.8 to 40 GHz, 15 to 2000 watts.

Don "Shep" Shepherd. Visionaire. President, Amplifier Research.



**The Force Behind The Field.**

**ISO 9001  
Certified**

Souderton PA • TEL 215-723-8181 • FAX 215-723-5688 • In Europe, call EMV—Munich: 89-614-1710 • London: 01908-566556 • Paris: 1-64-61-63-29

For an applications engineer call 800-933-8181

[www.ar-amps.com](http://www.ar-amps.com)

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

INFOCARD 38



**THE WORLD'S LARGEST SELECTION**

# **POWER SPLITTERS/ COMBINERS**

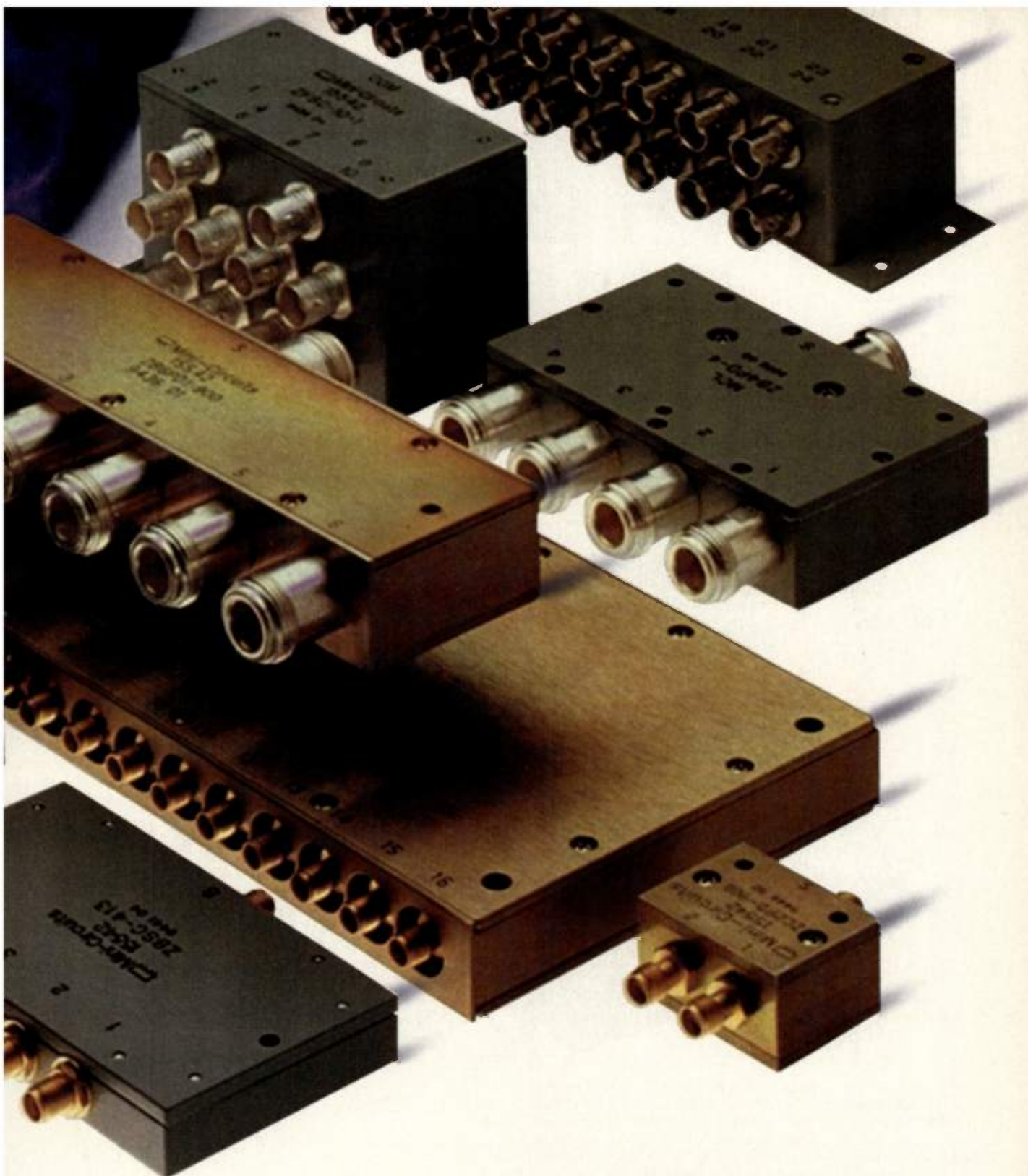


**2kHz-10GHz** from **\$2<sup>95</sup>**

Choose from over 480 standard off-the-shelf models from 2-way to 48-way; 0°, 90° and 180°; 50 and 75 ohms; covering 2kHz to 10GHz. Mini-Circuits will also supply your special needs such as wider bandwidths, higher isolation, lower insertion loss, and phase matched ports...all at catalog prices with rapid turnaround time. Models include surface mount, plug-in, flat-pack and standard connectorized designs such as SMA, N, TNC, C, and F connectors as well as custom designs. Ultra-miniature surface mount units provide excellent solutions in cellular communications, cable systems and countless wireless applications. All units come with a 1 year guarantee and "skinny" 4.5 sigma repeatability unit-to-unit and production run to production run. Catalog models are guaranteed to ship within one week.

***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 10 INT'L 15

CIRCLE READER SERVICE CARD

F 194 Rev A



# 1W AMPLIFIERS

## HIGH IP3 & IP2



**\$19<sup>95</sup>**  
only (ea. qty. 1-9)

Amplify RF signals and **minimize distortion** in multi-carrier environments such as cable TV and cellular with Mini-Circuits broad band 5MHz to 1000MHz HELA-10 amplifiers. These state-of-the-art 12V amplifiers deliver high linearity, 12dB typical gain response  $\pm 0.4$ dB flat over the frequency range, and provide very high IP2 and IP3. Plus, HELA-10's are equipped with a self contained heat slug allowing thermal dissipation for highly efficient 1W RF output and are supplied with matching transformers for 50 or 75 ohm operation. Leap frog ahead of the competition. Select the version that meets your needs and put high octane HELA-10 performance to work for you today!

For connectorized and higher gain models, see ZHL medium high power amplifier series section in our Designer's Guide or Online Catalog.

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



#### HELA TYPICAL SPECIFICATIONS:

| MODEL: HELA                        | -10A      | -10C      | -10B      | -10D      |
|------------------------------------|-----------|-----------|-----------|-----------|
| Impedance ( $\Omega$ )             | 75        | 75        | 50        | 50        |
| Freq. Range (MHz)                  | 50-1000   | 5-450     | 50-1000   | 8-300     |
| Gain, dB                           | 12        | 11.4      | 12        | 11.0      |
| Flatness, dB                       | $\pm 0.4$ | $\pm 0.4$ | $\pm 0.4$ | $\pm 0.4$ |
| Power Output, dBm<br>(@ 1dB comp.) | 30        | 30        | 30        | 30        |
| Dynamic Range                      |           |           |           |           |
| IP2, dBm                           | 88        | 88        | 88        | 88        |
| IP3, dBm                           | 47        | 48        | 47        | 48        |
| NF, dB                             | 3.5       | 3.5       | 3.5       | 3.5       |

Notes: Price and performance include matching transformers.  
DC power 12V, current 525mA.

#### APPLICATION DIAGRAM



# Mini-Circuits®

US 62 INT'L 63

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](http://WWW.RFGLOBALNET.COM)

**ISO 9001 CERTIFIED**

F 281 Rev A



# RF design<sup>®</sup>

## in this issue

F E B R U A R Y 1 9 9 9



### DEPARTMENTS

|                 |    |
|-----------------|----|
| Editorial       | 8  |
| Editorial Forum | 10 |
| Calendar        | 14 |
| Courses         | 16 |
| News            | 18 |
| Company Index   | 66 |
| Product Focus   | 80 |
| Products        | 83 |
| Software        | 92 |
| Literature      | 93 |
| Marketplace     | 95 |

20

*Featured technology: Signal processing*

**Designing an LNA for a CDMA front end** — LNA design is critical in communication systems. Understanding necessary additional design considerations can save both time and money. — *Jarek Lucek and Robbin Damen*

32

*Featured technology: Software*

**Computer programs that calculate field strength** — Here are two computer programs that can help you design your antennas. — *James Eagleson*

42

*Cover story: Automatic data collection*

**SAR advances conquer data acquisition challenges** — Major developments in software, hardware, signal, imaging and data processing technology have enabled SAR to assume increasing roles in a variety of applications. — *Ernest Worthman, Contributing Editor*

52

*Tutorial: Transmission/reception*

**Measuring multipath in the wireless cable environment** — Understand techniques to measure multipath in your system. — *Mark Kolber and Marc Ryba*

75

**Novel designs for elliptic bandstop filters** — This new way to design elliptic bandstop filters may lessen frustrations. — *Philip R. Geffe*

77

**ECL line receivers used as amplifiers: How do they work?** — The ECL differential line receiver has been used in amplifier and limiter applications. But did you know about its analog capability? — *Tom Balph and Bill Morgan*

102

**A moment with...Dr. Bami Bastani**

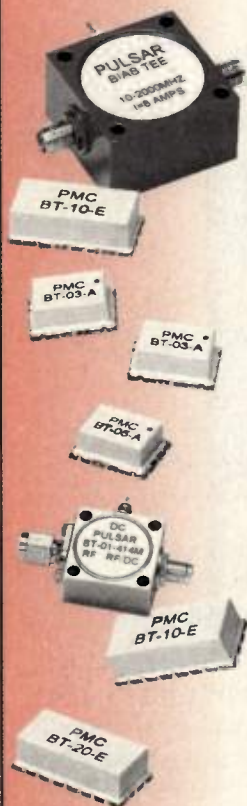
This month, Anadigics chief executive officer discusses third-generation and the future of RF semiconductors.



GET LINKED — RF Design Online now has three ways to link to companies mentioned in this issue: *advertiser links*, *product directory* and *editorial links*. See page 66 for more information.



# BIAS TEES



Wide Bandwidths  
• 0.1 - 6.0 GHz

High Current Ratings  
• 25 Amps

Superior RF/DC Isolation  
• 40 dB Minimum

Various Package Styles  
• Surface Mount  
• SMA, BNC, TNC or N Connectors

## Pulsar Microwave Corporation

48 Industrial West, Clifton, NJ 07012  
(973) 779-6262, Fax: (973) 779-2727  
E-Mail: sales@pulsarmicrowave.com

VISIT OUR WEB SITE!  
[www.pulsarmicrowave.com](http://www.pulsarmicrowave.com)

## RF editorial

# What's old is new again

By Don Bishop  
Editorial Director



Ask someone to define electronics, and you probably will be told that electronics is the use of materials and techniques to direct electron flow for various purposes, such as control, calculation, measurement and communication. Mechanical methods preceeded many of today's electronic applications. Hybrid, electromechanical methods combine the two, usually when certain mechanical methods remain less expensive than counterpart electronic methods.

Videocassette recorders (VCRs), as electromechanical devices, remain a ubiquitous example in consumer electronics. So do audio cassette recorders. Time is on the side of electronic replacements as digital converters and computer memory become less expensive.

Decades ago, the Columbia Broadcasting System (CBS) proposed an electromechanical method for color television—maybe not entirely expecting it to gain government approval, although it did for a while. It wasn't long before it was replaced by all-electronic television. Almost everyone wants the "new" electronics to supplant "old" mechanical methods wherever possible and as soon as it is affordable.

In this context, it's fascinating to see the emergence of micro-electromechanical systems (MEMS). Combining computer chips with mechanical systems that are so small that "microscopic" fails to describe their size, MEMS can oscillate at high frequencies, as can electrons, supporting functions at a level of miniaturization that purely electronic circuits may not. How much smaller a wireless telephone needs to be might be debatable, but adding multiple power-efficient features within a tiny wireless telephone package stimulates the competitive instincts. It's been predicted, by the way, that MEMS will reduce wireless telephones to wrist-

watch size. Exactly what will be the configuration of a really tiny wireless telephone? My guess is a combination throat microphone and earpiece similar to a hearing aid.

Going back to the turn of the century an electromechanical method—the high-frequency alternator—provided RF for long-distance radio communications. The motors, nozzles and valves that are part of some MEMS someday may be used to generate RF. If and when it happens, the transition will include some devices that cling to the "old" electronics methods until MEMS prices fall!

### Virtual networks

On another subject, have you noticed the proliferation of cellular and PCS base station antennas? I've seen towers that look as though they have antennas for four carriers. Some cities have six carriers, but I'm not sure I've seen that many system antennas on one tower yet. Makes me wonder how long it will be before we see "virtual networks."

System operators increasingly focus on "selling minutes." They say they are growing less interested in any part of the business besides the promotion and sale of airtime. That means outsourcing site management, network management, billing, fraud control, customer service and other functions. Maybe the time is coming for one of two mega carriers to consolidate everyone else's systems and to offer "virtual network airtime services to what would become "virtual carriers."

With virtually (sorry) no difference between the operational performance of each virtual carrier, the key to each one's success will be its management's selection of outsource providers. As wireless systems age, specialization increases.

RF





QUIETLY  
and QUICKLY...

GET A JUMP ON YOUR COMPETITION.

## VCOs & SYNTHESIZERS

With Low Noise, Lowest Cost and Quick Turnaround

Leading edge performance and the quickest delivery...  
PES products include standard and custom VCOs  
and Synthesizers (both variable and fixed frequency).

**Custom products are usually delivered  
in 4-6 weeks with no design fee.**

We pride ourselves on providing a high level of  
support to our customers. So for your radio, base  
station and hand-set applications, call us today.  
Let us bid on your next requirement...  
you'll be very glad you did!

**WE WORK HARDER *for you* EVERY DAY.**



**Princeton Electronic  
Systems, Inc.**

P.O. Box 8627, Princeton, NJ 08543

tel 609.275.6500

fax 609.799.7743

web: [pesinc.com](http://pesinc.com)

e-mail: [pes@pesinc.com](mailto:pes@pesinc.com)



Sample Specs Of VCOs & Synthesizers

| Part No.                              | Freq (MHz) | Phase Noise<br>@10KHz | Vcc, mA   |
|---------------------------------------|------------|-----------------------|-----------|
| PVS-1630 VCO                          | 1630-1700  | -85 dBc/Hz            | 5V, <4mA  |
| PV 810C VCO                           | 810-850    | -103 dBc/Hz           | 5V, <25mA |
| PSF 2510<br>Synthesizer<br>fixed Freq | 2510       | -105 dBc/Hz           | 5V, <40mA |
| PSB 1880<br>Synthesizer               | 1885-1945  | -101 dBc/Hz           | 5V, <25mA |



## Editorial Forum



*By Gregg V. Miller,  
Technical Editor*

### The honeymoon is over

Ever since I have been involved with the cellular industry, it has been the view of the cellular people that the cellular phone is not designed to replace the landline phone, but to complement it. Cellular can provide features that landline cannot and visa versa. And, this stance has been working well for both the cellular and landline industries.

However, recently there has been an advertisement from AT&T Wireless that says they want your cellular phone to be your only phone.

Excuse me?

This changes the whole ball game for everyone involved with cellular. For instance, in *Wireless Review*, a sister publication of *RF Design*, the editors and publisher tried to spend a week using their cellular phone as their only phone. While there were the normal advantages with using a cellular phone (anywhere connectivity, making a phone call and a fax at the same time, having people reach you after business hours), they were not happy with the performance to say the least.

Using the phone constantly brought out the disadvantages of cellular. The dropped calls, no service areas and limited battery life that cellular users usually can live with now became serious problems. Instead of looking at the cellular phone as an add-on benefit, they saw it as an inconvenience when compared to landline.

So once again, the marketing departments of the world have put their foot in their mouths. In an obvious effort to increase market penetration by touting the advantages of cellular, they are actually bringing the pitfalls of cellular to the forefront. And when customer service representatives start to hear more and more about these problems, who do you think will get the blame?

Congratulations, RF engineers. **RF**

# RF design.

Engineering RF & Wireless Products ... DC to Light

Established 1978

## Editorial offices

5680 Greenwood Plaza Blvd., Suite 100  
Englewood, CO 80111  
720-489-3100; Fax 720-489-3253;  
e-mail [rfdesign@intertec.com](mailto:rfdesign@intertec.com)  
Web site [www.rfdesign.com](http://www.rfdesign.com)

**Editorial Director** Don Bishop, 913-967-1741  
**Technical Editor** Gregg V. Miller  
**Senior Associate Editor** Roger Lesser  
**Associate Editor** Nikki Chandler  
**Editorial Assistant** Emily Reid  
**Contributing Editor** Ernest Worthman  
**Art Director** Valerie J. Hermanson

**Group Publisher** Mercy Contreras  
**Marketing Director** Patricia Zahner  
**Marketing Services Supervisor** Karen Clark  
**Sr. Classified Ad Coord.** Annette Hulsey, 913-967-1746  
**Ad Production Coord.** Janet Luckner, 720-489-3278  
**Senior Circulation Manager** Julie Neely

**Director of Production** Barbara B. VanSickle  
**Desktop Publishing Coordinator** Shawn Warren  
**Electronic Publishing Technician** Maurice Lydick  
**Electronic Publishing Technician** Bonnie Long  
**Directories Issues Manager** Deborah Dickson  
**Reprints Manager** Jenny Eisele, 913-967-1966  
**List Rental Manager** Lori Christie, 913-967-1876

**Customer Service** 800-441-0294

## Subscription inquiries

P.O. Box 12907, Overland Park, KS 66282-2907  
800-441-0294; Fax 913-967-1903

## Editorial Review Board

Andy Przedpelski, *Chairman* The Shedd Group  
Madjid A. Belkerdid, Ph.D. Univ. of Central Florida  
Alex Burwasser RF Products  
Robert Feeney, Ph.D. Georgia Tech University  
Joe Gorin Hewlett-Packard  
Dave Krauthheimer MITEQ  
Ed Oxner InterFET  
Raymond Sicotte American Microwave  
Robert J. Zavrel, Jr. IBM

## Intertec Publishing, A PRIMEDIA Company

9800 Metcalf Ave.  
Overland Park, KS 66212-2215  
913-341-1300; Fax 913-967-1898

**President / CEO** Raymond E. Male  
**President - Communications & Entertainment Division** Cameron Bis  
**Vice President - Production** Jack Mc  
**Vice President - Circulation** Nick Cav  
**Senior Managing Editor** Tom C  
**Director Advertising Services** Nancy H  
**Corporate Creative Director** Doug Cool  
**Circulation Director** Barbara Kum  
**Division Director of Marketing** Stephanie Hana

## PRIMEDIA Information Group

**President / CEO** Curtis Thomp

## PRIMEDIA Inc.

**Chairman / CEO** William F. B  
**President** Charles McC  
**Vice Chairman** Beverly C. C

Copies of most issues printed within the past two years are available for \$10 postpaid from Intertec Publishing Corporation, A PRIMEDIA Company customer service, 770-618-0398; Fax 770-618-0347. Photocopies are unavailable from the publisher.

Photocopies in paper and electronic formats are available from Information Express, 3221 Porter Drive, Palo Alto, CA 94304-1225, Tel: 650-494-87; Web: <http://www.express.com>. Photocopies are also available via microform and/or electronic database from UMI, a Bell & Howell Company, 300 North Zeeb Rd., P.O. Box 1346, Ann Arbor, MI 48106-1346; Tel. 800-521-0600 (+1 734-761-4700 outside North America) or check <http://www.umi.com> for additional information on format availability.



## advertising sales staff



**Wireless Symposium**  
**Feb. 23-25**  
**San Jose, CA**



**Phil Cook**  
**Marketing Manager-West**  
16795 Von Karman Ave.  
Suite 110  
Irvine, CA 92714  
Tel. 949-252-1146 Ext. 165  
Fax: 949-252-0556  
e-mail: [phil\\_cook@intertec.com](mailto:phil_cook@intertec.com)

**Europe: David Jeans**  
5680 Greenwood Plaza Blvd. Suite 100  
Englewood, CO 80111  
Tel. 720-489-3201; Fax: 720-489-3253  
e-mail: [david\\_jeans@intertec.com](mailto:david_jeans@intertec.com)

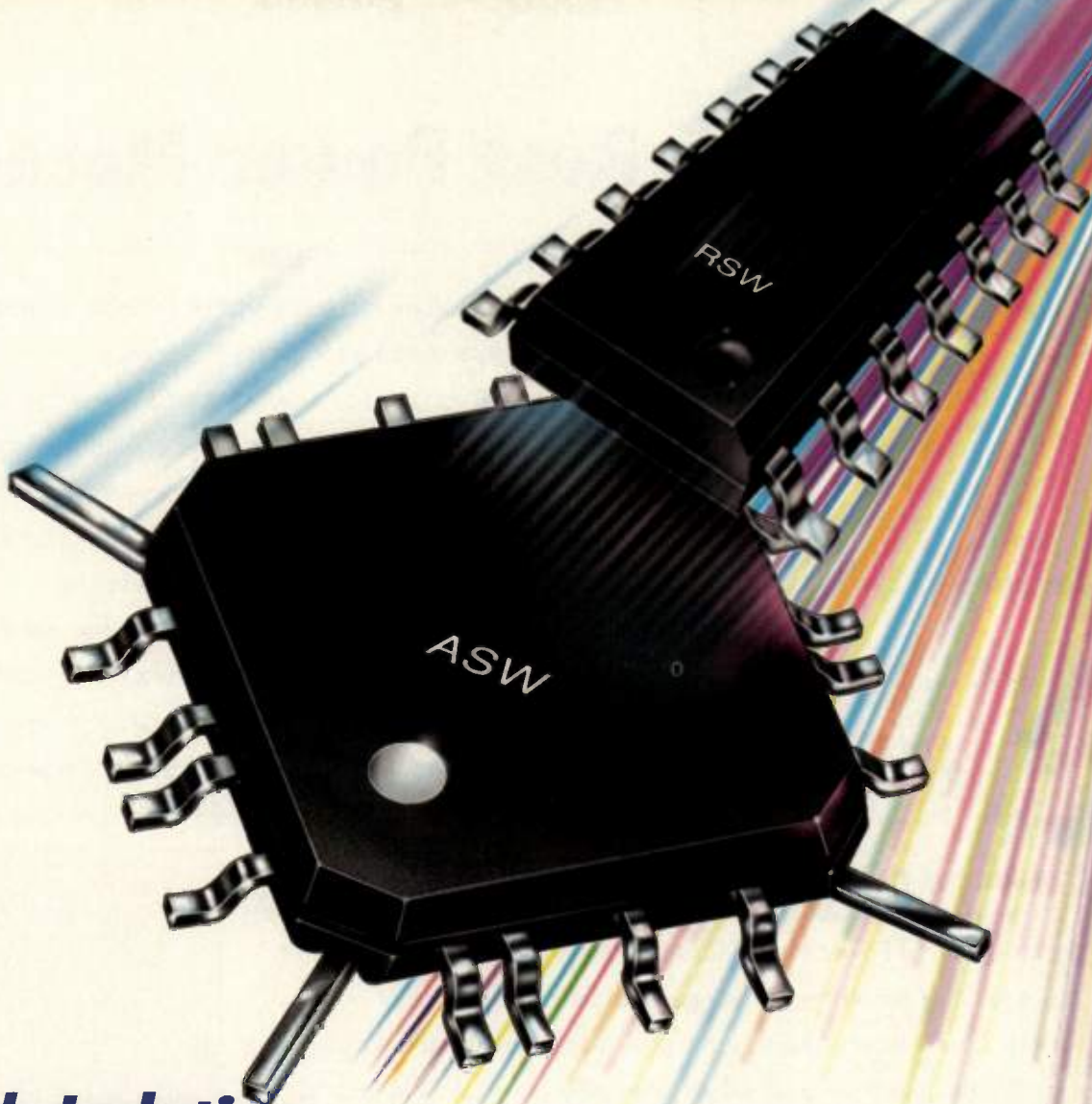
**Israel: Asa Talbar**  
Talbar Media  
Tel. +972.3.523.5394, 522.3621;  
Fax +972.3.524.2177  
e-mail: [talbar@inter.net.il](mailto:talbar@inter.net.il)



**David Jeans**  
**Marketing Manager-East**  
5680 Greenwood Plaza Blvd.  
Suite 100  
Englewood, CO 80111  
Tel. 720-489-3201  
Fax: 720-489-3253  
e-mail: [david\\_jeans@intertec.com](mailto:david_jeans@intertec.com)

**Classifieds: Jody Schrader**  
5680 Greenwood Plaza Blvd. Suite 100  
Englewood, CO 80111  
Tel. 720-489-3290; Fax: 720-489-3253  
e-mail: [jody\\_schrader@intertec.com](mailto:jody_schrader@intertec.com)





# High Isolation SWITCHES

**ASW DC to 5GHz with driver only \$1495**  
(qty. 10-49)

**RSW DC to 2.5GHz only \$395**  
(qty. 10-49)

Two kinds of high isolation SPDT switches are setting new price/performance benchmarks. They're Mini-Circuits ASW and RSW switches providing up to 50dB isolation typical at 2GHz...even more at lower frequencies! Housed in a specially designed package for high isolation, the DC to 5GHz ASW models incorporate a high speed internal TTL compatible driver for **tremendously fast 10nsec (typ) switching speed**. The DC to 2.5GHz RSW comes in a standard SOIC package and is engineered to simplify control signal generation by incorporating dual positive logic. This helps overcome the technical challenges of working with negative voltage. Engineer to stay ahead of today's changing markets. Switch to Mini-Circuits ASW and RSW solutions today!

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

## TYPICAL SPECIFICATIONS:

| Model                       | Freq.<br>(GHz) | Insertion<br>Loss*<br>dB | 1dB<br>Comp*<br>dBm | In-Out<br>Isol.*<br>dB | Price<br>Sea.<br>(qty.10-49) |
|-----------------------------|----------------|--------------------------|---------------------|------------------------|------------------------------|
| ASW-2-50DR<br>(Reflective)  | DC-5           | 1.0                      | 25                  | 50                     | 14.95                        |
| ASWA-2-50DR<br>(Absorptive) | DC-5           | 1.0                      | 25                  | 50                     | 14.95                        |
| RSW-2-25P<br>(Reflective)   | DC-2.5         | 1.0                      | 27                  | 48                     | 3.95                         |

\*1 to 2GHz

For actual data over entire frequency range, please see our internet web site.



ACTUAL SIZE

## Mini-Circuits®

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](http://WWW.RFGLOBALNET.COM)

**ISO 9001 CERTIFIED**

US 30 INTL 31  
CIRCLE READER SERVICE CARD

F 283 Rev A

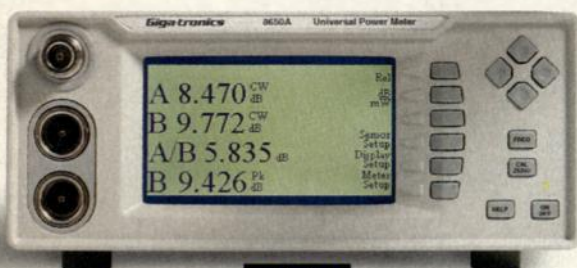


# Choose The Best Power Meter For

When it comes to choosing a power meter for fast, accurate measurements of complex, modulated communications signals, your choice is simple.



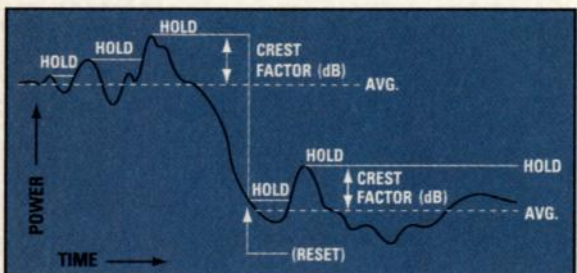
If you need to measure the CW, peak and average power of GSM, TDMA and CDMA signals with features such as time gating and crest factor measurement, choose the Giga-tronics 8540C Series Universal Power Meter. Since 1993, it has been the standard for communications testing.



**NEW**

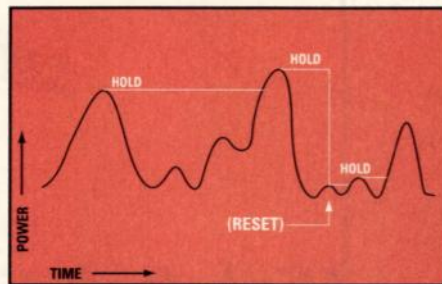
Series Universal Power Meters feature blazing speed and wide dynamic range for CW power measurements. But that's just the start.

Both meters let you measure the peak power directly, and you can even measure the maximum peak power level using our peak hold feature.



If you need these capabilities and features plus even greater speed, the bandwidth to measure third-generation CDMA signals over a wide range, and statistical power measurement analysis to evaluate communications system efficiency, choose the new Giga-tronics 8650A Series Universal Power Meter.

Both the Giga-tronics 8540C and new 8650A

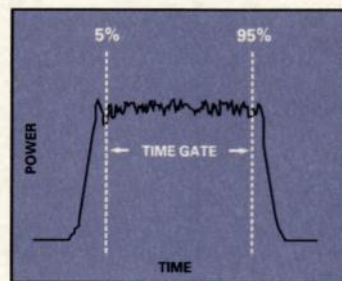


Both meters automatically measure average power during the 'on' period of amplitude modulated TDMA signals. And you can directly measure the crest factor of the burst signal.

Both meters have a time gating feature that lets you set a measurement start and duration time within the burst portion of a signal. For example, you can use this feature to accurately

measure average power during 5% to 95% of the burst duration — the 'useful' portion of the burst defined in the GSM specification.

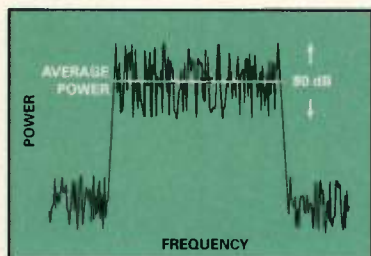
Both meters have the wide single sensor dynamic range required for CDMA signal open-loop tests, and the speed you need to quickly measure the 1 dB steps over a 48 dB range during closed-loop tests. And both meters feature random, as well as uniform, sampling to minimize the aliasing effects of modulated signals for faster average power measurement speeds.



**For More Information, Just Click [www.gigatronics.com](http://www.gigatronics.com)**



# Your Communications Test Needs



The new 8650A Universal Power Meter has a 10 MHz bandwidth to test third-generation CDMA signals over a 80 dB range with a single sensor.

A 20 MHz sampling rate lets you capture up to 26,000 readings per second. And statistical power measurement analysis lets you evaluate communications system efficiency.

Giga-tronics power meters achieve this unmatched level of performance

because meter architecture provides for a broad choice of sensors.

Just by changing a sensor, you can measure the CW, peak, or average power of TDMA, GSM and CDMA signals faster, more accurately, and over a wider range.



**NEW**

Check the chart to see how the 8540C and 8650A compare with meters from other leading manufacturers. Then contact Giga-tronics for more information on the best power meter for your communications test needs.

| Features and Specifications  | <b>NEW</b> Giga-tronics 8650A | Giga-tronics 8540C    | Anritsu ML2430A                               | HP EPM-440A     |
|--|-------------------------------|-----------------------|---|-----------------|
| <b>GPIO CW Measurement Speed (rdgs/s)</b><br>Normal Mode<br>Swift Mode<br>Buffered Mode        | >300<br>>1,750<br>>26,000     | >30<br>>175<br>>2,600 | 50-150<br>150-250 with display off<br>100-500 | 200<br>NA<br>NA |
| <b>GPIO Modulated Measurement Speed (rdgs/s)</b><br>Normal Mode<br>Swift Mode<br>Buffered Mode | >150<br>>300<br>>800          | 15<br>30<br>NA        | 10-15<br><50 with display off<br>NA           | NA<br>NA<br>NA  |
| Uniform Sample Rate  | 20 MHz                        | 10 kHz                | 35 kHz  | <10 kHz         |
| Random Sample Rate   | 2.5-5 MHz                     | 7-10 kHz              | NA  | NA              |
| Maximum Diode Sensor Video Bandwidth   | 20 MHz                        | 1.5 MHz               | 250 kHz                                       | ≈ 220 Hz        |
| Maximum CW Single Sensor Dynamic Range   | 90 dB                         | 90 dB                 | 90 dB   | 90 dB           |
| Maximum Single Sensor Dynamic Range  |                               |                       |   |                 |
| TDMA/GSM   | 60 dB                         | 87 dB                 | 90 dB   | 50 dB           |
| CDMA (IS-95)   | 80 dB                         | 75 dB                 | 50 dB   | 50 dB           |
| CDMA (10 MHz bandwidth)  | 80 dB                         | 50 dB                 | 50 dB   | 50 dB           |
| Maximum Peak Power Sensor Rise Time  | 100 ns                        | 100 ns                | 10 μs   | NA              |
| Automatic Time Gate Setting  | Yes                           | Yes                   | No  | No              |
| Direct Crest Factor Measurement  | Yes                           | Yes                   | No  | No              |
| Statistical Power Measurement Analysis   | Yes                           | No                    | No  | No              |

**Giga-tronics**

4650 Norris Canyon Road  
 San Ramon, California 94583  
 Telephone: 925-328-4650  
 Telefax: 925-328-4700

**or Call 1-877-GigaNow (444-2669)**



# RF calendar

**February 23-25 Wireless Symposium—San Jose, CA.**  
Information: Debbie Cameron, Wireless Symposium Exhibition, 611 Route 46W, Hasbrouck Height, NJ 07604. Tel. 1-888-wir-ereg; e-mail [wirelessreg@penton.com](mailto:wirelessreg@penton.com).

**March 19-21 Embedded Systems Conference—Chicago.** Information: Douglas St. John, Miller Freeman. Tel. 415-538-3848 or 888-239-5563; e-mail [esc@mfi.com](mailto:esc@mfi.com).

**23-24 10th Annual Digital Engineering Conference—The Consumer Electronics Future—Hasbrouck Heights, NJ.**  
Information: Consumer Electronics Manufacturers Association, 2500 Wilson Blvd., Arlington, VA, 2201-3834. Tel. 703-907-7660; e-mail [engcema@eia.org](mailto:engcema@eia.org).

**April 19-21 1999 International Conference on Gallium Arsenide Manufacturing Technology—Vancouver.** Information: Network Device, 1230 Bordeaux Drive, Sunnyvale, CA. Tel 408-734-9888; Fax 408-734-9889; e-mail [dday@network-device.com](mailto:dday@network-device.com); Web site [www.GaAsManTech.org](http://www.GaAsManTech.org).

**26-28 DSP World Spring Design Conference—**

**Santa Clara, CA.** Information: Liz Austin Miller Freeman. Tel. 415-538-3848 or 888-239-5563; e-mail [dspworld@mfi.com](mailto:dspworld@mfi.com).

**27-30 RF Design Seminar Series—Las Vegas.**  
Information: Intertec Trade Shows and Conferences, 6300 S. Syracuse Way, Suite 650, Englewood, CO, 80111. Tel. 800-288-8606 or 303-220-0600; Fax 303-770-0253.

**27-30 Base Station Workshops—Las Vegas.**  
Information: Intertec Trade Shows and Conferences, 6300 S. Syracuse Way, Suite 650, Englewood, CO, 80111. Tel. 800-288-8606 or 303-220-0600; Fax 303-770-0253.

**28-30 IWCE—Las Vegas.** Information: Intertec Trade Shows and Conferences, 6300 S. Syracuse Way, Suite 650, Englewood, CO, 80111. Tel. 800-288-8606 or 303-220-0600; Fax 303-770-0253.

**May 24-26 Markets and Applications for High Frequency Magnetic Materials 99—Santa Clara, CA.** Information: Karen Zacharias, Conference Coordinator, Gorham/Intertec Conferences, 411 US Route One, Portland, ME, 04105. Tel 207-781-9800; Fax 207-781-2150; e-mail [info@intertechusa.com](mailto:info@intertechusa.com).



High Quality  
Prompt Development  
World's Best Technology in Matching Circuit Solutions

## SAW Filters

/ AMPS / GSM / GPS / WLL / PCS / CDMA /



<http://lgsaw.lgcit.com>



Tel : 82-2-579-6470~2 Fax : 82-2-579-6473

INFO/CARD 18



Not  
So

RF Micro Devices Presents

# Great Moments in Wireless Communication



**1861 A.D. – St. Joe to Sacramento...**  
*history's greatest relay.*

*A cloud of dust trails across the plain as man and pony race to deliver the mail. Pounding hooves send echoes bouncing off canyon walls.*

*Ahead, the Sierra Madres and treacherous territory...behind, a loose lock and an open flap.*

*Envelopes go flying.*

*Airmail...1861-style.*

**1998 A.D. – It's all up to you.**

There's no time to backtrack – you either deliver this design today or you're history.

You need help to reach the finish, so hand off your specs to RFMD. We're waiting and ready to supply

you with a full line of highly integrated components.

Components like our RF2510 and RF2917, a fully functional transmitter and receiver pair. These monolithic ICs are low-cost, silicon-based and ideal for

**IMMEDIATE  
DELIVERY**

**RF**   
**MICRO-DEVICES**

**Proprietary, State-Of-The-Art  
RF Integrated Circuits**

North American and European ISM band FM/FSK

applications. Both components require only the addition of an external crystal to provide complete phase-locked oscillators. Best of all, they're ready-to-ship.

When you're racing against time, call RFMD...we deliver.

7625 Thorndike Road  
Greensboro, NC 27409-9421  
Phone 336.664.1233  
FAX 336.664.0454

Online: <http://www.rfmd.com>

**Mention NSG#5 when contacting us.**

©1998, RF Micro Devices, Inc.



# RF courses

**UCLA Extension**— *Project Management and Principles*— Feb 16-19; *Microwaves and Wireless Simplified*— Feb 17-19; *HBT IC Technology for Communications Applications*— Feb 18-20, Los Angeles; Information: UCLA Extension, Department of Engineering, Information Systems and Technical Management, Short Courses, 10995 Le Conte Ave., Suite 542, Los Angeles, CA, 90024-2883. Tel. 310-825-3858; Fax 310-206-2815; e-mail [mhennessi@unex.ucla.edu](mailto:mhennessi@unex.ucla.edu).

**University of Missouri-Rolla**— *Grounding and Shielding Electronic Systems—How to Diagnose and Solve Electrical Noise Problems*— Mar 8-10, San Diego; Apr 28-30, San Jose, CA; Jun 1-3, Toronto; Jun 8-10, Ottawa; *Circuit Board Layout to Reduce Noise Emission and Susceptibility*— Mar 8-10, San Diego; Apr 28-30, San Jose, CA; Jun 1-3, Toronto; Jun 8-10, Ottawa. Information: UMR Continuing Education, Tel 573-341-4132/4200; Fax 573-341-4992.

**Johns Hopkins University**— *GSM Systems Operations and Technology*— Mar 15-17; *Wireless Digital Communications Systems: Specification, Test, Components and Evaluation*— Mar 23-24, Research Triangle Park, NC; *Wireless and Personal Communications Systems*— Mar 29-31, Research Triangle Park, NC. Information: Anita Hellstrom. Tel. 800-683-7267; Fax 301-871-9608; e-mail [info.oei@spl.jhu.edu](mailto:info.oei@spl.jhu.edu).

**Besser Associates**— *Signal Integrity of High Speed Digital Design*— Feb 18-19; *RFIC Design*— Feb 22-26; *RF Circuit Design Using EM Field Simulators*— Mar 1-2; *Wireless Handsets: Architecture and Frequency Planning*— Mar 3-5; *RF and Wireless Made Simple*— Mar 8-9; *DSP Made Simple*— Mar 10-12; *Behavioral Modeling*— Mar 15-17, Mountain View, CA. Information: Besser Associates, 4800 El Camino Real, Suite 210, Los Altos, CA 94022. Tel. 650-949-3300; Fax 650-949-4400; e-mail [info@bessercourse.com](mailto:info@bessercourse.com); Web site [www.bessercourse.com](http://www.bessercourse.com).

**Georgia Institute of Technology**— *Electrical Engineering Refresher*— Mar 6; *RF/Wireless Principles and Practice*— Apr 19-23, Atlanta; *CMOS Analog Integrated Circuits*— Jun 14-18, Santa Clara, CA. Information: Distance Learning, Continuing Education and Outreach, Georgia Institute of Technology, Atlanta, GA, 30332-0385. Tel 404-894-2547.

**Tustin Technical Institute**— *Calibration and Measurement Systems*— Mar 4-5; *Test Procedures for EMI/EMC/ESD*— Mar 8-9; *Thermal Analysis and Heat Transfer*— Apr 14-16; *Grounding and Shielding for EMI/EMC/ESD*— Apr 19-21, Santa Barbara, CA. Information: Tustin Technical Institute, 22 East Los Olivos Street, Santa Barbara, CA 93105. Tel. 805-682-7171; Fax 805-687-6949; e-mail [Training@TTIedu.com](mailto:Training@TTIedu.com); Web site [www.tti.edu](http://www.tti.edu).

## RF Printed Circuit Board Specialist

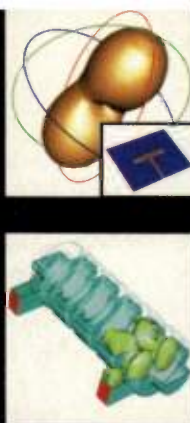
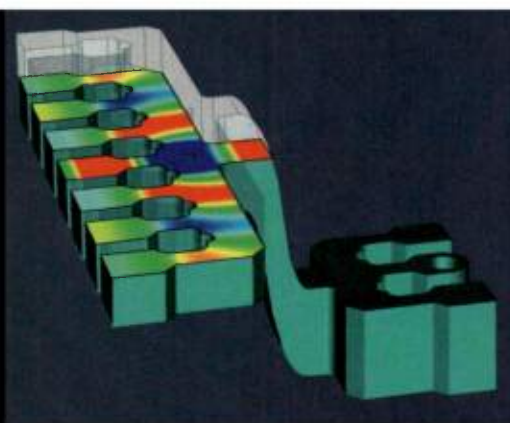
Marlo Electronics has manufactured multilayer Teflon and Duroid printed circuit boards for over 25 years. We specialize in RF technologies using Teflon materials from 1 inch to over 40 inches long. Established in 1966, Marlo is the largest Teflon PCB manufacturer in the southeastern United States.



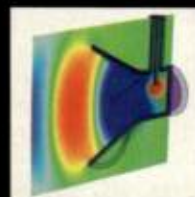
**MARLO ELECTRONICS INC.**  
Ft. Lauderdale, Florida USA  
1-954-565-4839 Fax 1-954-563-1309







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



**CST OF AMERICA**  
124  
Mount Auburn Street  
Suite 200N  
Cambridge, MA 02138  
Phone:  
(617) 576 - 5850  
Fax:  
(617) 576 - 5700  
CST\_America  
@COMPUTER-CONCEPTS.COM



## CEMA establishes new mobile standards group

The Consumer Electronics Manufacturers Association (CEMA), Arlington, VA, has created a new committee to establish new engineering standards for mobile electronics. The R-6 Mobile Electronics Committee will develop standards in conjunction with other organizations or standard bodies such as the Society of Automotive Engineers (SAE).

The R-6 committee will be co-chaired by James Tranchina, vice president of engineering of mobile electronics for Audiovox and Richard Coe, director of engineering and applications for Clarion Sales.

One of the first actions of the committee is to participate in the development of the Intelligent Transportation Systems (ITS) data bus (IDB) standards currently being developed by the SAE. Other areas the committee will pursue include the development of two working groups to consider high speed FM subcarrier standards.

The first meeting of the committee is scheduled for this month, February 1999, during the CEMA Engineering Forum in Point Clear, AL. Anyone interested in participating in the committee should contact Tom Mock, director of engineering for CEMA at 703-907-7649 or via e-mail at [tomock@eia.com](mailto:tomock@eia.com).

## ITS system market growth to be in the billions

The global market for in-vehicle intelligent transportation systems (ITS) is projected to grow from its current \$1 billion to \$18 billion per year in the next five-years. In a new report

from Allied Business Intelligence (ABI), Oyster Bay, NY, *Intelligent Transportation Systems: Wireless In-Vehicle Navigation and Communication Technologies, Global Markets & Forecasts*, the ITS market will be the next multibillion dollar market.

Major ITS systems include: in-vehicle communication systems (IVCS); in-vehicle navigation systems (IVNS); electronic toll collection (ETC) using smart cards and transponders; automatic vehicle identification (AVI); automatic vehicle location (AVL); and collision avoidance systems (CAS).

"CAS will be the big market winner," says Michael Kujawa, senior transportation analyst with ABI. "The CAS market will surpass \$10 billion per year within five-years."

ABI notes that more than 14,000 vehicles are now in the General Motors OnStar program. Drivers get voice-activated cellular communications, mayday support, navigation and point of interest directions from a central service. Other car manufacturers are watching the program very closely.

For more information concerning this report, go to ABI's Web site at [www.alliedworld.com](http://www.alliedworld.com).

## IVI gains new members in push toward interoperability

The Interchangeable Virtual Instruments (IVI) foundation has gained 10 new members including Advantest, Anritsu, Ascor, LeCroy, Racal Instruments, Rohde & Schwarz, Tektronix, Teradyne, TYK and Wavetek.

The IVI Foundation is an open consortium that builds on VXI plug and play driver standards so that users can change instruments in test systems without making software modifications. More information concerning the foundation is available on the foundation's Web site at [www.ivifoundation.org](http://www.ivifoundation.org).

## Contracts

**M-tron awarded \$1.8 million contract**—M-tron Industries, Yankton, SD, has received a contract from a major manufacturer of network switching equipment valued at \$1.8 million. The contract is for fre-

quency control products.

**Celeritek wins \$4.7 million award**—Celeritek, Santa Clara, CA has received a \$4.7 million contract from Innova, Seattle. Celeritek will provide Innova with transceiver products for Innova's XP2 single T1/E1 digital radio.

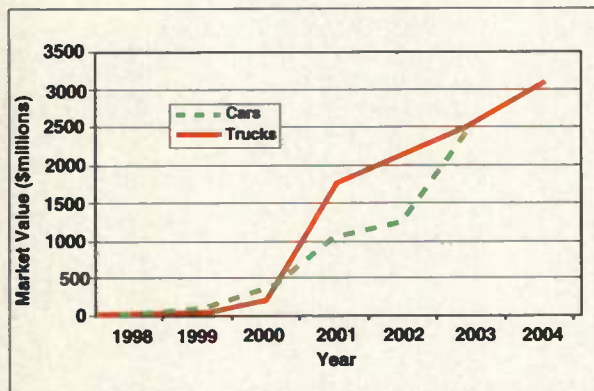
## Business Briefs

**Intarsia teams with Philips**—Intarsia, Silicon Valley, and Philips Components, The Netherlands, are teaming to develop standards for integrated passive devices in chip scale packages. The effort will focus on developing standard peripheral and grip array packaging outlines for use in future portable and handheld electronic devices.

**TAS acquires NoiseCom test lines**—Telecom Analysis Systems (TAS), Eastontown, NJ, has signed an agreement to acquire the wireless and satellite communications testing product lines of NoiseCom, Paramus, NJ, for \$19 million. The engineering, technical support and administrative staff from NoiseCom will join TAS to support existing NoiseCom products.

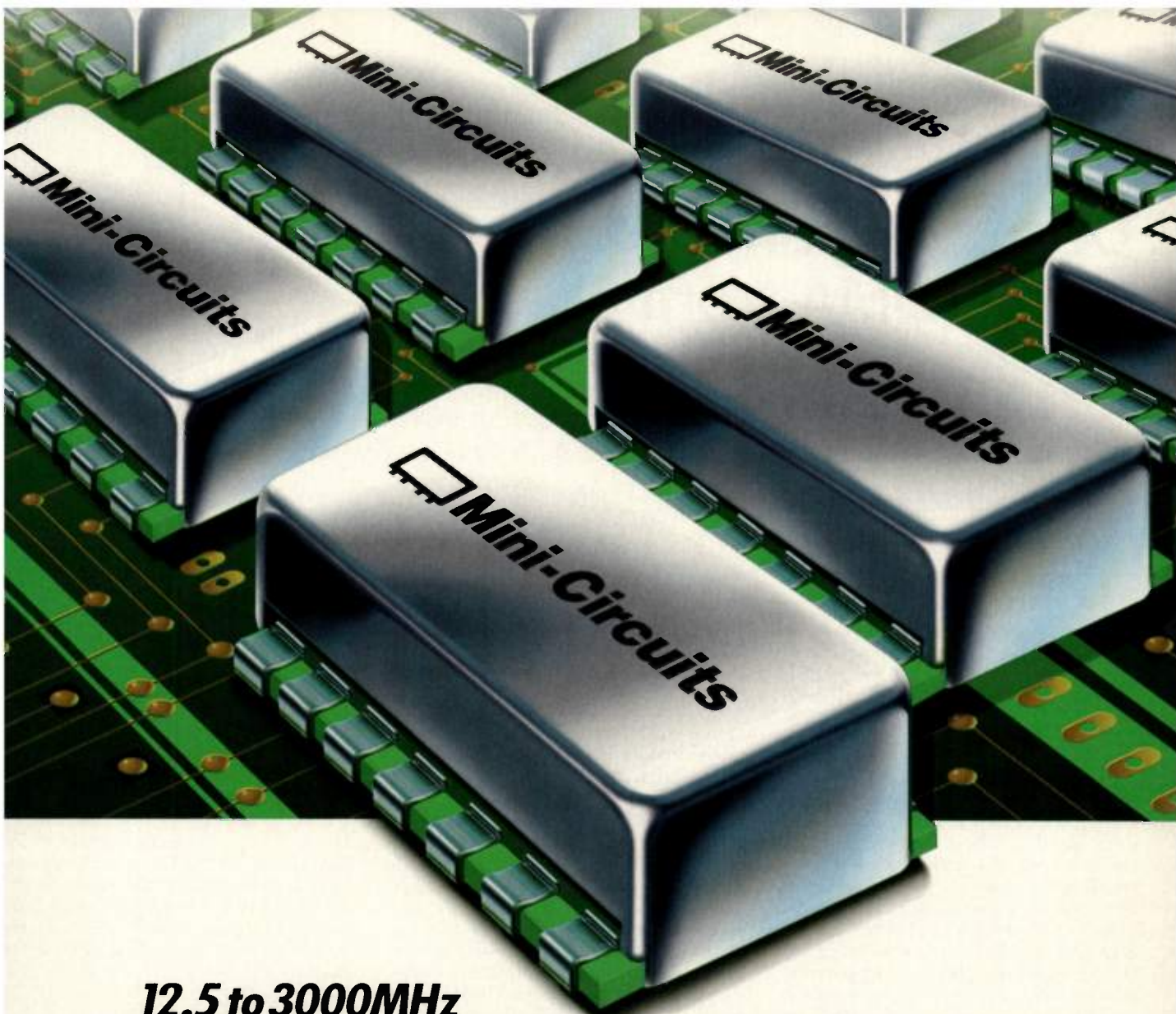
**Seattle Silicon and Microchip Technology join forces**—Seattle Silicon, Bellevue, WA and Microchip Technology, Chandler, AZ, have signed a shared technology licensing agreement to produce system-on-a-chip 8-bit microcontroller integrated circuits (ICs). Seattle Silicon will license Microchip's PIC16C5X 8-bit processor core as the standard platform for a new custom application-specific IC (ASIC) design.

**Sawgrass acquires Andersen Laboratories**—Sawgrass Electronics, Worcester, MA, has acquired Andersen Laboratories, Bloomfield, CT. The acquisition also includes Creative Electric, Auburn, NY. Anderson manufacturers high-performance acoustic signal processing devices.



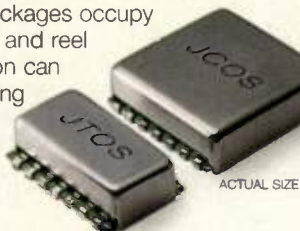
One of the leading technologies expected to have significant market growth is in truck and car collision avoidance systems.





## 12.5 to 3000MHz SURFACE MOUNT VCO's from \$13<sup>95</sup>

Time after time, you'll find Mini-Circuits surface mount voltage controlled oscillators the tough, reliable, high performance solution for your wireless designs. JTOS wide band 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.



ACTUAL SIZE

### JTOS/JCOS SPECIFICATIONS

| Model          | Freq. Range (MHz) | Phase Noise (dBc/Hz) SSB @ 10kHz Typ. | Harmonics (dBc) Typ. | V <sub>tune</sub> 1V to: | Current (mA) @ +12V DC Max. | Price Sea. (5-49)* |
|----------------|-------------------|---------------------------------------|----------------------|--------------------------|-----------------------------|--------------------|
| NEW 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       | 150-300           | -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              |
| NEW 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-1650      | 1200-1650         | -95                                   | -20                  | 13V                      | 30                          | 19.95              |
| JTOS-1910      | 1625-1910         | -92                                   | -13                  | 12V                      | 20                          | 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-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 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...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 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 67 INTL 68

CIRCLE READER SERVICE CARD

F 234 Rev D



# Designing an LNA for a CDMA front end

*LNA design is critical in modern communication systems. Understanding necessary additional design considerations can save both time and money.*

By Jarek Lucek  
and Robbin Damen

The smallest signal that can be received by a receiver defines the receiver's sensitivity. The largest signal that can be received by a receiver establishes an upper power level limit of what can be handled by the system while preserving voice or data quality. The dynamic range of the receiver, the difference between the largest possible received signal and the smallest possible received signal, defines the quality of the receiver chain. The low noise amplifier (LNA) function plays an important role in the receiver design. Its main function is to amplify extremely low signals without adding noise, thus preserving the required signal-to-noise ratio (SNR) of the system at extremely low power levels. Additionally, for large signal levels,

the LNA amplifies the received signal without introducing any distortions, which eliminates channel interference. Proper LNA design is crucial in today's communication technology. Because of the complexity of the signals in today's digital communications, additional design considerations need to be addressed during an LNA design procedure.

### Typical trade offs in LNA design

An LNA design presents a considerable challenge because of its simultaneous requirement for high gain, low noise figure, good input and output matching and unconditional stability at the lowest possible current draw from the amplifier. Code-division, multiple access (CDMA) systems add to the challenge because of their high linearity or high third-order intercept point (IP3) requirement. Although gain, noise figure, stability, linearity and input and output match are all equally important, they are interdependent and do not always work in each other's favor. Typically, the CDMA LNA requires:

- Low supply voltage ( $V_{CC} = 2$  V).
- Low current consumption ( $I_C \leq 10$  mA).
- High gain ( $\geq 15$  dB).
- High input IP3 ( $\geq 5$  dBm).
- Low noise figure ( $\leq 2$  dB).
- Unconditionally stable.
- Input return loss ( $\geq 10$  dB).
- High isolation.
- Small dimension/low part count.
- Low cost.

Most of these conditions can be met by carefully selecting a transistor and understanding parameter trade-offs. Low noise figure and good input match is rarely simultaneously ob-

tained without using novel feedback arrangements [1]. Unconditional stability will always require a certain gain reduction because of either shunt or series resistive loading of the collector. High IP3 requires higher current draw, although the lowest possible noise figure is usually achieved at lower current levels. Envelope termination technique can be used to improve IP3 performance while operating LNA at low current levels. Additional improvement of IP3 can also be achieved by proper power output matching (P1dB match). The P1dB match, being different from conjugate gain match, reduces the gain although improving IP3 performance.

### Transistor selection

Transistor selection is the first and most important step in an LNA design. The designer should carefully review the transistor selection keeping the most important LNA design trade-offs in mind. The transistor should exhibit high gain, have a low noise figure, offer high IP3 performance at the lowest possible current consumption, while preserving relatively easy matching at frequency of operation.

Examination of a datasheet is good starting point in a transistor evaluation for LNA design. The transistor's S-parameters should be published at different collector/emitter voltages and different current levels for frequencies ranging from low to high values. The data sheet should also contain noise parameters, which are essential for low noise design. Spice models for the transistor and its package are also useful for IP3 and P1dB simulations.

The designer should first look at

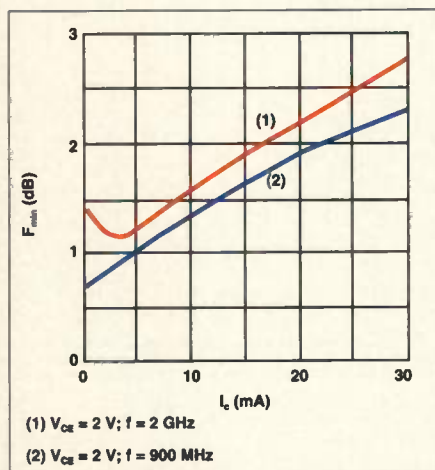


Figure 1. BFG425W minimum noise figure as a function of the collector current.

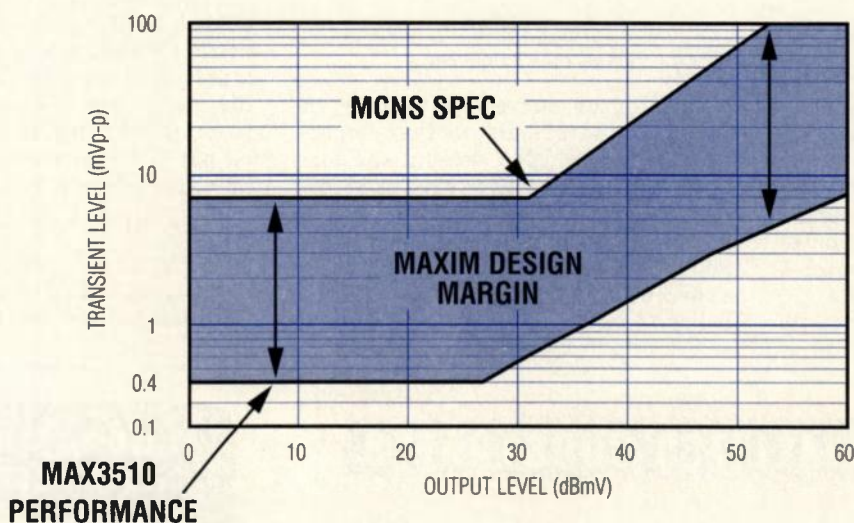


# ELIMINATE EXPENSIVE ANALOG SWITCHES IN YOUR NEXT MCNS CABLE MODEM DESIGN

## World's Lowest Transients and Output Noise from MAX3510 CATV Upstream Amplifier

The MAX3510 programmable-gain amplifier is ideal for use as the upstream driver in cable modems and set-top boxes. The MAX3510 not only delivers superior transients performance for packet-based cable modem transmitters, but also has the industry's lowest power-down output noise. All this with the output matched to 75Ω.

### MAX3510 Power-Up/Down Transients vs. Output Level



- ◆ No External Pads, Attenuators, or Switches Needed to Meet Industry-Standard Specs for Spurious and Noise Output
- ◆ Better than -50dBc Harmonics @ 59dBm V<sub>OUT</sub>—Guaranteed
- ◆ Gain Adjustable in 1dB Steps Over 60dB Range
- ◆ -47dBmV (160kHz) Transmit Noise Floor
- ◆ Single +5V Supply Simplifies Design

1998 EDITION!  
FREE FULL-LINE DATA CATALOG  
ON CD-ROM



CALL TOLL-FREE 1-800-998-8800 for a Data Sheet or Free Sample  
6:00 a.m. – 6:00 p.m. Pacific Standard Time

**MAXIM**  
<http://www.maxim-ic.com>



For Small-Quantity Orders Call (800) 835-8769 or Visit <http://www.maxim-ic.com>

MasterCard® and Visa® are accepted for evaluation kits and small-quantity orders.

Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086, (408) 737-7600, FAX (408) 737-7194.

Distributed by Arrow, Bell, CAM RPC, Digi-Key, Elmo, Marshall, Nu Horizons, and Zeus.  
Distributed in Canada by Arrow, Bell/Milgray, and Marshall.

MAXIM is a registered trademark of Maxim Integrated Products. © 1999 Maxim Integrated Products.

INFOCARD 48



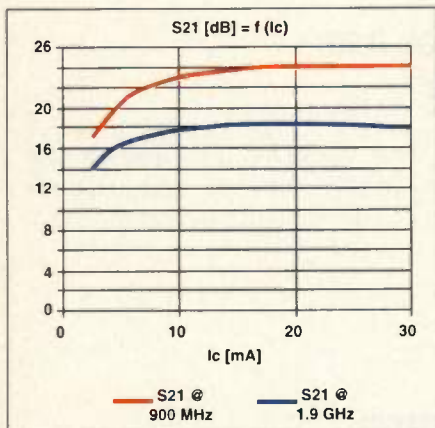


Figure 2. Forward transducer power gain.

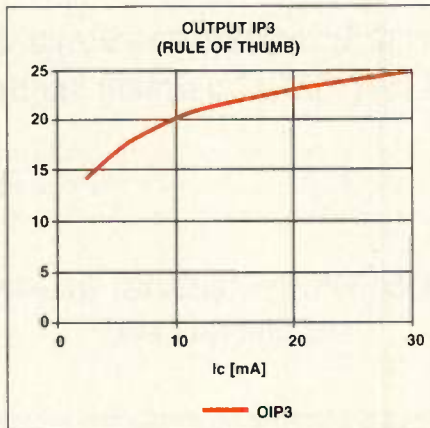


Figure 3. OIP3 vs. collector current.

three main design parameters: noise, gain and IP3, and decide what  $V_{ce}$  and  $I_c$  levels will produce optimal performance. A closer examination of NF vs. collector current, shown in Figure 1, indicates that the minimum noise figure can be achieved at around 4 mA at both 900 MHz and 1.9 GHz.

Gain available from the transistor

vs. collector current is shown in Figure 2 and reveals another important aspect in LNA design: the forward transducer power gain of 18 dB remains constant at 1.9 GHz for current levels above 10 mA (24 dB for 900 MHz). Small gain degradation is expected at low current operation, below 10 mA.

The forward transducer power gain represents the gain from the transistor itself with its input and output presented with  $50\ \Omega$  impedance. The  $S_{21}$  values are provided by the manufacturer of the transistor at multiple frequencies and different  $V_{ce}$  and current levels. Additional gain can be obtained from source and load matching circuits [2,3,4]. Maximum stable gain (MSG) and maximum power gain ( $G_{max}$ ) are good indicators of additional obtainable gain from the LNA circuit.

LNA linearity is another important CDMA LNA parameter. A figure of merit for linearity is the IP3. A two tone test is used for derivation of IP3 [5]. As a rule of thumb for bipolar junction transistors (BJT), the output-IP3 can be estimated from the following formula:

$$OIP3 = 10 \log(V_{ce} \cdot I_c \cdot 5) \text{ [dBm]}$$

where  $V_{ce}$  is in V and  $I_c$  is in mA.

The graph of OIP3 vs. collector current can be derived. Figure 3 shows

## THIN FILM METALLIZED SUBSTRATES

# FILE TO FINISHED PARTS IN 48 HOURS.

(YES. THIS INCLUDES THE MASK!)

## NOW...THAT'S FAST!



FILM MICROELECTRONICS INCORPORATED  
A SurCom Company

CALL US FOR OUR FREE DESIGN GUIDE.

### 978.975.3385

530 Turnpike Street • North Andover, MA 01845 • Fax: 978.975.3506  
e-mail: fmisales@erols.com

INFO/CARD 105

## CERAMIC RF CAPACITORS

### C-D/SANGAMO

MICA RF CAPACITORS



## JENNINGS

VACUUM CAPACITORS  
VACUUM RELAYS

SURCOM ASSOCIATES, INC.

2215 Faraday Avenue, Suite A  
Carlsbad, California 92008  
TEL (760) 438-4420  
FAX (760) 438-4759

INFO/CARD 73





*Neighborhood watch, Arctic style.*

# Test at the speed of the revolution.

Three hundred miles north of the Arctic Circle, the life of the Inupiaq still revolves around whales, seals and polar bears, as it has for centuries. They talk about it all the time. On their cell phones.

A wireless revolution is fast finding its way into the most remote corners of life. And perhaps more than anyone, the test engineer is feeling the pressure to keep pace. To push product out the door while at the same time having every confidence nothing is going out that isn't up to company standards.

No one is as prepared to help you live up to that responsibility as Hewlett-Packard. To give you wireless test equipment as flexible, and as capable of higher test throughput while maintaining accuracy of measurement. To be there with service and technical support when you need it.

For more information, call 1-800-452-4844, Ext. 6211. In the spirit of the times, we'll rush it right to you.

[www.hp.com/go/wireless](http://www.hp.com/go/wireless)

©1998 Hewlett-Packard Co. TMMID819RFD



INFOCARD3





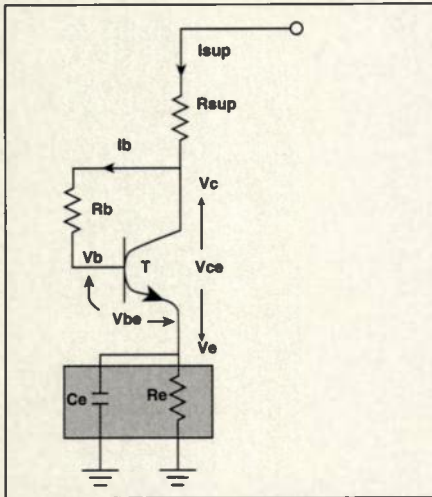


Figure 4. Typical LNA biasing circuit.

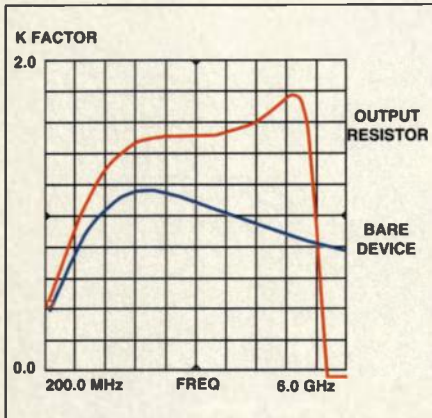


Figure 5. Stability factor over frequency.

the result. The relation between IIP3 and OIP3 is defined as:

$$IIP3 = OIP3 - \text{Gain} \text{ [dBm]}$$

Using 15 dB for target gain and by examining the graph of Figure 3, one can determine that the transistor will need to be operated at at least 10 mA to produce a 5 dBm of IIP3 without any margins. Additional IIP3 enhancement techniques will be needed to produce IIP3 of at least 5 dBm at 10 mA of collector current.

$V_{ce} = 2 \text{ V}$  and  $I_c$  of 10 mA is the point where the transistor will produce an acceptable gain of at least 15 dB with a noise figure below 2 dB at both 900 MHz and 1.9 GHz. IIP3 will also be above 5 dBm with a collector current level of 10 mA.

## LNA design

1. *DC biasing* represents the first step in LNA design. The chosen DC

bias circuit should exhibit stable thermal performance and reduce the influence of  $h_{FE}$  spread. It also should be a cost-effective and simple solution, one that does not increase the complexity of the design and preserves smallest possible size for the overall LNA. The resistive feedback arrangement shown in Figure 4 is the simplest form of DC biasing that fulfills all the major requirements.

Two bias feedback arrangements are possible: one with a combination of  $R_{sup}$  and  $R_b$  and a second one with a simple  $R_e$  and  $C_e$  combination. The operation of the  $R_{sup}$  and  $R_b$  is as follows:  $R_{sup}$  and  $R_b$  will establish a biasing point. Because the operation of the LNA is going to be class A (constant current draw for dynamic range of power levels), a stable biasing point over different temperatures and for different lot codes of transistors is needed, where a small variation in  $h_{fe}$  can be expected.  $V_c$  in terms of  $V_{sup}$  and  $I_{sup}$  can be expressed as follows:

$$V_c = V_{sup} - I_{sup} \cdot R_{sup}$$

As  $I_{sup}$  decreases, which could be the case with a part with lower  $h_{fe}$ ,  $V_c$  will increase at the same time. With an increase of  $V_c$ , higher  $I_b$  will result. With higher  $I_b$ , increase in  $I_c$  ( $\sim I_{sup}$ ) will take place as high as a stable level set by  $R_{sup}$  and  $R_b$ . The same circuit handles thermal variations well. With a temperature increase,  $I_{sup}$  will increase, which will lower  $V_c$ . Lower  $V_c$  will result in lower  $I_b$  and lower  $I_b$  will lower  $I_c$  ( $\sim I_{sup}$ ). This circuit is inexpensive, simple and takes little real estate, while its performance is well behaved and understood. For  $R_b$  to have little influence on source matching, which is crucial for noise performance, the feedback network should be decoupled with an inductor (making biasing invisible at RF band of operation).

Another possible bias feedback can be realized with emitter resistor and capacitor, shown in shaded color in Figure 4. With  $I_{sup}$  ( $\sim I_c$ ) decreasing,  $V_e$  will decrease.  $V_{be}$  will increase with a decrease in  $V_c$ . With increase in  $V_{be}$ ,  $I_{sup}$  will increase, although keeping a stable biasing point.  $C_e$  should be selected carefully, because  $R_e$  will also have a direct effect on RF gain of LNA.  $C_e$  should present a short at frequency of operation to limit its influence on gain and noise performance of the circuit.

Other biasing methods are suitable for class A networks. These are usually closed feedback arrangements with dynamic bias control provided by active components [6]. Although suitable for LNA application, these active feedback bias networks increase complexity of the LNA network, introduce additional components and increase the real-estate area of the solution.

2. *Stability design* analysis should be the next step in LNA design. Unconditional stability of the circuit is the goal of the LNA designer. Unconditional stability means that with any load presented to the input or output of the device, the circuit will not become unstable—will not oscillate. Instabilities are primarily caused by three phenomena: internal feedback of the transistor, external feedback around the transistor caused by external circuit, or excess of gain at frequencies outside of the band of operation. S-parameters provided by the manufacturer of the transistor will aid in stability analysis of the LNA circuit. Two main methods exist in S-parameter stability analysis: numerical and graphical. Numerical analysis consists of calculating a term called Rollet's Stability Factor K [2,3,4]. An intermitted quantity called delta ( $\Delta$ ) should be calculated first to simplify the final equation for the K-factor.

$$\Delta = S_{11} \cdot S_{12} - S_{21} \cdot S_{22}$$

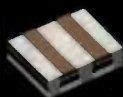
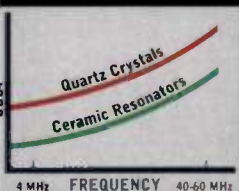
then

$$K = \frac{1 + |\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2 \cdot |S_{11}| \cdot |S_{22}|}$$

When the K factor is greater than unity, the circuit will be unconditionally stable for any combination of source and load impedance. When K is less than unity, the circuit is potentially unstable and oscillation may occur with a certain combination of source and/or load impedance presented to the transistor. The K factor represents a quick check for stability at given frequency and given bias condition. A sweep of the K-factor over frequency for a given biasing point should be performed to ensure unconditional stability outside of the band of operation. Figure 5 shows two stability factor curves: for the transistor itself and for the complete LNA circuit. The designer's goal is to design an LNA circuit that is uncondi-



We're about to shatter the perception that quartz is always the best choice for high frequency timing devices.



If you're using quartz crystals for applications such as hard disk drives, digital signal processing, USB, DVD or CD-ROM, here's something you should know. Our surface-mounted high frequency ceramic resonators offer an economical alternative to quartz, with some very compelling advantages - lower profile, greater

reliability, higher durability and frequency up to 60MHz. Not surprisingly, we're the world leader in ceramic resonators. After all, we pioneered the piezoelectric ceramic technology that makes them possible. So contact us before your next design project. We'll help you see new possibilities. Call 1-800-831-9172 or visit [www.murata.com](http://www.murata.com).

**muRata**

*Innovator in Electronics*



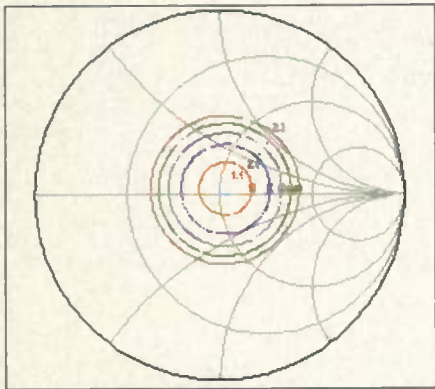


Figure 6. BFG425W 1.9 GHz, 2 V, 10 mA noise circles.

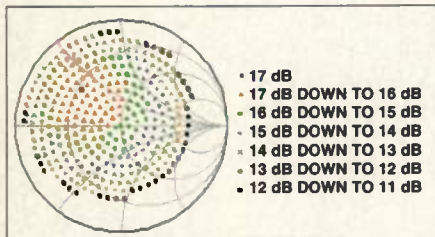


Figure 7. Gain contours for 1.9 GHz LNA.

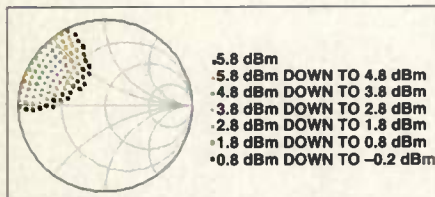


Figure 8. IIP3 contours for 1.9 GHz LNA.

tionally stable for the complete range of frequencies where the device has a substantial gain.

An LNA designer can use at least five methods for circuit stabilization. The first one consists of resistive loading of the input. This method, although capable of improving the stability of the circuit, also degrades the noise of the LNA and is almost never used. Output resistive loading is a preferred method of circuit stabilization. This method should be carefully used because its effects are lower gain and lower P1dB point (thus lower IP3 point). The third method uses collector to base resistor-inductor-capacitor (RLC) feedback to lower the gain at the lower frequencies and hence improve the stability of the circuit. The fourth method consists of filter matching, usually used at the output of the transistor, to decrease the gain at a specific narrow

bandwidth frequency. This method is frequently used for eliminating gain at high frequencies, much above the band of operation. Short circuit quarterwave lines designed for problematic frequencies, or simple capacitors with the same resonant frequency as the frequency of oscillation (or excessive gain) can be used to stabilize the circuit. The final stabilization method can be realized with a simple emitter feedback inductor. A small emitter inductor can make the circuit more stable at higher frequencies.

3. *Noise matching*—The next step in LNA design consists of noise and input return loss (IRL defines how well the circuit is matched to 50  $\Omega$ ) matching of the source. A typical approach in LNA design is to design an input matching circuit that terminates the transistor with a conjugate of  $\Gamma_{opt}$ , which represents the terminating impedance of the transistor for the best noise match. In many cases, this means that the input return loss of the LNA will be sacrificed. The optimal IRL can be achieved only when the input matching network terminates the device with a conjugate of  $S_{11}$ , which in many cases is different from the conjugate of  $\Gamma_{opt}$ . An emitter inductor feedback can rotate  $S_{11}$  closer to  $\Gamma_{opt}$ , which can help with obtaining close to minimum noise figure and respectable IRL simultaneously. This additional inductance at the emitter of the transistor will also reduce the overall available gain of the network and can be used in balancing trade-offs between the gain, IIP3 and stability in LNA design. A typical method used in designing input matching network is to display noise circles and gain/loss circles of the input network on the same Smith chart. This provides a visual tool in establishing an input matching network for the best IRL and noise trade off. This method is widely used and is also well published [7].

A slightly different design approach will be followed in the CDMA LNA example because of a special case described below. Figure 6 shows noise figure circles for a transistor at 2 V, 10 mA and 1.9 GHz. The input match is exclusively used for obtaining optimal noise performance of the LNA although preserving good IRL. A closer examination of Figure 6 reveals that  $\Gamma_{opt}$  coincides with the 50  $\Omega$  point. This means that almost no matching is required with the input network of the transistor (simple 50

$\Omega$  line along with the self resonating at frequency of operation coupling capacitor will be sufficient) to obtain minimum specified noise figure at the given frequency of operation and given operating point. For the 900 MHz circuit, a small emitter inductance will be used to bring  $S_{11}$  point and  $\Gamma_{opt}$  point closer together, thus preserving respectable IRL. This inductance will be achieved with small strip lines connected directly to the emitters of the transistor.

4. *Loadpull matching*—The last step in LNA design involves output matching of the transistor. Traditionally, this step used to be relatively simple. An additional resistor either in series or parallel, has been placed on the collector of the transistor for circuit stabilization. Conjugate matching has been exclusively used for narrowband LNA design to maximize the gain out of the circuit. With additional IP3 requirement forced on the LNA, the trade-off between IP3 and gain must be considered. Linearity matching is widely known by high-power amplifier designers, especially those who deal with linear systems, but is relatively unknown for a small signal designer. The so-called load pulling is used to establish IP3 and gain impedance contours. The load pulling can be realized by using nonlinear Spice model of the transistor with simulation software. Harmonic balance can be used for establishing two tone environment. The load pulling method sweeps impedance over the whole Smith chart and plots contours of constant gain and IP3 numbers. Figure 7 shows gain contours at 1.9 GHz and Figure 8 shows IIP3 contours. The optimal gain impedance point does not match the optimal IIP3 point, which means that the design will have to be realized by means of trade off. Typically, the designer should design the LNA circuit at the point where the gain does not degrade as much, and the IP3 is still respectable. If one were to draw a line between the optimal gain and IIP3 impedance points, every point on that straight line will represent a good area of trade-off, with the ends representing the two optimal points.

The rule of thumb for P1dB and IP3 is:

$$IP3 = P_{1dB} + 10 \text{ in dBm}$$

This means that by knowing the



# GaAs SWITCHES

**DC-2.5GHz Immediate Delivery** **\$2<sup>30</sup>**  
from **\$2.95** ea. (qty. 1000)


Finally! **SPDT absorptive, reflective, and transfer switches** that appeal to your technical side, and business side as well! It's Mini-Circuits GaAs switches...providing outstanding performance features such as very high isolation (up to 60dB), superfast 3nsec switching speed, and excellent compatibility with surface mount soldering techniques. Additionally, these switches are built extremely tough and are immediately available from stock with a guarantee to ship within 1 week. From only \$2.95 ea. (qty. 10), this top-of-the-line value is priced with your bottom line in mind! To order, contact Mini-Circuits with your requirements today.


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

| Model                     | Freq.<br>(GHz) | Insertion<br>Loss*<br>dB (Max.) | 1dB<br>Comp*<br>dBm (typ) | In-Out<br>Isol.*<br>dB (typ) | Price<br>\$ea.<br>(qty. 10) |
|---------------------------|----------------|---------------------------------|---------------------------|------------------------------|-----------------------------|
| RSW-2-25P<br>(Reflective) | DC-2.5         | 1.1                             | +29                       | 49                           | 3.95                        |
| MSW-2-20<br>(Reflective)  | DC-2.0         | 1.0                             | +24                       | 34                           | 2.95                        |
| MSWA-2-20<br>(Absorptive) | DC-2.0         | 1.3                             | +27                       | 40                           | 3.45                        |
| MSWT-4-20<br>(Transfer)   | DC-2.0         | 1.8 TX**<br>2.0 RX***           | +28 TX**<br>+20 RX***     | 30                           | 3.95                        |

\*Midband, 500MHz-1000MHz. \*\*Transmit. \*\*\*Receive.

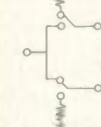
Package:

RSW in SOIC 14 pin, 

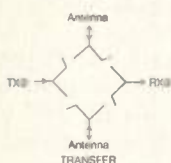
MSW in SOIC 8 pin 



SPDT REFLECTIVE



SPDT ABSORPTIVE



Antenna  
TRANSFER

**Buy 1** Customer  
Appreciation Offer  
**Get 1 Free!**

Buy Up To 1000 Units Of Each Model At The Regular Price  
Get An Equal Amount **FREE!**  
Offer expires April 30, 1999

 **Mini-Circuits®**

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](http://WWW.RFGLOBALNET.COM)

**ISO 9001 CERTIFIED**

F 174 Rev C

US 32 INT'L 33  
CIRCLE READER SERVICE CARD



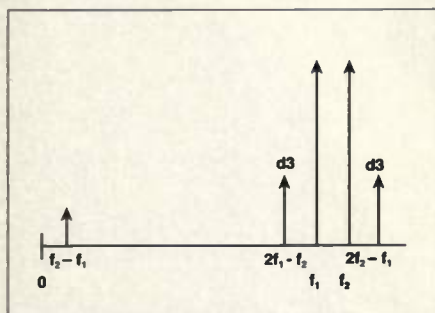


Figure 9. Two tones with in and out of band distortions.

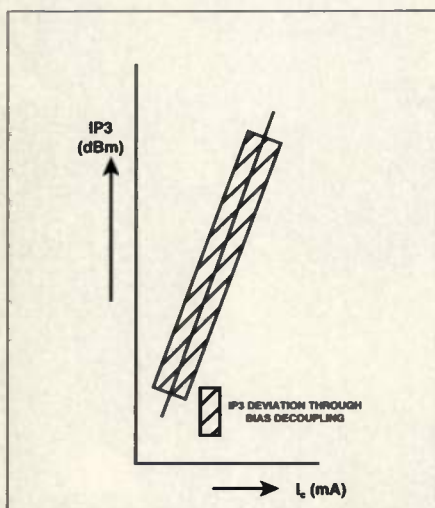


Figure 10. IP3 deviation through by-pass enhancement.

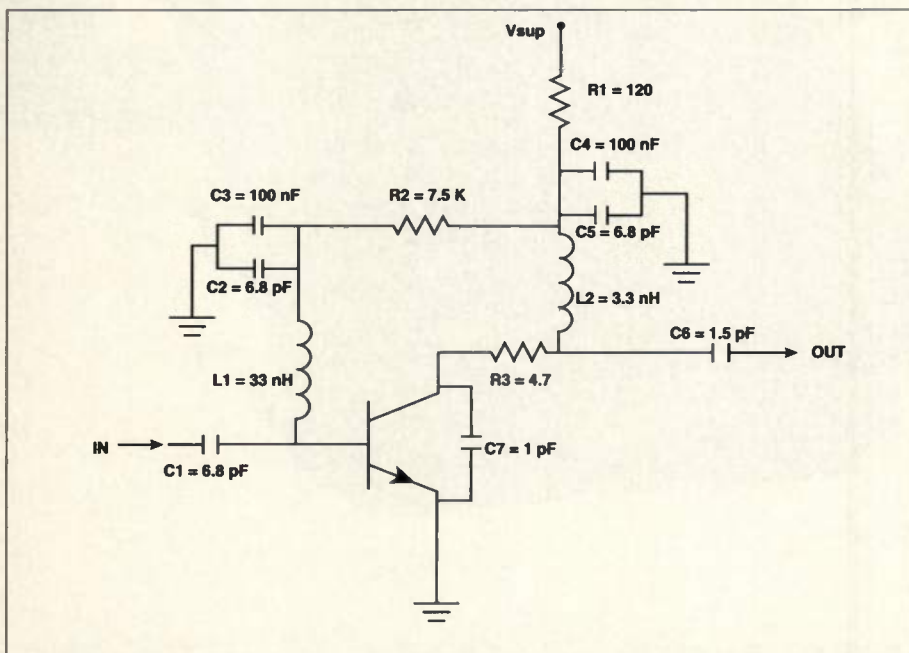


Figure 11. 1.9 GHz LNA.

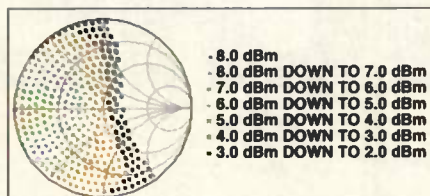


Figure 12. IP3 contours for decoupling corrected LNA circuit, 1.9 GHz LNA.

P1dB point, one can estimate the IP3 levels. The 10 dB rule can further be improved with appropriate bypassing of the base and collector [8]. As previously indicated, the IIP3 is established by injecting two equal-magnitude signals with small frequency offset into an active circuit. As the active circuit approaches non-linear region, close to P1dB, the two carriers will generate distortion products, both in and out of band. (See Figure 9.)

The low frequency products,  $f_2 - f_1$ , can modulate the base emitter and collector emitter LNA supply voltages. For improved linearity, the fluctuation of the base and collector voltages should be eliminated by means of proper by-passing, hence presenting the base and the collector with low impedance at so-called video frequencies (between DC and usually as high as 40 MHz, depending on the bandwidth of the signal that is being presented to the LNA). In the case of CDMA

system, the video bandwidth should extend well beyond 1.25 MHz or at least 5 MHz. The designer should exhibit caution during by-passing design. A poor selection of the by-pass capacitors could also degrade IP3 performance as shown in Figure 10.

Figure 11 shows 1.9 GHz LNA with the transistor. Capacitor C2 and C5 will resonate at frequency of operation. C3 and C4 combination will work at video frequencies, thus making sure that both collector and base bias are not modulated with the distortion signals. As a rule of thumb, the impedance of by-passing circuit should be lower than 25% of the input impedance of the transistor at particular frequency spacing. In that case, the following is valid:

The impedance of the transistor is:

$$Z_{in}(5\text{ MHz}) = \frac{h_{fe}}{g_m} = \frac{h_{fe}}{I_c} = \frac{70}{\frac{10}{25}} = 175\ \Omega$$

Cd should be 25% less than 175  $\Omega$ :

$$C_d < 0.25 \cdot 175\ \Omega = 44\ \Omega$$

At 5 MHz spacing, the Cd should be at least:

$$C_d \geq \frac{1}{2\pi f \cdot 44} \geq \frac{1}{2 \cdot (3.14) \cdot 5E6 \cdot 44} \geq 1\text{ nF}$$

Although preserving the gain performance of the LNA, the by-passing method (also known as an envelope termination technique) can improve LNA's IIP3 performance without increasing current consumption. Figure 12 shows IIP3 contours after implementation of video frequency decoupling. Comparison of Figure 12 and Figure 8 reveals substantial improvement in IIP3 trade off. Because the gain contours for IIP3 improved circuit will remain the same, the main improvement in IIP3 performance is achieved by extending the available IIP3 impedance points closer to the optimal gain impedance levels.

### LNA circuit realization

Figure 11 shows 1.9 GHz high IP3 CDMA LNA circuit with the transistor, and Figure 13 demonstrates a typical 900 MHz LNA. Both circuits were realized with design methods described in this article.

Table 1 summarizes the measured performance of 1.9 GHz LNA circuit. Table 2 summarizes the performance



# 75 ohm Superflex Flexible Cable Assemblies



| Cable Diameter | Jacket Material | VSWR 12" Assy. | Insertion Losses @ 3GHz | Frequency Range | Characteristics Impedance | Power CW Watts @GHz | Relative Shielding dB | Temp Range Deg C | Min.bend radii inch |
|----------------|-----------------|----------------|-------------------------|-----------------|---------------------------|---------------------|-----------------------|------------------|---------------------|
| .216           | Polyurethane    | 1.25           | 0.50                    | 3GHz            | 75 ohms                   | 27@3                | >100                  | -65+80           | 1.0"                |

Superflex 75 flexible cable assemblies are available with many connector choices to meet your specific application requirements.



MADE IN THE USA



Tensolite

**QMI**

A CARLISLE Company

Microwave  
Interconnects



301 Ballardvale St. Wilmington, MA 01887

**1-800-362-FLEX**

FAX: (978) 988-9393

www.qmiinc.com Email: sales@qmiinc.com

"Do it Yourself" - call QMI for cable and connector price and availability. Selected options and lengths in stock for immediate delivery from QMI's Worldwide Distributor:

**Richardson  
Electronics, Ltd.**  
ISO9002 Registered  
1-800-RF-POWER



| Parameters | Units | Measured performance with IIP3 by-pass improvement | Measured Performance without IIP3 by-pass improvement |
|------------|-------|--|---|
| Vsuply     | Volts | 3.3  | 3.3   |
| Vce        | Volts | 2  | 2   |
| Ic         | mA    | 10.3   | 10.3  |
| Gain       | dB    | 16.8   | 16.8  |
| NF         | dB    | 1.9  | 1.9   |
| IIP3       | dBm   | +5 (at 1.25 MHz spacing)                           | -2.5 (at 1.25 MHz spacing)                            |
| IRL        | dB    | 13   | 14  |
| ORL        | dB    | 11   | 10  |
| Isolation  | dB    | 27   | 27  |

Table 1. 1.9 GHz LNA performance.

| Parameters | Units | Measured performance with IIP3 by-pass improvement | Measured Performance without IIP3 by-pass improvement |
|------------|-------|--|---|
| Vsuply     | Volts | 3.3  | 3.3   |
| Vce        | Volts | 2  | 2   |
| Ic         | mA    | 10   | 10  |
| Gain       | dB    | 16.9   | 17  |
| NF         | dB    | 1.8  | 1.85  |
| IIP3       | dBm   | +5 (at 1.25 MHz spacing)                           | -4 (at 1.25 MHz spacing)                              |
| IRL        | dB    | 7  | 7   |
| ORL        | dB    | 11   | 11  |
| Isolation  | dB    | 28.5   | 28.5  |

Table 2. 900 MHz LNA performance.

of 900 MHz version of LNA.

RF

## References

1. S. Mercer, "An Introduction to Low-noise Amplifier Design," *RF Design*, July 1998, pp. 44-56.
2. S. Liao, *Microwave Circuit Analysis and Amplifier Design*, Prentice-Hall, 1988, pp. 123-160.
3. G. Gonzalez, *Microwave Transistor Amplifiers*, Prentice-Hall, 1984, pp. 139-193
4. N. Dye, H. Granberg, *Radio*

## Acknowledgment

Special thanks to Tom Buss, Korne Vennema and Norbert van der Bos from Philips Semiconductors. Our many fruitful discussions on the topics of LNA design greatly contributed to realization of this article.

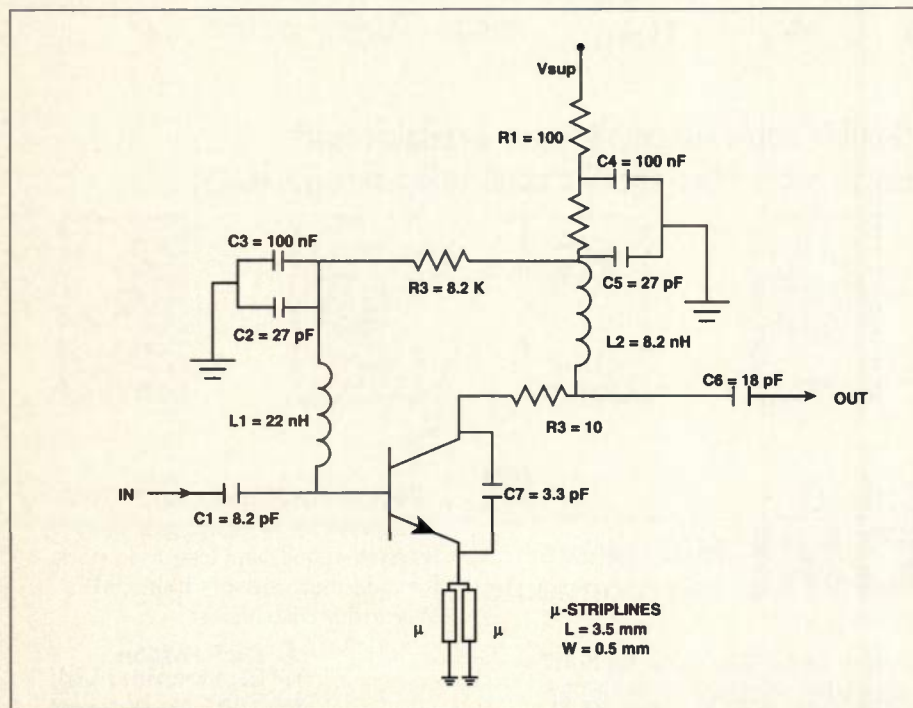


Figure 13. 900 MHz LNA circuit.

*Frequency Transistors Principles and Practical Applications*, Butterworth-Heinemann, 1993, pp. 204-231.

5. N. Dye, H. Granberg, *Radio Frequency Transistors Principles and Practical Applications*, Butterworth-Heinemann, 1993, pp. 18-23.

6. N. Dixit, "Design and Performance of a Low Voltage, Low Noise 900 MHz Amplifier," *RF Design*, March 1994.

7. S. Liao, *Microwave Circuit Analysis and Amplifier Design*, Prentice-Hall, 1988, pp. 145-149.

8. K. Vennema, "Ultra Low Noise Amplifiers for 900 and 2000 MHz with High IP3," Philips Semiconductors 1998 SC14 Wideband transistors databook.

## About the author

Jarek Lucek is currently working for Philips Semiconductors as a market application engineer. He is responsible for developing applications for LNAs, PA drivers, PAs, mixers and VCOs for subscriber applications. His previous experience includes designing high-power PA stages for 1, 1.5 and 2 GHz feedforward, highly linear infrastructure PAs for Motorola. He also has experience from Decibel Products in designing high-power PA repeaters. He holds a B.S.E.E. from the University of Illinois. He can be reached at 508-337-7927 or by e-mail at [jarek.lucek@sv.sc.philips.com](mailto:jarek.lucek@sv.sc.philips.com).

Robbin Damen works for Philips Semiconductors as a development engineer in Nijmegen, the Netherlands. He is responsible for developing transistors and MMICs for use in personal communications systems. He has designed devices for several applications including LNA, mixer, VCO, buffer and drivers for both analog and digital systems. He is currently designing MMICs for use in PA modules. He can be reached at 31-24-353-4375 or by e-mail at [robbin.damen@nym.sc.philips.com](mailto:robbin.damen@nym.sc.philips.com)

The transistor described in this article is the BFG425W from Philips Semiconductors.



# Keeping you ahead of the race - patent information for the engineering industry.

In an industry that moves as quickly as yours, it is vital for all engineering professionals to monitor technological trends. Patent information is essential in this process as it provides a record of significant commercial developments as they happen.

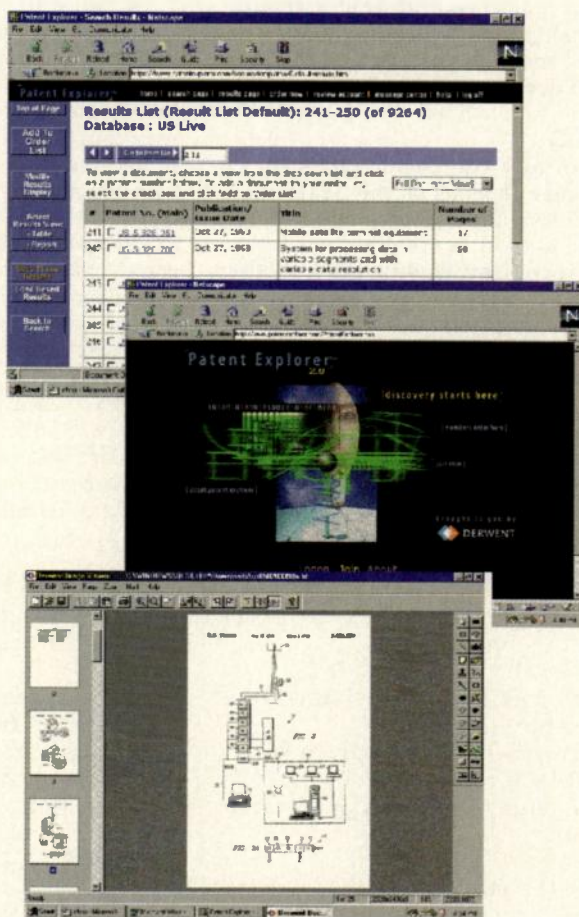
Derwent's Patent Explorer™ ([www.patentexplorer.com](http://www.patentexplorer.com)) brings this critical information to your desktop. Patent Explorer's instant, easy access to patent information helps spark innovation, promote current awareness and maximize R&D dollars instead of duplicating efforts. Patent Explorer is a user-friendly, fully customizable service which provides the precise information you need.

- Search US, European, and World (PCT) patent documents.
- Create automatic profiles to maintain current awareness.
- View full patent specifications with a sophisticated image viewer.
- Download patents directly to your computer.

Sign up online at  
[www.patentexplorer.com](http://www.patentexplorer.com)  
or call

**1-800-DERWENT**

[www.derwent.com/derwent/info.html](http://www.derwent.com/derwent/info.html)  
LONDON • TOKYO • WASHINGTON



## DERWENT

Scientific and Patent Information



## Computer programs that calculate field strength

*Here are two computer programs that can help design antennas.*

By James Eagleson

When designing RF systems for any application, the idea is to get a signal from at least one point to another point without using wires, cables or a waveguide. For wireless communications, the transducer used to convert radio energy into an electromagnetic wave is, of course, an antenna. The function of an antenna is essentially the same whether the application is data transfer across a wireless local-area network (WLAN); voice communication over a two-way radio; cordless, cellular or personal communications service (PCS) phones; radar systems; or any of a variety of low power devices such as radio frequency identification (RFID), radio control, remote access, wireless alarms or remote keyless entry (RKE) systems.

Two programs are helpful in determining antenna design performance. The first is AFCALC. This program allows simple calculation of antenna factor (AF) when antenna gain and frequency are known, or it calculates antenna gain if frequency and AF are known. These are useful when making Federal Communications Commission (FCC), Industry Canada, or European Community / European Telecommunications Standards Institute (EC/ETSI) measurements regarding field strength or when trying to establish actual effective isotropic radiated power (EIRP) or path loss.

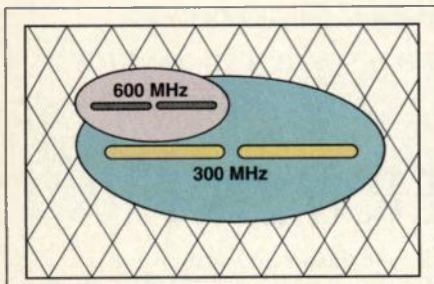


Figure 1. Antenna capture area.

The second program, FSCALC, is really a compilation of several short routines that allow calculation of "path loss," field strength, required power to obtain a given field strength, EIRP and other variations of these calculations. It was developed to quickly evaluate antenna and field strength relationships while designing various low- and medium-power radio communication devices and systems.

### AFCALC

Essentially the power received by an antenna depends on the power density of the signal at the antenna's location, the antenna's orientation relative to the incoming wavefront and the ability of the antenna to capture the power that is available.

Calculating power density at a given distance is basically the same as finding the area of a sphere. At a given radius, "R," a sphere has a given surface area. When using an antenna radiating equally well in all directions (a point source or isotropic radiator), power density at a given distance will be

$$S = \frac{P_o}{4\pi R^2} \quad (1)$$

where

S = Power Density (usually in watts/meter<sup>2</sup>)

P<sub>o</sub> = Power Output (usually in W)

π = 3.1416

R = Radius (r = radius or distance in meters)

Thus, the power density at a given distance is totally independent of frequency because frequency is not an element in this formula.

But antenna size is not independent of frequency. It is related to frequency by the relationship

$$L = \frac{F}{300,000,000} \quad (2)$$

where

L = λ or wavelength (in meters)

F = Frequency (in Hz)

The formula is more conveniently used in MHz, not Hz, and becomes

$$L = \frac{F}{300} \quad (3)$$

In one-millionth of a second (one cycle or wavelength at 1 MHz) a wave will travel 300 meters in air (or space). Thus, at 300 MHz, wavelength calculates to one meter and at 600 MHz, wavelength is only a half meter.

Because a resonant dipole is a half wavelength long, it will be 0.50 meter long at 300 MHz and 0.25 meter long at 600 MHz. (The effect of antenna construction on its length will be ignored for simplicity.) The electrically active area around the antenna (or "capture area") will be shaped somewhat like Figure 1 so that the area (length × width) of the 300 MHz antenna will be four times (2<sup>2</sup>) that of the 600 MHz antenna. AF takes this effect into account.

AF can be calculated by

$$AF \text{ (dB)} = 20 \log(F) - G - 29.78 \quad (4)$$

where

F = frequency (in MHz)

K = 29.78 (a correction factor)

AFCALC uses this formula to either calculate AF from antenna gain and frequency or to calculate the antenna gain from a given AF and frequency. The first thing it does is to ask which method is to be used.

>>>ANTENNA FACTOR CALCULATOR v1.00<<<

CALCULATE:

1 = Antenna Factor  
2 = Antenna Gain

q = quit

Enter selection . . .

If working in the 300–320 MHz spectrum (often used for Part 15 devices of various kinds), the antenna



# Foresight.



# Hindsight.



**Site Master™**  
lets you see  
potential quality  
problems  
before your  
customers do.

Customers expect perfection. Better preventive maintenance is the way to deliver it. That's why there's Site Master.

Site Master makes sure small problems don't turn into big ones. It records antenna system signa-

ture characteristics and stores them for comparison over time. Site Master even works in the presence of live site interference. And thanks to Frequency Domain Reflectometry, potential problems can be pinpointed and repaired,

saving time and money. That's what preventive maintenance is all about.

But seeing is believing. For information or to set up a demonstration, call 1-800-ANRITSU today.



**Site Master**

## Anritsu

**One world. One name. Anritsu.**

©1997 Anritsu Company. Site Master is a trademark of Anritsu Company. Sales Offices: United States: 1-800-ANRITSU, Canada: (613)828-4090, Europe: 44(0)15821433200, Japan: 81(0)33446-1111, Asia-Pacific: 65-2822400, South America: 55(21)286-9141, <http://www.global.anritsu.com>

INFOCARD 35





factor for a resonant dipole would be found by entering its gain and frequency.

Antenna Gain (dBi) = 2.15 <Enter  
Antenna Gain Ratio = 1.64  
Frequency (MHz) = 315 <Enter  
Antenna Factor = 18.04 dB

In this example, the theoretical 2.15 dBi gain of a dipole over an isotropic radiator is used. This assumes a perfect match and 100% efficiency for the antenna even though this often is not the case in the real world. Most of the time, the error is small for a test dipole.

### So why know the AF?

When using a spectrum analyzer to determine field strength, path loss or antenna gain, the AF needs to be measured, known or calculated for each antenna in the test setup. It is fairly easy to determine the exact path loss between two antennas if they are not far apart. This is commonly done to calibrate a three- or 10-meter test site to allow accurate measurement either of intentional or unintentional radiation from electronic equipment.

If the signal source cable is directly connected to the spectrum analyzer or milliwattmeter cable, the variations of all of these test elements are directly accounted for in the resulting measured level,  $P(\text{direct})$ .

If each cable is then connected to its respective antenna and a new measurement is made, the result will provide the loss (or gain) present caused by antenna gain(s) and path loss ( $L_p$ ).  $L_p$  can be found using

$$L_p = PD - PR - AF_1 - AF_2$$

where

PD = Power Direct (directly connected)

PR = Power Received

$AF_1$  = Antenna Factor of Antenna 1

$AF_2$  = Antenna Factor of Antenna 2

This is the heart of techniques spelled out by the American National Standards Institute (ANSI) in document C63.4 for certifying the accuracy of three- and 10-meter sites and other field strength test sites. ANSI C63.4 is also specified by the FCC in Part 15 as an appropriate standard to use when making measurements for certifications and verifications of electronic equipment.

Another formula useful when trying to determine field strength (FS) is

$$FS = 107 + PR + AF \quad (6)$$

where

107 = A Constant derived from the fact that 0 dBm is 107 dB above 1  $\mu\text{V}$  at 50  $\Omega$ .

If a 315 MHz tuned dipole is connected to a spectrum analyzer that receives 0 dBm from a radiating source, FS is

$$FS = 107 + 0 + 18.04 = 125.04 \text{ dB}\mu\text{V/m}$$

However, by the time UHF frequencies go above 300 MHz, there is significant loss in even a fairly short coaxial cable. Because there will be cable loss between the antenna and the analyzer, the field strength must actually be slightly higher than 125.04 dB $\mu\text{V/m}$ . In fact, it will be higher by the amount of loss in the cable.

Modifying the formula to account for cable loss adds a factor, LC, or loss of cable. The simplest thing to do is to add the cable loss as a positive number (absolute value) so the formula becomes

$$FS = 107 + Pr + AF + |LC| \quad (7)$$

If cable loss is -0.76 dB at 315 MHz, FS becomes 0.76 dB higher than the previous calculation

$$FS = 107 + 0 + 18.04 + |-0.76| = 125.8 \text{ dB}\mu\text{V}$$

When working with Part 15 devices, it is common to add a peak-to-average factor as allowed by FCC rules. If, for example, the FCC allows 67 dB $\mu\text{V/m}$  average FS at a distance of three meters, they also allow a duty factor (DF) to be used according to the formula

$$DF(\text{dB}) = 20 \log \left( \frac{T}{100} \right) \quad (8)$$

where

T = Time (milliseconds)

This allowance accounts for the lower potential for interference that short pulses have compared to continuous wave (CW) signals but the FCC sets a limit on this factor of -20 dB. They also require that DF must be calculated for the worst case 100 ms period within any given transmission.

Three examples give the CW, 50% duty and 10% DF

$$T = 100 \text{ ms}; DF = 20 \log (100/100) = 0 \text{ dB}$$

$$T = 50 \text{ ms}; DF = 20 \log (50/100) = -6 \text{ dB}$$

$$T = 10 \text{ ms}; DF = 20 \log (10/100) = -20 \text{ dB}$$

Note that the DF is a negative value. Average power is lower than peak power by the amount shown in the formula. Because a spectrum analyzer actually displays *peak* values adding DF to this will give the average value.

Thus, for the previous examples, average power when the analyzer gives 67 dB $\mu\text{V/m}$  as the peak value are:

$$FS = 67 \text{ dB}\mu\text{V/m} + 0 \text{ dB} = 67 \text{ dB}\mu\text{V/m}$$

$$FS = 67 \text{ dB}\mu\text{V/m} + (-6) = 61 \text{ dB}\mu\text{V/m}$$

$$FS = 67 \text{ dB}\mu\text{V/m} + (-20) = 47 \text{ dB}\mu\text{V/m}$$

Putting it all together produces a final formula

$$FS = 107 + Pr + AF + |LC| + DF \quad (9)$$

A level of 0 dBm and a 10% (10/100) DF of -20 dB gets

$$FS = 107 + 0 + 18.04 + |-0.76| + (-20) = 105.8 \text{ dB}\mu\text{V/m}$$

When trying to meet various regulations for products, the level the analyzer will see at the allowed limit is what needs to be known. This is done by re-arranging the formula

$$PR = FS - (107 + AF + |LC| + DF) \quad (10)$$

Because the previous example was giving a level of 125.8 dB $\mu\text{V/m}$ , it is clearly in violation of the FCC level that was cited earlier. Even if data transfer rate requirements allow use of a 10% DF (-20 dB), the result is still 105.8 dB $\mu\text{V/m}$  average FS—well above the levels allowed at 300 MHz by the FCC.

If requirements for data transfer allow use of a 10% DF and several other restrictions can be tolerated (see Part 15.241e), the full peak-to-average advantage of -20 dB means that to achieve 67 dB $\mu\text{V/m}$  average field strength, as high as 87 dB $\mu\text{V/m}$  peak signal (i.e., 87 dB $\mu\text{V/m}$  peak - 20 dB duty factor = 67 dB $\mu\text{V/m}$  average) can be used.

However, when Equation 10 is used to get PR, it is the wrong answer.

$$Pr = 87 - (107 + 18.04 + 0.76 + (-20))$$

$$= 87 - (105.8) = -18.8 \text{ dBm}$$

This is because the spectrum analyzer reads peak, not average, so ignore DF when back tracking to the expected PR because it is already th

**Co-Located at:**



# RF DESIGN SEMINAR SERIES



**April 28-30, 1999**  
**Las Vegas Convention Center**  
**Las Vegas, Nevada U.S.A.**

In the competitive marketplace of wireless communications, you cannot afford to be left behind. The RF Design Seminar Series, co-located at IWCE, offers technical sessions and tutorials vital to radio frequency design engineers and managers heading to the forefront of merging technologies, applications and strategies. Plan now to take your operation into the future with up-to-the-minute industry developments. Seminar topics include:

**TECHNOLOGY TRACK:**  
(Technology Introduction)

- Wireless Communications for Non-Engineers
- Antenna Array Design
- Measuring the Wireless Transmission Spectrum

**ENGINEERING FUNDAMENTALS TRACK:**  
(Engineering Introduction)

- RF and Wireless Engineering Part 1: Fundamental Concepts
- RF and Wireless Engineering Part 2: Fundamentals of Amplifier Design
- RF and Wireless Engineering Part 3: Amplifier Design

**SUBSYSTEM DESIGN TRACK:**  
(Intermediate)

- Filter Design: Digital & Active Filters
- High-Frequency Filter & Oscillator Design Part 1
- High-Frequency Filter & Oscillator Design Part 2

**DIGITAL APPLICATIONS TRACK:**  
(Intermediate to Advanced)

- Frequency Synthesis & Phase-Locked Loops for RF Applications
- Digital Signal Processing

Get conference details, speaker information, exhibitor updates and housing and travel information when you call **FAX-ON-DEMAND** at 1-800-601-3858 or +1-732-885-6723, or visit us at [www.iwceconexpo.com](http://www.iwceconexpo.com)

Sponsored by:

**RF design**

With support from these other PRIMEDIA Intertec publications: *Satellite Communications, Global Telephony, Telephony, Mobile Radio Technology, Cellular & Mobile International* and *Wireless Review*

Produced and managed by PRIMEDIA Intertec Exhibitions & Conferences, a division of PRIMEDIA Intertec

**Contact IWCE 99 today to receive the details.**

☐ Please send me more information about registering for the RF Design Seminar Series at IWCE '99.

☐ I'm interested in speaking opportunities at IWCE 99 ☐ I'm interested in exhibiting at IWCE 99.

**YES! PLEASE CONTACT ME FOR MORE INFORMATION.**

First Name:

Last Name:

Title:

Company:

Address:

City:  State:

Zip:  Country:

Phone:\*  Fax:\*

E-mail:\*\*

INFO/CARD 50

\*International guests, please include country and city codes.  
\*\*Provide only if you wish to receive news and updates by e-mail.

Source code: AD

**PLEASE RETURN TO: IWCE 99 • PRIMEDIA Intertec Exhibitions & Conferences • 9800 Metcalf Avenue •**



# NEW ERA AMPLIFIERS

**WOW!** DC to 8GHz **\$1<sup>19</sup>**  
(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.<br>(MHz) | Gain<br>(dB) | Max. Power Out<br>(dBm, @ 1dB Comp) | Dynamic Range<br>NF(dB) | IP3(dBm) | @Device<br>Current(mA) | ①Price<br>\$ 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

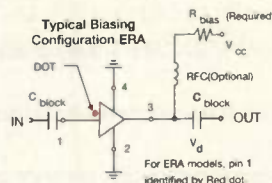
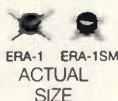
K2-ERA: 10 of each ERA-4, -5 (20 pieces) only \$69.95

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 12c 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 65 INTL 66

CIRCLE READER SERVICE CARD

F 214 Rev F





Only **\$36<sup>95</sup>**  
ea.(qty. 1-49)

## 2W SMA DC to 18GHz ATTENUATORS

How can you buy attenuators that combine world renowned engineering expertise with high quality stainless steel construction, low cost, and off-the-shelf availability? Specify Mini-Circuits fixed attenuators! Built tough to handle 2 watts average with 125 watts peak power, this attenuator series supplies precision accurate 1dB to 40dB attenuation values with high temperature stability and excellent phase linearity in the wide DC to 18GHz band. Call Mini-Circuits and capture this next generation of value for your system integration today!

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

**Buy 1** Customer  
Appreciation Offer  
**Get 1 Free!**

Buy Up To 25 Units Of Each Model At The Regular Price  
**Get An Equal Amount FREE!**  
Offer expires March 31, 1999



| Model    | Attenuation (dB) |           | Length<br>(Inches) |
|----------|------------------|-----------|--------------------|
|          | Nominal          | Accuracy* |                    |
| BW-S1W2  | 1                | ±0.40     | .85                |
| BW-S2W2  | 2                | ±0.40     | .85                |
| BW-S3W2  | 3                | ±0.40     | .85                |
| BW-S4W2  | 4                | ±0.40     | .85                |
| BW-S5W2  | 5                | ±0.40     | .85                |
| BW-S6W2  | 6                | ±0.40     | .85                |
| BW-S7W2  | 7                | ±0.60     | .85                |
| BW-S8W2  | 8                | ±0.60     | .85                |
| BW-S9W2  | 9                | ±0.60     | .85                |
| BW-S10W2 | 10               | ±0.60     | .85                |
| BW-S12W2 | 12               | ±0.60     | .85                |
| BW-S15W2 | 15               | ±0.60     | .99                |
| BW-S20W2 | 20               | ±0.60     | .99                |
| BW-S30W2 | 30               | ±0.85     | .99                |
| BW-S40W2 | 40               | ±0.85     | .99                |

Equipped with SMA male and female connectors.  
.312" across hex flats.

\*At 25°C includes power and frequency variations up to 12.4GHz. Above 12.4GHz add 0.5dB typ. to accuracy.

**ALL VALUES IN STOCK**

**Mini-Circuits®**

US

27

INT'L

28

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](http://WWW.RFGLOBALNET.COM)

**ISO 9001 CERTIFIED**

F 276 Rev B



peak level. The formula should be  

$$Pr = FS - (107 + AF + LC) \quad (11)$$

The level for the example becomes  

$$Pr = 87 - (107 + 18.04 + 0.76)$$

$$= 87 - (118.8) = -38.8 \text{ dBm}$$

Thus, to remain below required FCC levels, the peak signal seen on the spectrum analyzer must remain below -38.8 dBm, which is the correct answer.

## FSCALC

The second program has a number of selections for general use when working with antennas and field strength. FSCALC also uses a menu to select the calculation desired. The same function can be reused by pressing the same letter used to select the function initially or make another selection. Return to the menu by pressing "m" or exit the program by pressing "q."

| FIELD STRENGTH CALCULATOR              |                                 |
|--|---------------------------------|
| SELECT DESIRED FUNCTION:               |                                 |
| a.) PATH LOSS:                         | Given Frequency & Distance      |
| b.) EIRP:                              | Given Po, Lc, Ga                |
| c.) dBuV/m:                            | Given EIRP, Distance            |
| d.) dBuV/m:                            | Given Po, Lc, Ga, Distance      |
| e.) dBuV/m:                            | Given Pr, Lc, AF                |
| f.) Required EIRP:                     | For Desired dBuV/m @ Distance   |
| g.) Required Po:                       | For Desired dBuV/m @ Lc, Ga, DI |
| h.) Required Pr:                       | For Desired dBuV/m @ Lc, Ga     |
| i.) Required Ga:                       | For Desired dBuV/m @ Lc, Pr, DI |
| j.) Antenna Factor:                    | Given Frequency & Gain          |
| Selection <a-j, <m> = menu, <q> = quit |                                 |

Selecting a letter from "a" to "j" selects one of the calculations described below.

• **PATH LOSS**—The following formula is used to calculate "path loss"  

$$Lp = 27.125 - (20 \log(F) + 20 \log(R)) \quad (12)$$

where

$Lp$  = Path Loss (dB)  
 $R$  = radius (distance in meters)  
 $K = 27.125$  (constant assuming MHz and meters)

A sample calculation is:

$$Lp = 27.125 - (20 \log(315) + 20 \log(3)) = -32.4 \text{ dB}$$

The program will trap certain errors such as zero distance or a distance too close to obtain an accurate path loss calculation.

• **EIRP**—The following formula is used to calculate EIRP

$$EIRP = Po + Lc + Ga \quad (13)$$

where

$Po$  = Power Output (dBm)

$Lc$  = Loss of Cable (dB)

$Ga$  = Gain of Antenna (dBi)

• **INPUT UNITS**—The program also allows selection of either Watts or dBm for most calculations. Whichever is selected, the program makes the appropriate conversion(s) first and the final answer is given in both units.

The formula used to convert from Watts to dBm is

$$Po = 10 \log(1000 \times PW) \quad (14)$$

where

$PW$  = Power Output (W)

$K = 1,000$  (Converts W to mW)

The formula used to convert from dBm to Watts is

$$PW = \frac{10^{\frac{EIRP}{10}}}{1000} \quad (15)$$

where

$1,000$  = conversion to W from mW

The answer is given in dBm as well as  $\mu W$ , mW or W, depending on the final value. If an answer is less than 0.001 W, it will be given in  $\mu W$ . If the answer is less than 0.01 W but greater than 1 mW, the answer is given in mW. Otherwise the answer is given in W.

• **FIELD STRENGTH**—Three ways are provided to calculate FS with the answer given in dBuV/m.

1. **dBuV/m given EIRP and distance**—If EIRP and distance are known, Equations 16 and 17 are used

$$VM = \frac{\sqrt{30 \cdot PW}}{DI} \quad (16)$$

where

$VM$  = V/m

$DI$  = distance

Then,

$$DBUV = 20 \log(1 \times 10^6 \cdot VM) \quad (17)$$

where

$DBUV$  = dB above 1  $\mu V$  per meter

$1 \times 10^6 = 1,000,000 \mu V$  per V

2. **dBuV/m given PO, LC, GA and**

**distance**—By combining the EIRP equation with the equations just used FS can be found by filling in the blanks on antenna gain, cable loss, power out and distance.

First EIRP is calculated the same way as was done with Equation 13. The same selection for dBm or W is provided and the same conversion take place as required. This value is then used in Equations 16 and 17 to calculate the answer.

3. **dBuV/m given PR, LC, AF**—This calculation determines FS from milliwattmeter or spectrum analyzer readings. A word of caution, however. Most spectrum analyzers read peak power although most wattmeters read average power so when measuring anything having less than 100% duty cycle, a conversion must be made to get the desired value.

If using an averaging wattmeter, average field strength will be provided by this calculation. To convert to peak field strength, add  $20 \log$  (Period/Pulse Width). In this case, period is the time between pulses (or pulse chains). Pulse width is the width of total "on" time for a single or a chain of pulses in a given period (e.g., 10 pulses of 1 m each would be 10 ms total "on" time regardless of their spacing.) A transmission having one such pulse train for each 100 ms period yields  $20 \log(10) = 20 \text{ dB}$ .

If using a spectrum analyzer, because it reads peak, not average, the calculation provides peak field strength. To find the average field strength subtract  $20 \log$  (Period/Pulse Width).

$$DBUV = 107 + PR + AF - LC \quad (18)$$

where

$DBUV$  = dB above 1  $\mu V$  per meter

$107$  = constant based on 0 dB being 107 dB above 1  $\mu V$

$LC$  = Loss of Cable (in dB...watch the sign, it will be -x dB)

This is the formula used earlier.

• **CALCULATING REQUIREMENTS FOR FS**—The program provides calculations of four required parameters to generate a desired FS.

1. **Required EIRP given dBuV/m, DI**—If desired distance and FS are known, the EIRP needed to generate the desired goal can be calculated using



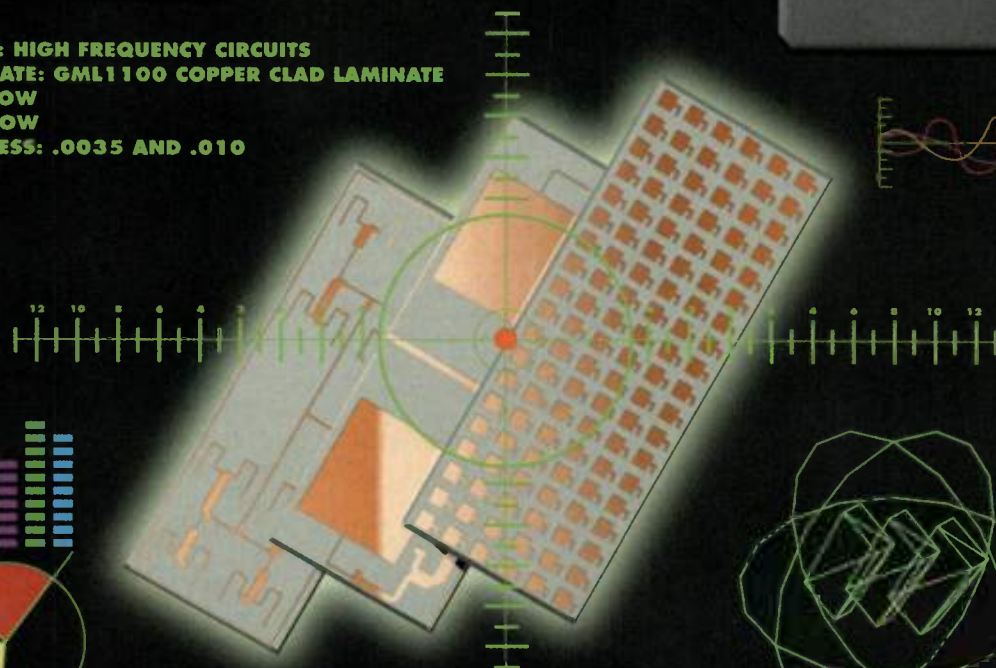
# Introducing GML 1100

## Thin Core Copper Clad Laminate



**ETS** (Economy Targeting System)  
**ONLINE**

**TARGET: HIGH FREQUENCY CIRCUITS**  
**SUBSTRATE: GML1100 COPPER CLAD LAMINATE**  
**COST: LOW**  
**LOSS: LOW**  
**THICKNESS: .0035 AND .010**



**MISSION: Design Low Cost/Low Loss Wireless Circuits**  
**SOLUTION: Copper Clad Laminates From GIL**

- The GML 1000 product line has been extended to include GML 1100 Thin Core. Thicknesses of < .010 inch thick are targeted for multi-layer and thin circuit applications.
- GIL Technologies also offers:
  - GML 1000 Low Loss Laminate in .020, .030, and .060 for high frequency circuits with low loss requirements
  - MC5 Intermediate Loss Laminate in .020, .030 and .060 for high frequency circuits with intermediate loss requirements
  - MC3D Rigid Laminate in .031 and .062 to replace FR-4 for circuits that require a stable Dk

175 Commerce Rd  
Collierville, TN 38017  
[www.gilam.com](http://www.gilam.com)  
Phone: 1-800-537-1306



See us at the Wireless Symposium  
in San Jose Feb. 23 - 25, 1999  
email: [gilam@gilam.com](mailto:gilam@gilam.com)  
FAX: 901-853-8664

INFOCARD 6



$$VM = \frac{10^{\frac{DBUV}{20}}}{1 \times 10^6} \quad (19)$$

$$W = \frac{(DI \cdot VM)^2}{30} \quad (20)$$

$$EIRP = 10 \log(W) + 30 \quad (21)$$

where

30 = constant added to power in dBW to obtain dBm

(Note: 10 log (W) produces dBW or dB above one W)

The answer is provided in both dBm and  $\mu$ W, mW or W and is automatically converted to the units that make the most sense (1 mW instead of 0.001 W, for example).

2. *Required PO given dB $\mu$ V/m, DI*—This calculates EIRP, then determines power output (PO)

$$PO = EIRP - GA - LC \quad (22)$$

where

GA = Gain of Antenna (in dBi)

LC = Loss of Cable (in dB... a minus

value)

3. *Required PR for desired DBUV, GA, LC*—To know the received power in dBm expected from a given cable, antenna and FS, use

$$PR = DBUV - 20 \log(FR) + 77.213 + LC + GA \quad (23)$$

where

PR = Power Received (dBm)

FR = Frequency (MHz)

4. *Required GA given dB $\mu$ V/m, LC, PR*—To determine what antenna gain is needed to provide a desired signal level, pr (in dBm) into a receiver and the FS, cable loss and frequency is known

$$AF = DBUV - (LC + PR + 107) \quad (24)$$

a derivative of an earlier formula.

$$GR = \sqrt{\frac{FR}{30.82 \times 10^{\frac{AF}{20}}}} \quad (25)$$

where

GR = Gain ratio of the antenna

$$GA = 10 \log(GR) \quad (26)$$

(Standard conversion of ratio to dB)

• *AF given GA, FR*—This is done using the equation from AFCALC.

## Conclusion

These formulas and description should provide help for those needing to calculate various antenna, field strength and related relationships. The programs are available for download on the *RF Design* Web site. Although I do not expect to update this set of programs, I will be happy to correspond with anyone with suggestions, additions or corrections. My Web site and e-mail address are included. Both programs run using Windows 3.1 or Windows 95. Be advised that because I am not a programmer by trade, little error correction is present in either of these programs so that incorrect input results in ungraceful exit. Personally, I have not had it hang up the computer but the program does need to be restarted if you type in bad information (Garbage In = Garbage Out). There is some automatic scaling of certain variables ( $\mu$ W, mW or W, for example,) and FSCALC traps things like division by zero or too close distance and so forth.

RF

## Reference

Good references about antennas and FCC measurements include:

1. *A Guide to FCC Equipment Authorizations* by Willmar K. Roberts
2. *Modern Antenna Design* by Thomas Milligan, McGraw Hill 1985
3. ANSI Publication C63.4.
4. FCC OET Bulletin No. 63 October 1993, reprinted February 1996.
5. Various EMC and EMI Web site links via my Web site.

## About the author

James Eagleson is a senior RF engineer at RF Technologies, Brookfield, WI, 53005

More information can be obtained at:

[www.qsl.net/wb6jnn](http://www.qsl.net/wb6jnn)  
[www.execpc.com/~jimeagle](http://www.execpc.com/~jimeagle)  
[www.rftechnologies.com](http://www.rftechnologies.com)  
 e-mail: [jimeagle@execpc.com](mailto:jimeagle@execpc.com)

**Interested  
in trying  
the programs  
mentioned  
in this article?**



Go to the downloadable  
software section of RF  
Design Online at  
**[www.rfdesign.com](http://www.rfdesign.com)**



# TECHNICAL BOOKS

## RF & microwave circuit fundamentals



### Radio Frequency Principles and Applications

**Albert A. Smith, Jr.**

A wealth of accessible, practical information on radio system behavior, wave propagation and system-level considerations.

IE-15 ..... \$70.00



### Introduction to Radio Frequency Design

**Wes Hayward**

A guide for practicing engineers, with special attention to the circuits that make up a radio system, with a receiver as the main example.

AR-7 ..... \$30.00



### RF Design Guide

**Peter Vizmuller**

A design "cookbook" that covers circuit examples with sufficient theoretical background. Includes a software workbook of design examples and equations.

AH-8 ..... \$99.00

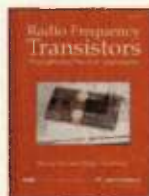


### HF Filter Design and Computer Simulation

**Randall W. Rhea**

An excellent basic design book on LC and distributed filters; for engineers who must build filters with the desired performance.

NP-2 ..... \$59.00



### Radio Frequency Transistors

**Norm Dye and Helge Granberg**

Solid state amplifier design from microwatts to kilowatts, from HF through UHF, is the subject of this book. A concise book based on the authors' many years of experience.

BH-1 ..... \$48.00



### Microwave Transistor Amplifiers

**Guillermo Gonzales**

The classic book on network theory and Smith Chart-based design techniques for amplifiers. Complete coverage of noise, stability, matching and other necessary considerations.

PH-1 ..... \$91.00



### Electronic Applications of the Smith Chart

**Phillip Smith**

The original book by the author of the most powerful RF design tool ever developed. Learn matching and analysis using the Smith Chart.

NP-4 ..... \$59.00



### Oscillator Design and Computer Simulation

**Randall W. Rhea**

A unified approach to oscillator design with many active device types and all the important resonator types: LC, crystal, SAW, etc.

NP-1 ..... \$64.00



### Practical Microwaves

**Thomas S. Laverghetta**

Lessons in the full range of microwave theory in down-to-earth language. Covers materials, components, design methods, test equipment and measurements.



### Radio-Frequency Electronics: Circuits and Applications

**Jon B. Hagen**

A good introduction to radio concepts and circuits. Basic, but with enough technical depth to properly cover many RF circuits.

CU-1 ..... \$53.00



### Microstrip Circuits

**Fred Gardiol**

A valuable overview of high-frequency distributed-element printed circuits. For engineers with interest in microwaves, antennas, and even high-speed digital design.

JW-18 ..... \$90.00



### RF Circuit Design

**Chris Bowick**

Get started with Smith Chart-based low noise amplifier, power amplifier and oscillator design. An excellent tutorial approach to RF circuits, transmission lines and matching techniques.

HS-1 ..... \$25.00

THE POWER OF INFORMATION

www.noblepub.com



### Crestone Technical Books

Division of Noble Publishing Corp.

4772 Stone Drive

Tucker, GA 30084

Tel: 770-908-2320

Fax: 770-939-0157

INFOCARD 34

Order today by phone, fax or on the web, using your VISA, Mastercard or American Express!



# SAR advances conquer data acquisition challenges

*Major developments in software, hardware, signal, imaging and data processing technology have enabled SAR to assume increasing roles in a variety of applications.*

By Ernest Worthman,  
Contributing Editor

The science of radar-based data acquisition, both automated and manned, has been significantly enhanced by the technological developments of the late 20th century. One of the major recipients of this technological revolution is synthetic aperture radar (SAR).

Although some SAR has existed since the late 1970s, it is really coming of age in the 1990s because of rapidly developing computer processing capabilities. SAR can address many of the problems that have plagued optical sensing and real aperture radar. And SAR is impervious to all but the most extreme conditions that obstruct both optical and real radar from acquiring accurate data.

Digital signal processors (DSPs), analog-to-digital converters (ADCs), image processing software and high-speed computer data analysis all contribute to SAR's ever increasing share of the image and data acquisition market. SAR has given markets such as geology, meteorology and ecology, as well as the military, the ability to acquire precise and detailed data, with unprecedented accuracy, from aircraft and satellites.

It is difficult to assess the impact that SAR will have on these and other data acquisition markets over the next few years. SAR is still relatively expensive to use because it is mainly aircraft- or satellite-based. And, because SAR is computer synthesized, it requires high-power processing and analysis hardware to process the image. Just over the last few years, the cost of the electronics required for SAR processing has become more affordable. However, one can rea-

sonably expect to see SAR become economically feasible for smaller scale applications as we turn the century. Currently, many SAR projects are implemented by the military, government or government-affiliated entities such as the jet propulsion laboratory (JPL) and Sandia Labs.

Two issues will have a significant effect upon SAR implementation over the next 10 years:

1. The cost of hardware is expected to continue to decline.

2. Developments in processing power are making logarithmic leaps in capability.

Bearing these in mind, it is reasonable to assume SAR will become a significant source for data acquisition and monitoring in the future.

## Technology and theory of operation

Over the years, radar has been refined from its invention in 1935 by Si-

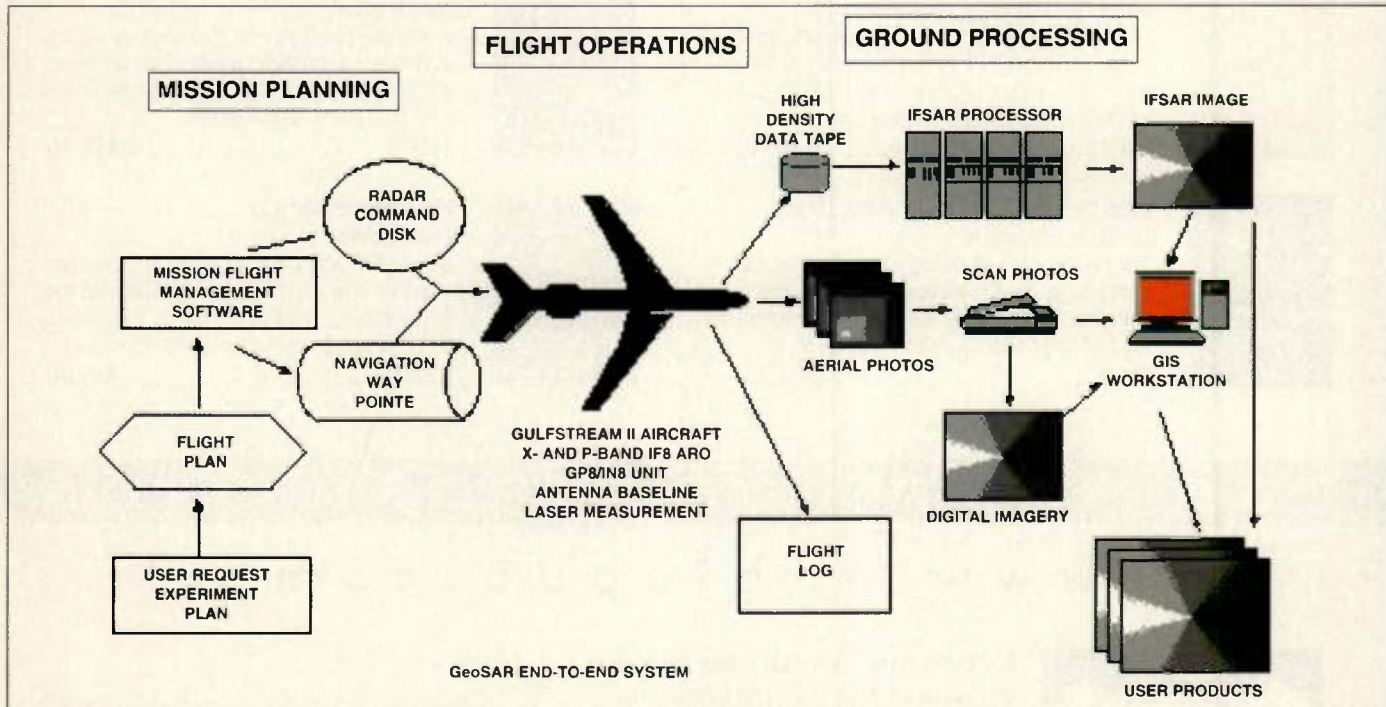


Figure 1. A GeoSAR schematic (courtesy of NASA and JPL).



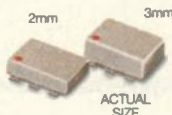
# INNOVATIVE MIXERS

**.smaller size .better performance .lower cost**

**1 to 4200MHz from \$2.95**  
(10-49)



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 \$2.95 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:

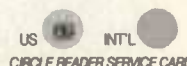
| Model    | Height (mm) | Freq. (MHz) | LO (dBm) | Conv. Loss Midband (dB) | L-R Isol. Bandwidth (dB) | IP3 (dBm) @ Midband | Price (\$ea.) Qty. 10-49 |
|----------|-------------|-------------|----------|-------------------------|--------------------------|---------------------|--------------------------|
| ADE-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-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-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-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-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 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](http://WWW.RFGLOBALNET.COM)

**ISO 9001 CERTIFIED**

F267 Rev.E



Robert Watson-Watt and its early WWII 100+ MHz frequency band, to today's large aperture radar (LAR), Doppler-effect radar and SAR at as much as 40 GHz.

Essentially, radar is the science (and art) of measuring the distance of one object in reference to another. Radar

uses the time delay that occurs when a pulse of energy is transmitted to the time it is received back as a reflection of the object.

A far cry from the past's relatively low frequency and short (a few thousand meters at best) range, today's SAR can be implemented at a number of frequencies

and can range thousand of kilometers. The wavelengths around the center frequencies of the most popular SAR microwave bands are K~ 0.3-1 cm; X~ 1-1.5 cm; C~ 5-6 cm; L~ 24-25 cm; and P~ 65-75 cm. The fundamental technology is the same, regardless of frequencies.

SAR differs from real aperture radar (RAR) and LAR by using the Doppler shift effect. Comparing the Doppler shifted frequencies (because of the movement of the emissions source) to a reference frequency allows many returned signals to be "focused" on a single point as the real aperture moves through a series of positions along the projected track.

SAR uses narrower pulses compared to conventional radar. This particular technique increases the azimuth resolution and is commonly called azimuth compression and virtualizes the aperture to appear larger than it really is.

The way that SAR synthesizes an antenna aperture, using the Doppler effect, is by first modulating a chirp modulation of the received pulse, then taking the reversed characteristics of the chirp modulation and applying it to a matched filter scheme. This effectively increases the length of the antenna that is imaging that particular point and is commonly called *synthesizing the antenna's size or aperture*.

Because this increases the azimuth resolution for the same technique adopted for range direction in RAR, it reduces the physical antenna size while maintaining the precision of LAR systems.

But without the high-tech, high-speed digital processing hardware, developing SAR images would be painstakingly time consuming because SAR processing requires that the variation in Doppler frequency for each point is correctly matched to image. This requires precise knowledge of the relative motion between the platform and the imaged objects and requires tremendous mathematical analysis.

SAR's moving platforms are, as previously stated, almost exclusively air plane or satellite-based (I say *almost* because there is also some implementation with moving ground-based vehicles). SAR image areas can be as small as a few meters, or as large as several hundred km.

Typical pulse widths are 10-50  $\mu$ s and typical bandwidths are 10-200 MHz around the center frequencies.

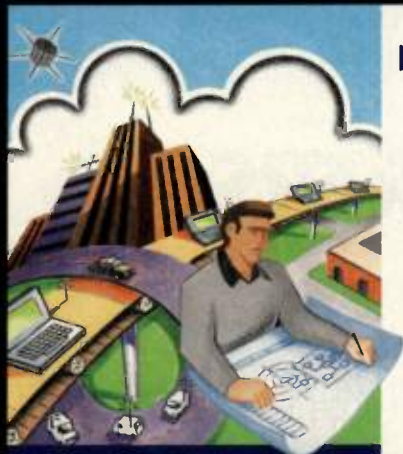
Because SAR uses wavelength be-

YOU NEED AN ANTENNA.

YOU NEED MAXRAD.

ENGINEERING • PROTOTYPING • MANUFACTURING

Contact us about our complete line of 2.4 GHz ISM wireless data antennas.



**A**t MAXRAD, we always have available a full line of high-quality antennas capable of fitting a wide variety of RF applications. But when your project calls for a custom antenna, we excel at working closely with you to build the right product, on time, on budget and on target with the specifications you require. Big job or small, we will do what it takes to satisfy your antenna needs.

#### ▶ ANTENNAS BUILT TO YOUR SPECS

Our expert staff is equipped to engineer and manufacture custom antennas and accessories to your specifications. We utilize the latest simulation and modeling techniques to quickly prototype and develop your antenna products. We pride ourselves on getting the job done right the first time as an extension of your team.

#### Consider us your antenna experts.

- Low Band
- VHF
- UHF
- 800/900 MHz
- I.S.M. Bands
- Yagis
- Omni-Directional
- Mobile
- Portable



**MAXRAD**  
STATE OF THE ART ANTENNAS

CALL (800)323-9122

[www.maxrad.com](http://www.maxrad.com)



# A Spectrum Analyzer Worth Looking Into.



**The 2390A Series:  
The most spectrum  
analyzer you can  
get for the money.**

If performance, at a price you can afford, are factors you look for in a spectrum analyzer, then consider the IFR 2390A series.

Starting with technology to meet a broad range of applications, we then added an impressive set of standard features, including: a wide 30 MHz resolution filter with fast sweep speed and pre-triggering for pulsed signal analysis, resolution bandwidths down to 3 Hz; built-in AM/FM receivers; and a +30 to -135 dBm measurement range.

And with a 1 Hz resolution frequency counter, digital oscilloscope and FFT analyzer, large internal storage capacity, plus

an external mixer capability that increases the frequency range to 300 GHz, it's easy to see why the 2390A series leads the industry in performance and value.

Choose from three models, with frequency ranges from 9 kHz to 2.9 GHz, 22 GHz & 26.5 GHz, which feature options that include quasi-peak and CISPR filters for pre-compliance testing, and a built-in 2.9 GHz tracking generator.

So, if you are looking into a spectrum analyzer that combines performance with value, contact your local IFR office, or visit our web site.



For more information call your local IFR office - USA Tel +1 (316) 522-4981 Toll Free 1-800-835-2352 (U.S. Only) Fax +1 (316) 522-1360

Latin America Tel +1 (817) 430-5842 Fax +1 (817) 430-5843 UK Tel +44 1438 742200 Free phone (UK only) 0800 282388 Fax +44 1438 727601

France Tel +33 1 60 79 96 00 Fax +33 1 60 77 69 22 Benelux Tel +31 13 463 95 40 Fax +31 13 463 96 63 Germany Tel +49 81 31 2926-0 Fax +49 81 31 2926-130

Spain Tel +34 1 640 11 34 Fax +34 1 640 06 40 Hong Kong Tel +852 2-832-7988 Fax +852 2-834-5364 Singapore Tel +65 281 8885 Fax +65 281 0113

E-mail: [info@ifrsys.com](mailto:info@ifrsys.com)

[www.ifrinternational.com](http://www.ifrinternational.com)

INFOCARD 45



tween 1 cm and 1 meter, it sees through clouds and smoke, as well as works without external illumination (it is often referred to as self-illuminating imaging), such as what is required by optical data acquisition systems. Still, SAR remains a basic radar technology, however; so in spite of its precise capability, it uses con-

ventional radar techniques, such as side-looking sensors, and acquires its data through standard radar range measurement and resolution techniques.

#### A bit more detail

If we take a cursory look at the theory behind SAR, we find that funda-

mentally, SAR produces a 2-D image.

One image dimension is along the track, commonly called *range*. Because SAR uses narrow pulses as opposed to conventional radar, SAR yields fine range resolutions. Although this has a significant impact upon resolution, this is not the unique parameter of SAR that yields the greatest benefit.

The parameter largely responsible for SAR's precision is the azimuth, the dimension on the perpendicular axis to range. The relationship between this axis and the antenna parameter is quite simple—the finer the azimuth resolution, the larger the antenna needs to be. Thus, to obtain a fine enough resolution to obtain highly detailed data for such applications as environmental monitoring, earth resource mapping and military reconnaissance, a large antenna is needed to provide a sharp bearing. Unfortunately, such antennas are impractical for airborne and space vehicles.

However, synthetic aperture engineering is a relatively complicated process of analyzing received signal and phases from moving objects with a small antenna. What is really being done is mathematically converting the effects of a larger antenna, i.e. synthesizing a smaller aperture length.

The azimuth resolution can be derived using a formula. By applying the formula, the resolution of the azimuth direction ends up being  $\frac{1}{2}$  of the real aperture radar. However, it is not that simple.

As with all virtualization and synthesis (as well as real data acquisition), error is introduced. With SAR data must be enhanced and corrected based upon the extrapolations involved. Remember that the aperture is enhanced mathematically, thus, a lot of closer attention must be paid to ensure the data interpolation is accurate. Unfortunately, a full discussion of the mathematics and error analysis is beyond the scope of this article. However, major issues such as errors introduced by azimuth range compression techniques, velocity effects upon the Doppler effect, and the fact that correcting for the synthetic aperture length is more challenging at lower altitudes must all be addressed. Essentially, SAR satellites that gather extremely detailed data must be very high, and airplane-based SAR requires tremendously accurate interpolation, as well as having lower detail capability.

However, even with these issues:

## introducing new low cost trimmers

### MODEL 9450

We Redesigned Our 9402 Capacitor  
Into A Low-Cost Version

- Innovative Design
- High Quality
- Excellent Performance

All at a very cost-effective price.

(10,000 Minimum Order)



### FREE DEMO KIT!

Our new trimming tool makes trimming 3-5 times faster! Just send us your application and we'll send you a free Demo Kit.

*Johanson*

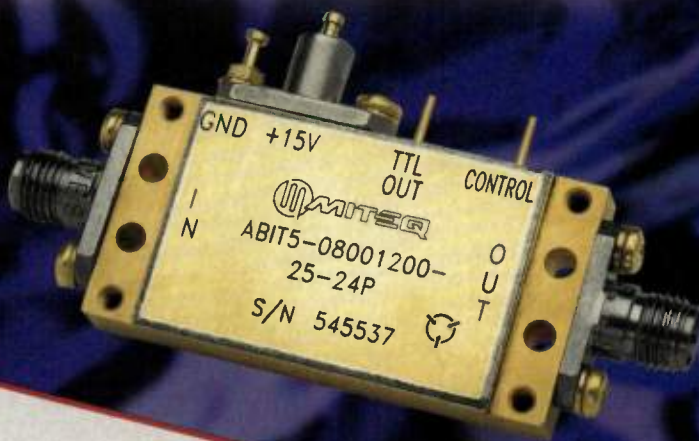
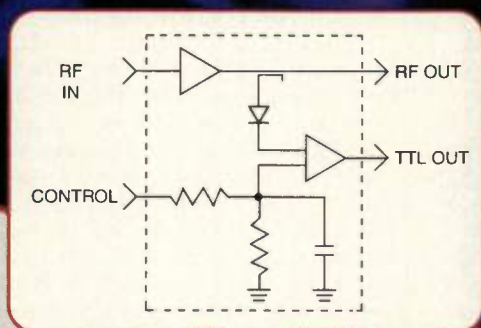
Tuned To Your Needs

Johanson Manufacturing Corporation  
Rockaway Valley Road Boonton, New Jersey 07005  
Tel 973 • 334 • 2676 Fax 973 • 334 • 0967

[www.johansonmfg.com](http://www.johansonmfg.com)



# Built-In Test Detector AMPLIFIERS



## Features

- External threshold control via voltage divider or external power supply
- Independent TTL output
- Up to 1/2 Watt CW power output
- Hermetically sealed Kovar chassis capable of meeting rigorous military environments
- Available with various electrical parameters, alternate connectors, and detector output (no RF)



## Typical Model Performance

| Model number           | ABIT5 08001200 25 24P                             | ABIT5-04000800-25-25P                             |
|------------------------|---|---|
| Frequency range        | 12 GHz  | 4-8 GHz   |
| Gain                   | 30 dB minimum                                     | 30 dB minimum                                     |
| Noise figure           | 2.5 dB maximum                                    | 2.5 dB maximum                                    |
| 1 dB gain compression  | +24 dBm minimum                                   | +25 dBm minimum                                   |
| BIT detector threshold | <+20 dBm *  | <+20 dBm *  |
| BIT detection format   | TTL single ended                                  | TTL single ended                                  |
| Output power           | Logic 1 = +3.7±1.3 VDC<br>Logic 0 = +0.4 ±0.4 VDC | Logic 1 = +3.7±1.3 VDC<br>Logic 0 = +0.4 ±0.4 VDC |

\*Other levels available via adjustment to the threshold control.

For further information, please contact Naseer Shaikh at (516) 439-9296  
or e-mail [nshaikh@miteq.com](mailto:nshaikh@miteq.com).



100 Davids Drive, Hauppauge, NY 11788  
TEL.: (516) 436-7400 • FAX: (516) 951-4338/436-7430  
[www.miteq.com](http://www.miteq.com)



SAR still offer significant resolution advantages over other types of radar and overcomes the visual limitations that optical data collection has.

### The next step—Inferometry

Earlier, I mentioned that SAR is, fundamentally, a 2-D image acquisition

process. However, there is a great deal of interest in applying Interferometry to SAR. Using Interferometry, SAR is capable of acquiring 3-D images.

Essentially, Interferometric Synthetic Aperture Radar is SAR collecting data (echoes) from the same target using two spatially-separated receiving antennas.

(Does the term diversity come to mind? Because the diversity signal is slightly out of phase, two separate images can be produced. From these images, the "interferogram" can be developed and used to determine terrain characteristics. Elementally, in SAR, the radar uses interference phenomena between the reference wave and the Doppler-shifted wave to measure indices of refraction, wave lengths and wave velocities. This technique can measure small distances and thicknesses of the imaging area.

Through a technique called phase unwrapping (which requires supercomputing capability), the two images can be integrated and an A/B analysis can be used to differentiate and resolve height, density, and other 3-D parameters. After resolution, a 3-D DEM (Digital Elevation Model) digital terrain model can be built. To oversimplify, IFSAR is, basically, SAR with a second antenna—similar to using binoculars over a telescope.

Another interesting SAR technique along the lines of multidimensional modeling is *multipolarization SAR*. Depending on the SAR configuration, transmitted pulses can be either horizontal or vertical and received in the same domain.

If you analyze all of the combinations of these polarized pulses, you end up with four possible combinations: horizontal transmit/receive (HH); horizontal transmit/vertical receive (HV); vertical transmit/receive (VV); and vertical transmit/horizontal receive (VH). As SAR becomes more complex, and with a third frequency used, polarization can be used to give the image yet another axis to integrate. Additionally, some SARs can also measure phase differences in the returned multipolar echoes.

### LightSAR—lightweight, accurate and cost-effective

SAR systems, in spite of the declining equipment costs and muscle-up computing power, are still expensive to build and implement. For this reason, an accurate, yet economical alternative is being researched.

Lightweight Synthetic Aperture Radar (LightSAR) is a high-technology, low-cost Earth-imaging SAR designed to provide scientific research on a number of topical issues. Some of these objectives include seismic and volcanic deformation mapping, vector ice sheet and glacier velocity mapping, topographic mapping and surface characterization. Essential

## EMI/RFI Filters for wireless & microwave designs

You can improve the EMC design and implementation of your wireless product programs by choosing the industry's most responsive team... Spectrum Control and Richardson Electronics. Spectrum Control's wide range of filtering products will help you eliminate EMI/RFI from your designs and Richardson will ensure you get these products when you need them.



#### • Low Pass EMI/RFI Filters

Wide range of discrete filters and new wireless filters such as the Spec-mini press, microcircuit packages and spanner filters.

#### • Filtered Arrays

Filter plates and filtered terminal blocks simplify installation and reduce costs.

#### • Filtered Connectors

Complete line of filtered D-sub connectors in range of footprints, configurations, shell sizes and filter types.

#### • SPEC POWER Products

Filter EMI where the power source enters the system with single line filters, power arrays, power entry filters, multisection filters and custom assemblies.

#### • Ceramic Capacitors

New line of ceramic capacitors include single layer chips, temperature compensating (TC), high voltage, switch-mode power supply, ultra Q and ultra high Q, and specialty capacitors.

Give us a call to find out how the partnership of Spectrum Control and Richardson Electronics can help improve your wireless & microwave programs.



SPECTRUM CONTROL INC.

A Control Products and Systems Company

6000 West Ridge Rd. • Erie, PA 16506  
Phone: 814-835-4000 • Fax: 814-835-9000  
Web site: [www.spectrumcontrol.com](http://www.spectrumcontrol.com)

More than 60 locations worldwide to serve you. Toll Free US/Canada: 1-800-RF POWER or 1-800-737-8637, Argentina: +54 (327) 55750, Australia: Baywater +61 (3) 9738 0733, Castle Hill +61 (2) 9694 7288, Brazil: Sao Paulo +55 (11) 820-6199, Canada: (905) 795-6300, France: +33.1.55.06.00.30, Germany: Puchheim +49 (89) 890 214-0, Indonesia: +62 (21) 912-0727, Italy: Agrate Brianza (MI) +39 (039) 553 145, Rome +39 (06) 41.73.37.51, Sesto Fiorentino (FI) +39 (055) 42.08.31, Japan: Osaka +81 (6) 314-5557, Tokyo +81 (3) 5215-1577, Korea: +82 2 539-4731, Mexico: +52 (5) 548-0015, Singapore: +65 744-2128, Spain: Barcelona +34 (93) 415 83 03, Madrid +34 (91) 528-3700, Sweden: +46 8 780 4680, Taiwan: +886 (2) 86915238, Thailand: +66 (2) 749-4402, The Netherlands: +31 20 448 7070, United Kingdom: Lincoln +44 (01522) 342631, Slough +44 (01753) 733010, Vietnam: +84 8.8428775, Corporate Headquarters: LaFox, IL (630) 208-2200, Fax (630) 208-2550. ©1998 Richardson Electronics, Ltd. MK9248

ISO9002 Registered • 1-800-RF POWER • [www.rfpower.net.com](http://www.rfpower.net.com) • [ssc@rell.com](mailto:ssc@rell.com)





# {NO ASSEMBLY REQUIRED}

GET TO MARKET FASTER AND MORE COST-EFFECTIVELY WITH  
QUIKPAC™ HIGH-POWER RF AMPLIFIER MODULES.

QuikPAC™ modules deliver repeatable, predictable performance right out of the box. So, instead of designing and assembling RF power and IMD correction stages from scratch, you can save time and money using our cost-effective, building block approach. And the talent normally assigned to these projects can be reallocated to other areas of amplifier development.

RF designers will love QuikPAC's flexible, open architecture. It gives them countless design possibilities. Furthermore, QuikPAC's 50-Ohm interfaces and single-polarity operation let you plug them into your designs like building blocks.

Your customers will love QuikPAC's LDMOS technology, which delivers outstanding performance in the 400- to 2,500-MHz frequency range. And like all SMDs, QuikPACs are very manufacturing-friendly, allowing you to automate production, slash lead times and lower the cost of assembly even further.

So, while you're waiting for your next RF amplifier to be designed, assembled and aligned, find out more about Xemod QuikPAC "no assembly required" high-power RF amplifier components. For more information, call 1-408-733-7229 or visit [www.xemod.com](http://www.xemod.com).





these are objectives that can be met with repeat-pass Interferometry with single and dual (HH/VV) polarization—an objective that can generally be met with a single-frequency L-Band system.

Because many images don't need the crème de la crème SAR systems to acquire adequate data, LightSAR looks

promising. Such a system is a compromise of the multifrequency, multipolarization high-end systems with adequate imaging ability and a reasonable cost to deploy.

#### It all comes together in GeoSAR

Perhaps one of the most promising



Figure 2. A SAR image taken from the ERS-Satellite (photo courtesy of NASA).



Figure 3. A non-SAR image (photo courtesy of NASA).

projects under current development in GeoSAR. This project is designed to generate high-resolution 3-D maps of the geology of California.

The system is a dual-frequency Interferometric system capable of mapping above, through and below the vegetation layer. Such data is important in seeing how the earth's geography has formed under the vegetation layer. It will also be of immeasurable value in providing data for geologic seismic analysis and hazard identification.

The GeoSAR system has impressive technical specification. It will use both X- and P-Band frequencies, which will allow DEMs with resolution as low as 0.5 meter.

#### And the direction is...

Although SAR is not entirely 1990s technology, the technological developments of the 1990s have played a large part in enabling SAR development and deployment. GeoSAR, for example, will not be operational until at least early 2000.

Other SAR deployments both from satellite and aircraft will see increased usage as we turn the century. Continued maturation of processing software and digital conversion hardware will render mountains of acquired data manageable. This will provide extremely accurate and timely information for disaster management and research, terrain resource mapping and planning, ecological and environmental assessment, search and rescue, security and military intelligence, just to name a few.

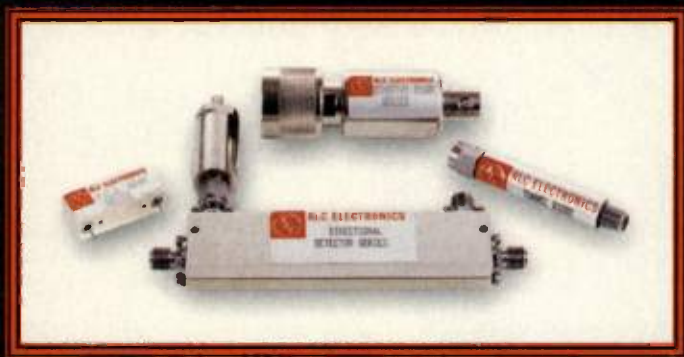
The applications seem endless, and the technological opportunities should follow.

RF

Presenting...

# Detectors

SCHOTTKY & TUNNEL



## RLC Broadband Detectors, Customized to Your Needs:

- Frequency Range of 10 MHz to 40 GHz
- Excellent Stability Over Temperature
  - A High Degree of Sensitivity
  - Excellent Flatness
  - Low Video Impedance
- Can Be Supplied with Couplers and DC Blocks
  - N, BNC, SMA and TNC Connectors
- Can Be Optimized for Your Power Range in Terms of Linearity and Output

Call, fax or e-mail your requirements.



## RLC ELECTRONICS, INC.

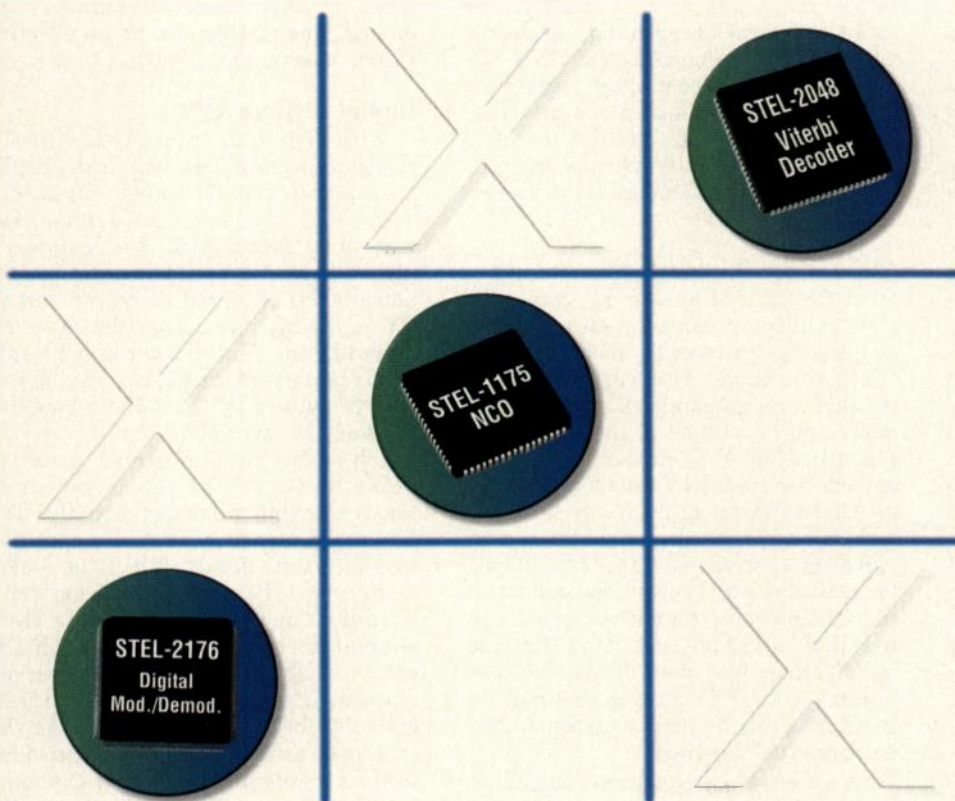
83 Radio Circle, Mount Kisco, New York 10549 • Telephone: 914-241-1334 • Fax: 914-241-1753  
e-mail: [sales@rlcelectronics.com](mailto:sales@rlcelectronics.com) • [www.rlcelectronics.com](http://www.rlcelectronics.com)

RLC is your complete Microwave Component source...

Switches, Filters, Power Dividers, Couplers, Terminations, Attenuators, DC Blocks, Bias Tees & Detectors.



HERE'S A *winning*  
*combination* FOR ALL YOUR  
*digital* COMMUNICATIONS *designs*



Stanford Telecom offers a broad selection of ASIC and board-level assemblies for applications including PSK, QAM or CDMA modulation and demodulation, digital down conversion, data transceivers, forward error correction, adaptive equalization and direct digital frequency synthesis. Product highlights are shown below.

*Contact us for more information, including a copy of our new Short Form catalog.*

**PSK, QAM or CDMA Modulator/Demodulator Products**

- Burst or continuous applications
- Data rates from 19.2 Kbps up to 8 Mbps
- Performance at less than  $1/2$  dB from theory
- CDMA transceiver for telemetry, wireless Internet access, vehicle positioning
- Single ASIC transceiver for MCNS cable modems

**Direct Digital Synthesis (DDS) Products**

- Numerically Controlled Oscillator (NCO) ASICs for FM, PM or chirp generation
- CMOS and GaAs technologies - up to 800 MHz clock rates
- Separate or selectable sine and/or cosine outputs
- Up to 48-bit frequency resolution (STEL-1173)
- Single chip NCO + DAC

**Forward Error Correction (FEC) ASICs**

- Convolutional encoding / Viterbi decoding
- Data rates to 45 Mbps
- Selectable coding rates of  $1/2$  through  $7/8$
- Scrambling and descrambling based on industry standard polynomials
- New 2 Mbps decoder starting at \$20 flat pricing

**STANFORD  
TELECOM**

480 Java Drive • Sunnyvale, CA 94089  
Tel: (408) 745-2660 • Fax: (408) 541-9030  
e-mail: [tpg.marketing@stelhq.com](mailto:tpg.marketing@stelhq.com)  
Internet: [www.stanfordtelecom.com](http://www.stanfordtelecom.com)



## Measuring multipath in the wireless cable environment

*Understanding techniques to measure multipath can get your system off to a quick start.*

By Mark Kolber  
and Marc Ryba

**M**ultipath is one of the most significant transmission impairments in the wireless cable environment. Multipath occurs when two or more propagation paths exist between the transmitter and receiving sites. The transmitted signal may arrive at the receiver from multiple paths exhibiting various amounts of delay and attenuation. The indirect paths may result from reflections from man-made or natural structures, repeaters or the use of multiple transmitters.

Multipath on analog National Television System Committee (NTSC) transmitted signals results in a ghost-like image horizontally displaced from the main image by an amount proportional to the reflected signal's delay. Multipath degradation is not visible in a digitally demodulated picture until the "threshold" of the digital signal is reached, resulting in a loss of demodulator lock.

With digital transmission, uncorrected multipath introduces intersymbol interference (ISI) that results in a closure of the eye pattern, making the signal more susceptible to decoding errors. Use of an adaptive equalizer in the receiver can minimize the effects of multipath and improve system perfor-

mance. Multipath outside the time range of the demodulator's adaptive equalizer is perceived as additional noise and causes degradation to the received signal-to-noise ratio (SNR). In severe cases, uncorrected multipath causes a total loss of demodulation. However, there are different methods to recognize and quantify multipath in a digital transmission system to correct such situations.

### Measuring multipath with analog

In the case of analog TV transmission, multipath can be seen on-screen as ghosting, horizontally displaced from the main image. This can be used to provide a rough gauge of both the time delay and amplitude of the multipath. For an NTSC-M system, the duration of each horizontal TV line is about 63.5  $\mu$ s. Of this, about 11  $\mu$ s are used for the horizontal synchronization and blanking interval, leaving about 52.5  $\mu$ s for active video. Typical over-scan will reduce this value somewhat, so we can round off to 50  $\mu$ s. Assuming that the multipath is less than 50  $\mu$ s, the percentage of the TV screen in that a ghost is delayed can be used to estimate the multipath's delay time.

$$\text{Delay} = \% \text{ of TV screen displaces} \times 50 \mu\text{s}$$

For example, if a ghost is displaced 25% from the main signal, the multipath delay is approximately 12.5  $\mu$ s.

The amplitude of the multipath can also be determined by comparing the ghost's amplitude to the original object. This can be measured using a video waveform monitor, but it is difficult to do using active video. A waveform monitor with the appropriate triggering to view only the vertical integral test signals (VITSs) would make the job easier. The magnitude of the multipath can be determined as:

$$20 \cdot \log \left( \frac{\% \text{ of amplitude}}{100} \right)$$

For example, if multipath creates a ghost that is 25% the amplitude of the

original waveform, it is -12 dBc, or 12 dB below the desired signal. If one or more of the transmitted channels are analog, this method can be an effective way to measure multipath.

### Digital SNR vs. C/N

With digital TV transmission, uncorrected multipath does not create visible ghosting on the TV screen but rather degrades the demodulated noise margin by creating ISI. For example, a digital signal may have a carrier-to-noise (C/N) of 35 dB or better, but at the same time the SNR estimate as reported by the demodulator may be only 27 dB because of multipath. This difference is caused by the different definitions of C/N and SNR.

C/N is the ratio of carrier power to noise power. Here, noise power is taken to mean random thermal noise. C/N measurements must also specify a measurement bandwidth. It is convenient to use the symbol rate bandwidth because the measured C/N is then equivalent to  $E_s/N_0$  (the ratio of the observed signal density to the observed noise density).  $E_s/N_0$  and C/N in 5.05 MHz can be measured directly on the spectrum analyzer with no bandwidth factor corrections needed. For example, Figure 1 shows a 64-quadrature amplitude modulation (QAM) signal with  $E_s/N_0 = 34.3$  dB and equivalently with the  $C/N|_{5.05 \text{ MHz}} = 34.3$  dB. To ensure that the measurement is accurate, the spectrum analyzer noise floor must be at least 10 dB below the system noise floor.

SNR or modulation error ratio (MER) as reported by the QAM demodulator, on the other hand, is a measure of the spread of the demodulated constellation points (also known as the constellation cluster variance) expressed as a noise ratio. Here, the SNR estimate includes any impairment that causes a spreading of the received constellation points from the ideal reference constellation points. Phase noise, ISI caused by multipath, as well as

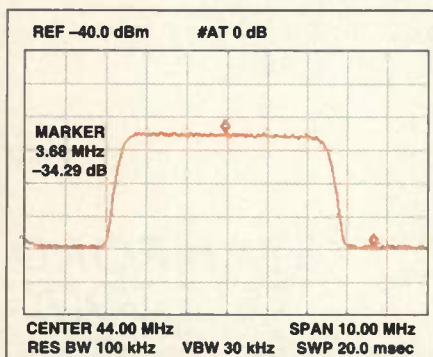
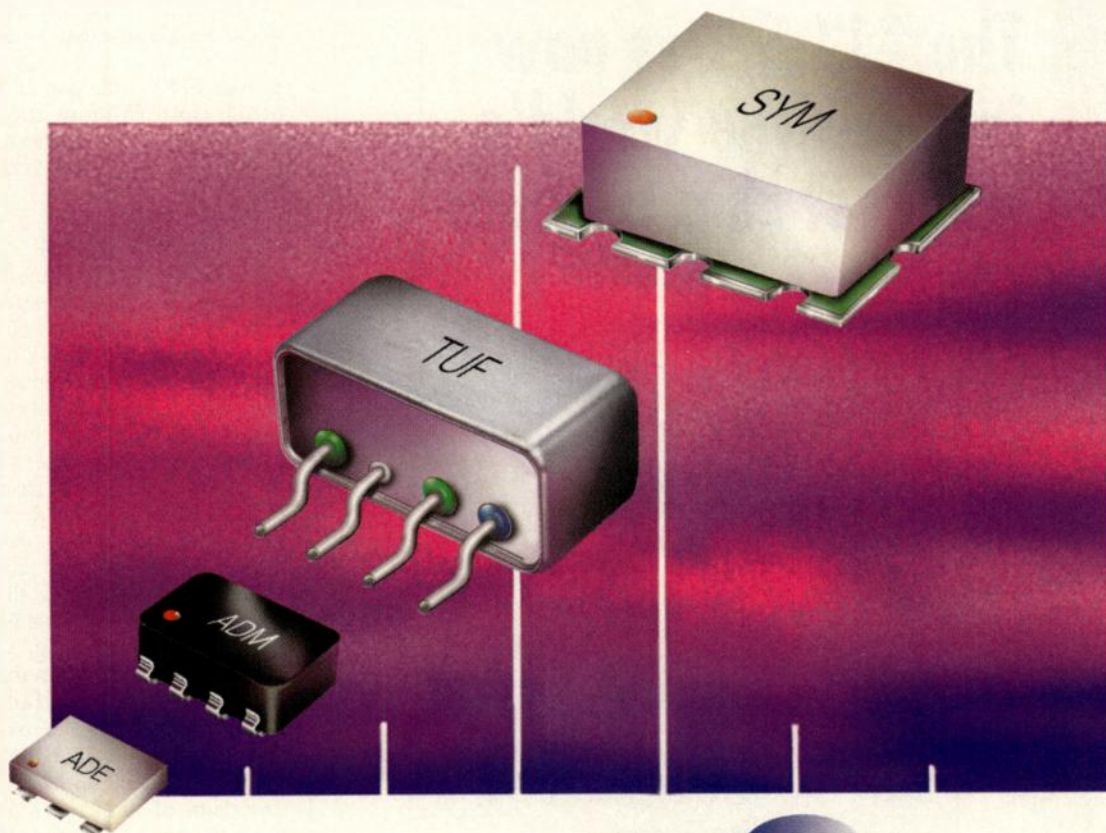


Figure 1. 64-QAM signal with  $E_s/N_0 = 34.3$  dB.



# HIGH IP3 MIXERS

**suppress noisy intermods**



**+30dBm IP3 100 to 2200MHz** **\$7.95** **WOW!**  
from (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), Surface Mount

| Model       | Freq.<br>(MHz) | IP3<br>Midband<br>(dBm) | Isol.<br>Bandwidth<br>L-R L-I (dB) | Conv.Loss<br>Midband<br>(dB) | Price \$ea.<br>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-10DH    | 800-1000       | 31                      | 45 29                              | 7.6                          | 18.95                   |
| SYM-22H     | 1500-2200      | 30                      | 33 38                              | 5.6                          | 19.95                   |
| •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

•Plug-in version available, specify TUF-18DH  
Available in tape and reel.

**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 INTL  
CIRCLE READER SERVICE CARD

F 270 Rev Org



thermal noise and other transmission impairments will all be reflected in the SNR/MER. If no impairments other than random thermal noise are present, the reported SNR/MER should be nearly equal to the input C/N. The reported SNR/MER is usually worse than the measured C/N because of other im-

pairments besides random thermal noise existent in the signal. Phase noise and multipath are two examples of impairments that do not directly affect C/N but do affect the constellation point spread and therefore decrease the reported SNR/MER. A large discrepancy between the observed C/N and re-

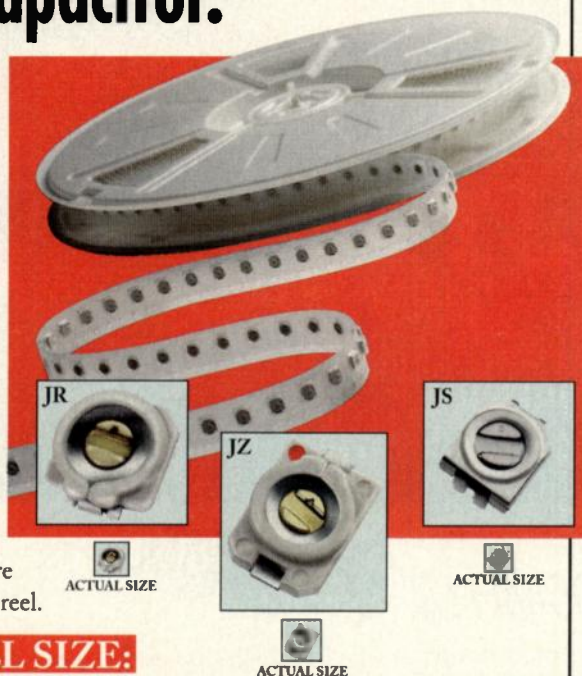
**Voltronics**  
debunks  
the myths  
*Myth:*  
Surface  
mount  
trimmers  
sacrifice  
performance  
for size  
and cost.

## The "J" Series now includes the world's smallest chip trimmer capacitor.

Voltronics J Series variable ceramic chip capacitors deliver unparalleled stability at a cost no more than less capable designs. They operate through 3 GHz, have Q's twice that of the closest competitor, are compatible with all types of SMT manufacturing and are supplied on tape and reel.

### NEW SMALL SIZE:

The JS (2.8mm x 2.2mm x 1mm) the newest member of the J Series family, combines all of these features, along with capacitance ranges of 3.0 to 10 pF and 4.5 to 20 pF, and the smallest footprint in the industry. To find out more about our J Series trimmers, call us today at (973) 586-8585 for data sheets, samples... and our new low prices.



**50,000 pieces  
any model  
4 weeks  
or less...  
Guaranteed!**

**Voltronics**  
INTERNATIONAL CORP.

*The Trimmer Capacitor Company*

100 Ford Road  
Denville, NJ 07834  
973.586.8585  
FAX 973.586.3404  
e-mail: info@voltronicscorp.com  
Visit our web site at:  
http://www.voltronicscorp.com  
WRITE, CALL OR FAX FOR CATALOGS

INFO/CARD 40

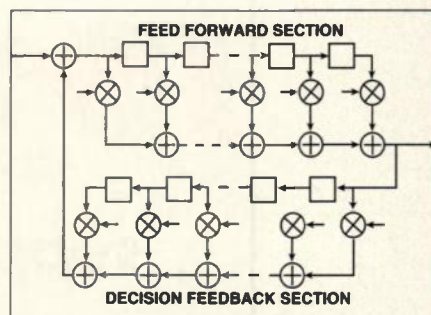


Figure 2. Adaptive equalizer block diagram.

ported SNR indicates that impairment other than random thermal noise is present, and it is often multipath that is beyond the adaptive equalizer's range.

### Adaptive equalizers

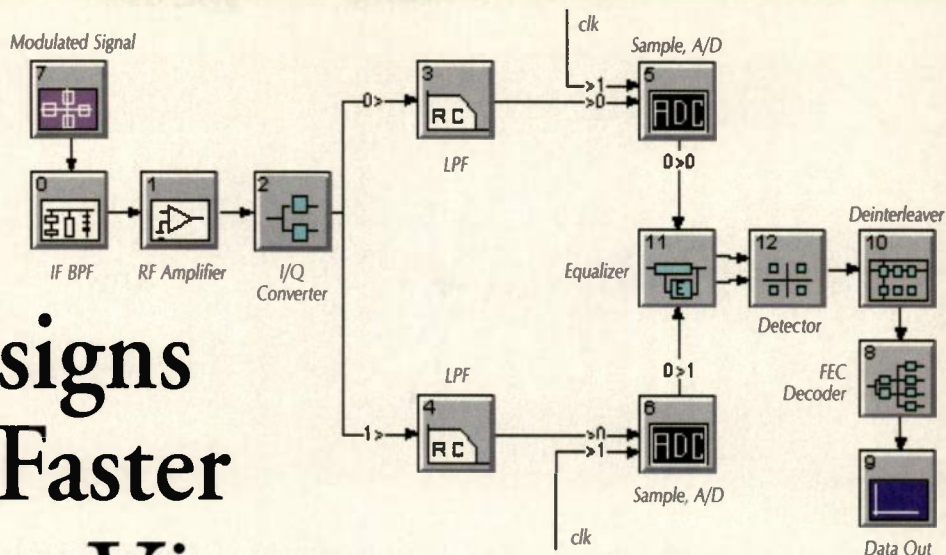
Practical QAM demodulators must contain an adaptive equalizer (AE) to reduce the effects of multipath and ISI. Think of an AE as a tapped delay line that creates delayed versions of the main signal that are used to cancel out the multipath. A block diagram of a typical AE is shown in Figure 2. The AE can have only a finite number of taps and can only cancel multipath that is within its time delay range. The number of taps, the symbol rate and the tap spacing determine the time delay range. Most AE designs are either T (T = symbol rate), spaced (also called synchronous designs) or T/2 spaced (also called fractionally spaced designs). For example, a 64-QAM ITU-T J.83(B) signal with a symbol rate of 5.05 Msps has a symbol duration of about 0.2  $\mu$ s. Therefore each tap in a T-spaced AE contributes 0.2  $\mu$ s of delay range. With a 16-tap decision feedback equalization (DFE) AE, the maximum echo that could be corrected would be  $16 \times 0.2 \mu$ s = 3.2  $\mu$ s. Echoes with a delay greater than this would be beyond the range of the AE and would appear as noise to the system.

Multipath occurs in two forms, pre-echoes (leading the desired signal) and post-echoes (lagging the desired signal), with the latter the most common. The decision feedback section of the AE cancels post-echoes. Usually the feedback is taken after the decision slicer function that determines the bit value. This is DFE and has the advantage of rejecting some noise. Pre-echoes can occur when repeaters are used. They can result



# Get Your Comm Designs to Market Faster Using *SystemView*

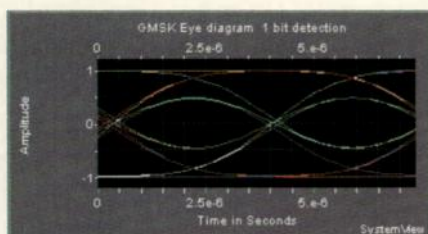
BY ELANIX®



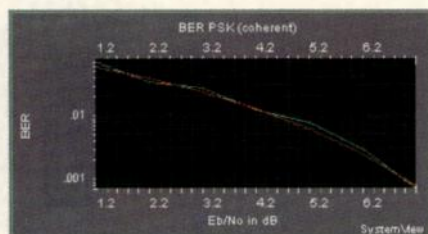
Mixed-Mode Receiver System Simulation

You've tried other design software, but you simply haven't found the digital and analog design tools you need in a single integrated environment. Until now.

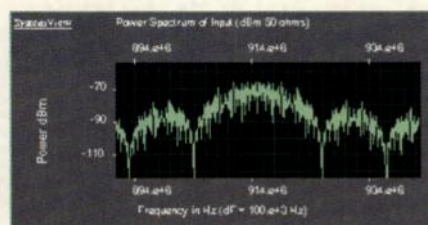
SystemView by ELANIX bridges the gap between digital and analog design. It provides the tools you need to model your complete system, from RF to bits.



GMSK Eye Diagram (1-bit Detection)



Theoretical vs. Actual BER (Coherent PSK)



Input Power Spectrum

## ■ End to End Comm Systems

Design and test digital/analog communications systems such as CDMA, GSM, DVB, QPSK, and QAM. Includes your choice of error correcting encoders/decoders and modulators/demodulators.

## ■ Bit-True DSP Design

Specify the exact arithmetic mode used by your target processor. SystemView by ELANIX will simulate it accurately to the bit level and generate overflow, underflow and carry flags.

## ■ Distortion-True RF/Analog Design

Include in your design circuit components such as distortion-true mixers, amplifiers, RLC circuits, opamp circuits and more. Create complete TX/RX systems, including propagated noise figure.

## ■ Xilinx® FPGA Option

Automatically implement your bit-true DSP design in a Xilinx FPGA. Xilinx LogiCOREs are directly supported in SystemView.

## ■ Interface to MATLAB®

Use the new SystemView M-library to incorporate MATLAB, Simulink® and third party libraries and systems into your SystemView design.

## What They're Saying About SystemView

"No other program with so much simulation power is as easy to use. When you finish a session with SystemView you realize that you've spent all the time applying engineering principles and none of the time struggling with the computer."

- Richard Chick, MIT Lincoln Labs -

"We use SystemView very heavily, not only in the brainstorming/prototyping stage, but also throughout the development process — right up to the point where we're actually building silicon."

- Steven Hall, CommQuest Technologies -

"For digital filter design, SystemView was indispensable due to its accurate simulation of the fixed point arithmetic mode employed on the actual DSP processor used in my design."

- Bisla Balvinder, Itron -

Request or download your FREE evaluation software today:

**1-800-5-ELANIX**  
**www.elanix.com**





# NEC Silicon RF IC Solutions... from 25¢

Want to make life simpler? Reduce the parts count in your design with low cost NEC Silicon RF ICs.

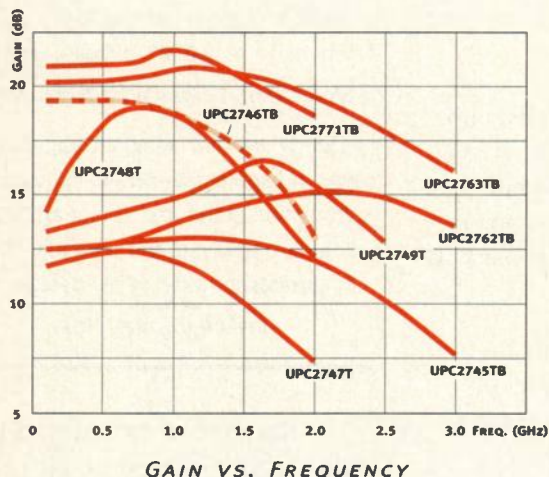
But be aware of the side effects!

Fewer parts can make your design more reliable. Your QC easier. And your assembly faster and more efficient.

NEC RF ICs come in a variety of package styles, including low cost plastic and surface mount, plus

they're available on tape and reel. Best of all, their quality and reliability are proven. With a production rate exceeding 20 million RF ICs a month, no one knows this technology like NEC.

Our *Silicon RF IC Selection Guide* lists specifications for these and dozens of other devices. For a copy, call CEL or one of our distributors. Or call our Fax Hotline and request *Document #502*.



## NEC

### 5V WIDEBAND RF IC AMPS—FROM 25¢

| PART      | FREQ. RANGE    | GAIN (dB) | NF (dB) | P <sub>1dB</sub> (dBm) | I <sub>CC</sub> (mA) | f <sub>TEST</sub> |
|-----------|----------------|-----------|---------|------------------------|----------------------|-------------------|
| UPC1678GV | 50 MHz–2.0 GHz | 23        | 6       | +15.9                  | 49                   | 500 MHz           |
| UPC2708T  | 50 MHz–2.9 GHz | 15        | 6.5     | +9.2                   | 26                   | 1.0 GHz           |
| UPC2709TB | 50 MHz–2.3 GHz | 23        | 5       | +8.7                   | 25                   | 1.0 GHz           |
| UPC2710T  | 50 MHz–1.0 GHz | 33        | 3.5     | +10.8                  | 22                   | 500 MHz           |
| UPC2711TB | 50 MHz–2.9 GHz | 13        | 5       | -2.6                   | 12                   | 1.0 GHz           |
| UPC2712TB | 50 MHz–2.6 GHz | 20        | 4.5     | -0.4                   | 12                   | 1.0 GHz           |
| UPC2713T  | 50 MHz–1.2 GHz | 29        | 3.2     | +0.3                   | 12                   | 500 MHz           |
| UPC2776TB | 50 MHz–2.7 GHz | 23        | 6.0     | +6                     | 25                   | 1.0 GHz           |
| UPC2791TB | 50 MHz–1.9 GHz | 12        | 5.5     | +1                     | 17                   | 500 MHz           |
| UPC2792TB | 50 MHz–1.2 GHz | 20        | 3.5     | 0                      | 19                   | 500 MHz           |

### 3V WIDEBAND RF IC AMPS—FROM 35¢

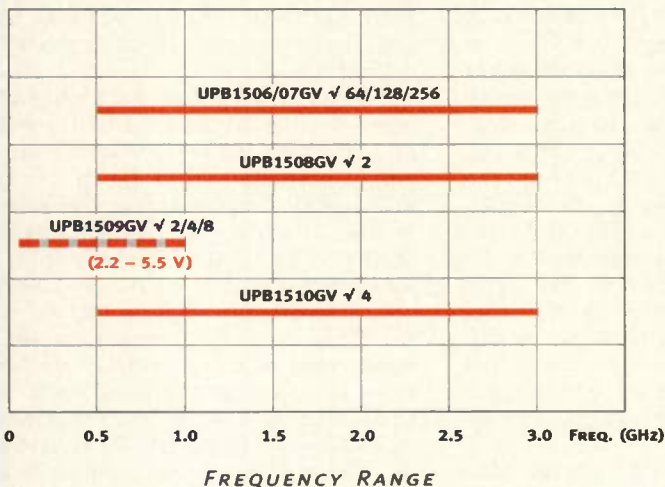
| PART      | FREQ. RANGE     | GAIN (dB) | NF (dB) | P <sub>1dB</sub> (dBm) | I <sub>CC</sub> (mA) | f <sub>TEST</sub> |
|-----------|-----------------|-----------|---------|------------------------|----------------------|-------------------|
| UPC2745TB | 50 MHz–2.7 GHz  | 12        | 6       | -3.0                   | 7.5                  | 500 MHz           |
| UPC2746TB | 50 MHz–1.5 GHz  | 19        | 4       | -3.7                   | 7.5                  | 500 MHz           |
| UPC2747T  | 100 MHz–1.8 GHz | 12        | 3.3     | -11                    | 5                    | 900 MHz           |
| UPC2748T  | 200 MHz–1.5 GHz | 19        | 2.8     | -8.5                   | 6                    | 900 MHz           |
| UPC2749T  | 100 MHz–2.9 GHz | 16        | 4       | -12.5                  | 6                    | 1.9 GHz           |
| UPC2762TB | 100 MHz–2.9 GHz | 14.5      | 7       | 7                      | 27                   | 1.9 GHz           |
| UPC2763TB | 100 MHz–2.4 GHz | 20        | 5.5     | 6.5                    | 27                   | 1.9 GHz           |
| UPC2771TB | 100 MHz–2.1 GHz | 21        | 6       | 11.5                   | 36                   | 900 MHz           |

Prices at 100K quantity





### 5V PRESCALERS—FROM 70¢



### PLUS DISCRETES...!

These NEC bipolars are ideal for amplifier and oscillator applications in your portable wireless designs. Priced from 20¢.

#### NE686 BIPOLAR TRANSISTORS

- High  $f_T$  (15 GHz)
- Low Noise
- Excellent Insertion Power Gain

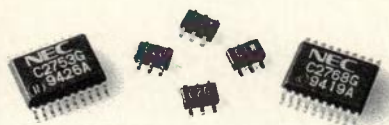
#### NE687 BIPOLAR TRANSISTORS

- Low Noise (1.3 dB @ 2 GHz)
- High Gain Bandwidth
- Noise match close to 50 ohms

#### NE688 BIPOLAR TRANSISTORS

- Low Phase Noise Distortion
- Low Noise, High  $f_T$
- Large Absolute Max Collector Current

All are available in eight different low cost surface mount packages.



### 3V FREQUENCY CONVERTERS—FROM 60¢

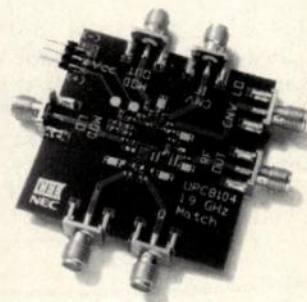
| PART                   | RF Frequency (MHz) | $I_{CC}$ (mA) | Conversion Gain (dB) | Output $IP_3$ (dBm) |
|------------------------|--------------------|---------------|----------------------|---------------------|
| UPC2756T <sup>1</sup>  | 100 - 2000         | 5.9           | 14                   | 0                   |
| UPC2757T <sup>1</sup>  | 100 - 2000         | 5.6           | 13                   | 0                   |
| UPC2758T <sup>1</sup>  | 100 - 2000         | 11            | 17                   | +6                  |
| UPC2768GR <sup>1</sup> | 10 - 450           | 7             | 80                   | -17                 |
| UPC8106T <sup>2</sup>  | 100 - 2000         | 9             | 9                    | +1                  |
| UPC8112T <sup>1</sup>  | 800 - 2000         | 8.5           | 13                   | -10                 |
| UPC8116T <sup>3</sup>  | 100 - 500          | 4.1           | 6.5                  | —                   |

1. Downconverter 2. Upconverter 3. AM/ASK Receiver IC

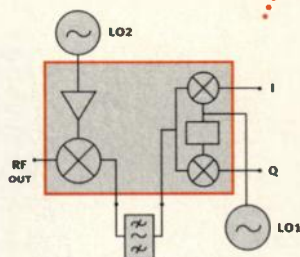
### UPC8104GR

#### IQ MODULATOR

Evaluation boards for most NEC MMICs are available free from CEL



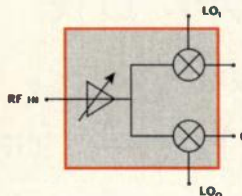
### MODS & DEMODS—FROM \$1.60



### UPC8104GR

#### IQ MODULATOR w/UPCONVERTER

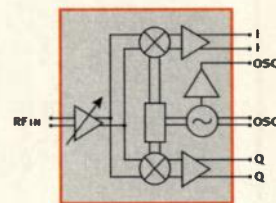
- 3 - 5 Volt operation
- Ports for IF filter
- 10 MHz I/Q BW
- 400 MHz IF Bandwidth
- 1.9 GHz RF Output



### UPC2766GR

#### IQ DEMODULATOR

- RF BW - DC to 1 GHz
- IF BW - DC to 100 MHz
- 35 dB typ AGC dynamic range
- 30 dBc typ distortion



### UPC2781GR

#### IQ DEMODULATOR

- RF BW - 440 to 520 MHz
- IF BW - 0.3 to 20 MHz
- On Chip 90° Phase Shifter
- 35 dBc typ distortion

See us at Wireless Symposium  
Booth # 617  
Feb 23-25 • San Jose, CA

\*Need Product Information Fast?  
Use CEL's Automated Fax System!

**CEL FAX**  
800-390-3232  
(U.S. and Canada Only)

**CEL** California Eastern Laboratories

4590 Patrick Henry Drive ■ Santa Clara, CA 95054 ■ 408 988-3500 ■ [www.cel.com](http://www.cel.com)

DISTRIBUTORS: Repton Electronics (888) REPTON Bell Industries (800) 525-6666

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



when the stronger desired signal is received via a longer path through a repeater and the weaker undesired signal is received via a shorter path directly from the main transmitter. The feed-forward section of the equalizer (FFE) cancels pre-echoes. This portion cannot take advantage of the noise rejection properties of the decision slicer.

In both sections, the tap values or weights are adaptively adjusted based on the results of the constellation decisions. These are called decision-directed equalizers (DDE). Generally, the least mean squares (LMS) algorithm is used to adaptively adjust the tap values to minimize the spread or mean square error of the constellation points and thus achieve the highest SNR or MER. Most AEs used in digital TV applications train or adapt using the normal data signal. This is known as blind equalization. Other approaches require that a known training sequence be transmitted.

The tap values of the AE, after it has adapted to a particular echo, can

be used to characterize the multipath. It is important to note that the AE taps only indicate the presence of multipath that is within the AE's time range. If multipath is present outside this time range, it will not be reflected in the tap values. In other words, the AE can only report multipath that it is capable of correcting. Multipath that is longer than the correction range of the adaptive equalizer is perceived by the demodulator as random noise and, depending on its amplitude, can sometimes be corrected by the demodulator's forward error correction [1]. However, this places an extra burden on the error-correction budget, thereby reducing the capability to correct errors caused by other impairments.

If the multipath is within the AE's time range, the value of the DFE taps will directly indicate the time delay and magnitude of the post-echo multipath. For the ITU-T J.83B example where the tap spacing is about 0.2  $\mu$ s, a post-echo that is 1.0  $\mu$ s in delay will activate the fifth DFE tap.

The magnitude of the tap relative to the main tap indicates the amplitude of the echo. Often this can be directly displayed in dB. If the multipath falls between two tap values, the taps on either side of the echo will activate.

The situation becomes slightly more complex in the FFE for the case of pre-echoes. In compensating for a single pre-echo, the FFE itself creates additional pre-echoes. The result is that a single pre-echo activates a series of FFE taps. For example, a single pre-echo at  $-0.5 \mu$ s at  $-10$  dB will activate the  $-0.5 \mu$ s tap at  $-1$  dB. This, however, creates an additional echo of the echo that also activates the  $-1.0 \mu$ s tap at  $-20$  dB. In turn creating another echo that activates the  $-1.5 \mu$ s tap at  $-30$  dB and so on. This continues until there are no more taps and the residual is left over. For the purposes of measuring multipath, the first activated tap (in this example, the tap at  $-0.5 \mu$ s) corresponds to the actual echo. The DFE does not suffer from this echo of the echo problem caused by the inherent feed-

## Simplify Your Life

Choose the Harris PRISM™ Radio Chip Set  
with Sawtek's Low-Loss Wideband SAW Filter...

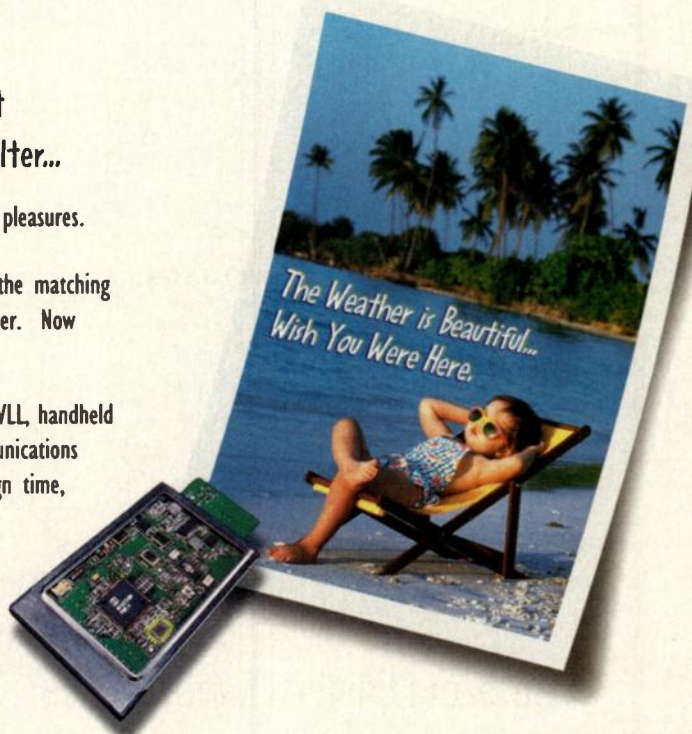
...and you'll find you have time to enjoy life's simple pleasures.

Harris and Sawtek have worked together to optimize the matching network between the PRISM chip set and the SAW filter. Now you, the system designer, don't have to.

For those wireless data applications like WLAN links, WLL, handheld data transceivers, and point-to-point microwave communications systems, this is the most efficient way to reduce design time, minimize your risks, and improve performance.

We've taken the complexity out of designing wireless systems to give you more time to kick back and relax. Call us today and simplify your life.

Telephone: 407-886-8860 • Fax: 407-886-7061  
Web: [www.sawtek.com](http://www.sawtek.com) or [www.semi.harris.com/prism/full/](http://www.semi.harris.com/prism/full/)  
PRISM™ is a registered trademark of Harris Corporation.



**SAWTEK**  
INCORPORATED





Performance is....

Heavy Upper Sidelobe Suppression



**SUPPRESSOR<sup>TM</sup>**

Reduced Interference

Improved Signal Quality

Reduced Stray Signals

Precise Control of the Signal

Eases System Optimization



**THE PERFORMANCE LEADER**

 **EMS WIRELESS**  
The Performance Leader

[www.emswireless.com](http://www.emswireless.com)

Tel: +1(770) 582-0555 ext. 5310 Fax: +1(770) 729-0036



back in its DFE structure.

### Using adaptive equalizer data to measure multipath

The DFE and FFE AE tap values can be used to measure multipath that is within the AE's time range. Figure 3 shows the tap value coefficients of an

AE with 8 DFE taps and 8 FFE taps. Note that one of the FFE taps is designated as the "main tap" or "reference tap" that passes the non-reflected desired direct signal. The other 7 FFE and 8 DFE taps are available for echo cancellation. In this example, the main or reference tap has been set to a

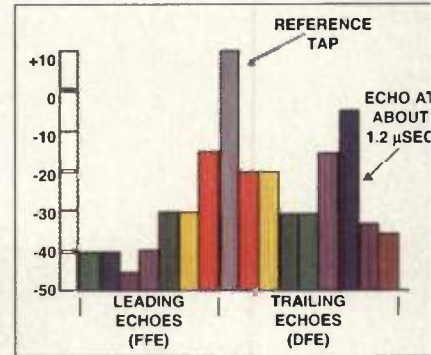


Figure 3. Adaptive equalizer tap values.

value of +10 dB. This value is arbitrary and is a function of the particular AE design. To cancel the multipath, the adaptation algorithm has set the sixth DFE tap to -4 dB or -14 dB relative to the main tap. This indicates that an echo exists at about 1.2  $\mu$ s and -14 dBc. The fifth tap at 1.0  $\mu$ s is also activated at about -25 dBc. This could be caused by a second echo at 1.0  $\mu$ s but because the seventh tap is quite low, it probably means that the single echo is actually occurring between the fifth and sixth taps or between 1.0-1.1  $\mu$ s but closer to 1.2  $\mu$ s. The -0.2  $\mu$ s FFE tap is activated at -25 dBc and most of the taps are also partially activated. This could be caused by low-level echoes or a slight tilt in the channel. Multipath and frequency response tilt are closely related, and both are corrected by the AE. Some AE read-out provide for a frequency response display that is calculated as the Fourier transform of the tap values.

Some systems that include a QAM demodulator provide for reading the AE tap values. As mentioned, this feature can be used to measure multipath that is within the time range of the AE. A vector signal analyzer such as the HP 89441 that is equipped with the AE option can also be used to measure multipath. The AE in this instrument can be configured for as many as 99 spaced taps covering a time range of about -3.7  $\mu$ s to +15.6  $\mu$ s. The adaptation in this type of instrument is much slower compared to that in an actual demodulator AE, typically taking 1 second to acquire initial lock and as much as a minute to optimize the adaptation. Unlike the AE used in a typical 64-QAM demodulator, the HP 89441 uses a finite impulse response (FIR) FFE for both the pre- and the post-echo section. Because the FI

## Stellux Microwave Systems

**Complete Solutions to your**

### RF and Microwave Applications

Stellux Microwave Systems is a proven industry leader in the design and manufacture of RF and Microwave components and subsystems. For over 40 years, Stellux products have been designed into sophisticated defense electronic systems, satellite communications systems, and high-end commercial applications.

The Stellux Advantage is dedication to design, advanced packaging and manufacturing processes. This balance between electrical, mechanical and process design is unique and offers our customers these benefits:

*Cost-effective production*

*Highest quality and reliability*

*Rapid time-to-market*

For more information, fax us at 650-813-2030 or call our 800 number:

**1-800-321-8075**

[www.stelluxms.com](http://www.stelluxms.com)

### The Stellux Advantage



- Frequency Range: DC to 26 GHz
- LO Drive Levels: +7 dBm to +27 dBm
- Packaging: Surface Mount, Microstrip, Open Carrier, TO & SMA Designs



- Frequency Range: 0.005 to 12 GHz
- LO Drive Levels: +10 dBm to +23 dBm
- Packaging: Various Hermetic, Open Carrier & SMA



- Frequency Range: 0.001 to 12 GHz
- Designs: Bipolar, GaAs FET/MMIC, & PHEMT
- Packaging: Surface Mount, TO & SMA Designs



- Frequency Range: 0.005 to 4 GHz
- Designs: Bipolar, GaAs FET & MMIC
- Packaging: Surface Mount, TO & SMA Designs



- 2-10 GHz low cost, low noise TO-8 style YIG Oscillators. Ideal for DRO replacement
- 2-14 GHz low cost, low noise, broad tuning range YIG Oscillators



- Frequency Range: 0.005 to 4 GHz
- Designs: PIN/HP Diode Linearized & Non-linearized
- Packaging: Surface Mount, TO & SMA Designs



- Highly integrated custom military and commercial subsystems
- In-house metal injection molding and glass molding for rapid low cost packaging



- Highly integrated custom military and commercial subsystems
- Advanced mixing technology for up and down conversion



**Stellux**

MICROWAVE SYSTEMS

Stellux Microwave Systems, Inc.  
3333 Hillview Avenue, Palo Alto, CA 94304-1223  
email: [sales@stelluxms.com](mailto:sales@stelluxms.com)

**See us at Booth #1915  
at the Wireless Symposium!**

INFO/CARD 52



## COMPACT SMT VCXO



With a wide frequency range of 2 to 55 MHz, Champion's K1526A Series features compact ceramic construction in a 4 J-leads, SOJ-20 industry-standard footprint. Additionally, the Series provides  $\pm 25$ ppm stability performance.

INFOCARD 88

## FULL PERFORMANCE SMT VCXO



The 5V and 3.3V Full Performance K1526B Series comes in a 6 J-leads SOJ-20 ceramic package including a standard tri-state selectable pin with optional  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  operating temperature range.

INFOCARD 89

## LOW COST SMT VCXO

An efficient, low cost option in surface mount VCXOs, the K1526LC Series features an Absolute Pull Range (APR) that meets your PLL tuning needs. Tri-state output selectable with a frequency range from 2 to 55 MHz and 3.3 Volt optional supply.

INFOCARD 90



## NEW SMT VCXO

The K1526C Series Champion's newest innovation in 5 Volt Full Performance SMT VCXOs, features a 4 J-leads SOJ-20 industry-standard footprint. It also provides  $\pm 25$ ppm stability, optional 3.3 Volt operation and frequency performance to 55 MHz.

INFOCARD 91



## 5x7mm SMT VCXO

Champion's newest SMT configuration is a 5 x 7mm 5V and 3.3V extremely low profile ceramic leadless chip carrier (CLCC). The CMV Series offers an operating temperature range option of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  as well as a frequency range of 2 to 52 MHz.

INFOCARD 92



## SMT VCXOs: PICK YOUR PACKAGE!

### Champion's affordable, high performance selection

- ▶ Wide, industry-leading offering
- ▶ 2.0 to 55.0 MHz frequency range
- ▶ Rugged, compact ceramic packages
- ▶ 5 x 7mm CLCC (CMV Series)
- ▶ 4-pin and 6-pin SOJ-20 industry-standard footprints
- ▶  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  industrial temperature range available
- ▶ Custom-designed configurations available
- ▶ 3.3 Volt operation feature

[www.champtech.com](http://www.champtech.com) or 800-888-1499

In addition to our broad product offering, Champion defines the industry standards for service and lead times. Innovative, affordable technology. No matter your shape, size or cost requirement, our SMT VCXOs will meet your need.

**Champion**  
TECHNOLOGIES, INC.

*Where Engineering Solutions Begin*

INFOCARD 93



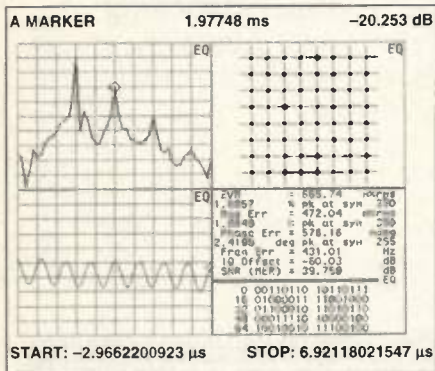


Figure 4. HP 89441 display.

filter structure has no feedback, both pre- and post-single echoes will create multiple tap responses. In the typical demodulator AE, multiple responses to a single echo occur only in the pre-echo FFE section.

Recommended settings for using an HP 89441 to measure multipath on an ITU-T J.83 B signal are given in Table 1.

Figure 4 provides an example of the QUAD display format from the HP 89441 that has been configured as described. The upper-left display is the impulse response of the AE that shows the values of the 51 taps over the range of about  $-3 \mu\text{s}$  to  $+7 \mu\text{s}$ . For this example, a single echo at  $+2 \mu\text{s}$  and  $-20 \text{ dBc}$  was created, as is shown by the marker. Notice the main tap at 0

dBc to the left of the echo. Also notice the "echo of the echo" tap at  $+4 \mu\text{s}$  and  $-40 \text{ dBc}$  as well as the additional "echo of the echo of the echo" at  $+6 \mu\text{s}$  and  $-60 \text{ dBc}$ . Remember, these additional echoes are not actually present in the channel but are the result of the operation of the FFE-type AE that is used in the HP 89441, which has no inherent feedback. The lower-left display shows the frequency response of the channel based on calculating the FFT of the AE impulse response. The display is 1 dB per division and shows ripples spaced at 500 kHz with peak to valley amplitude of about 1.7 dB. The upper-right-hand display shows the 64-QAM constellation that has been demodulated by the HP89441 using the AE. The lower right hand display shows the demodulated error vector magnitude (EVM), SNR (MER) and other parameters of the demodulated signal using the AE.

Some signals may require changing the AE convergence speed factor. Although a smaller convergence number will provide a more accurate result and is more likely to converge, it will require more time. A larger convergence number will usually converge faster but may fail to converge with some signals and will give a less accurate result. A good strategy is to start out with a larger number such as  $5 \times 10^{-6}$  for fast initial convergence and

then reduce the value for a more accurate result.

### Measuring multipath using a spectrum analyzer

In some cases, a HP 89441 or the tap values of the demodulator AE may be unavailable. Also, as mentioned, an AE cannot indicate multipath that is beyond its time range. When this is the case, an ordinary spectrum analyzer can be used to characterize multipath on digital signals. The spectrum of a digital signal, after averaging, is essentially flat across most of the symbol rate bandwidth. If, however, multipath is present, constructive and destructive interference of the reflected path with the direct path will cause ripples in the otherwise flat spectrum. The inverse of the frequency spacing of the ripples indicates the time delay of the multipath. Ripple spacing can be measured from peak-to-peak or from null-to-null. By measuring the frequency delta between adjacent ripples, the time delay can be determined as:

$$\text{Time delay } (\mu\text{s}) = \frac{1}{\text{frequency } \Delta} (\text{MHz})$$

For example, if the ripple is observed with peaks spaced at 1.25 MHz, the time delay is  $1/1.25 \text{ MHz}$ , that equal  $0.8 \mu\text{s}$ . Note that as the time delay increases, the frequency delta between the ripple peaks decreases. A long-time

# Point, click, specify . . .



Everything you ever wanted to know from your crystal manufacturer will soon be just a click away

Watch this space.

# RAKON

PRECISION QUARTZ CRYSTALS

RAKON LIMITED

1 Pacific Rise, Mt Wellington, Auckland, New Zealand.  
Private Bag 99943, Newmarket.

Fax: 64-9-573 5559, Phone: 64-9-573 5554 (64 IS THE COUNTRY CODE, 9 IS THE AREA CODE)

INFO/CARD 20



# *fast* easy affordable

(We knew you wouldn't want slow,  
difficult, and expensive design software.)

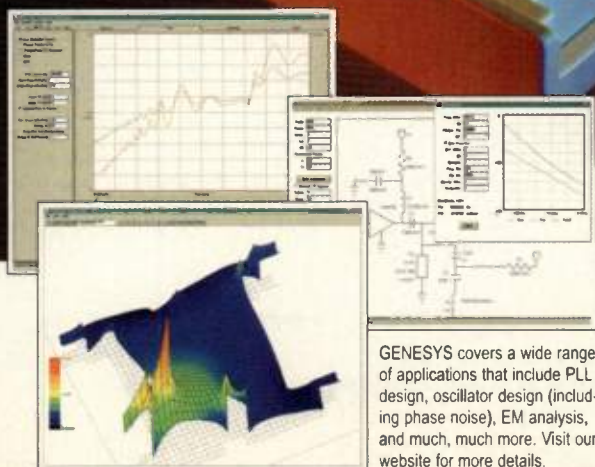
## GENESYS

Without a doubt, our software will help you finish your design faster and with less effort than ever before. Synthesis tools quickly and easily eliminate tedious design tasks: you input the specs, the software delivers the first-pass design. Simulators with just the features you need are incredibly fast. Our "keep it simple" philosophy results in software that's easy to learn and easy to use. So easy, in fact, that technical support is free.

Doing business with Eagleware is also fast and easy. Reach us by phone, fax, e-mail, or through the Web. Order by PO or credit card. Receive the software within days of ordering.

The complete GENESYS/EM design suite is \$8990. For individual products, prices start at \$999, and technical support is **FREE**.

So don't wait. Contact us today to get your own fast, easy, and affordable design software.



GENESYS covers a wide range of applications that include PLL design, oscillator design (including phase noise), EM analysis, and much, much more. Visit our website for more details.

## EAGLEWARE

**RF and Microwave Design Software**

4772 Stone Drive • Tucker, GA 30084 USA  
eagleware@eagleware.com • www.eagleware.com  
Tel: 770.939.0156  
Fax: 770.939.0157



# Ultra-Broad Band AMPLIFIERS



## ULTRA BROAD BAND

| Model      | Freq. Range<br>GHz | Gain<br>dB min | Gain<br>dB max | 1 dB Comp.<br>dB | 3rd Order<br>ICP typ |
|------------|--------------------|----------------|----------------|------------------|----------------------|
| JCA018-200 | 0.5-18.0           | 24             | 3.8            | 2.5              | 0                    |
| JCA018-203 | 0.5-18.0           | 20             | 5.0            | 2.5              | 7                    |
| JCA018-204 | 0.5-18.0           | 25             | 4.0            | 2.5              | 10                   |
| JCA018-300 | 0.5-18.0           | 30             | 3.8            | 2.5              | 0                    |
| JCA018-303 | 0.5-18.0           | 27             | 5.0            | 2.5              | 7                    |
| JCA018-400 | 0.5-18.0           | 37             | 3.8            | 2.5              | 0                    |
| JCA018-403 | 0.5-18.0           | 35             | 5.0            | 2.5              | 7                    |
| JCA018-504 | 0.5-18.0           | 40             | 5.0            | 2.5              | 10                   |
| JCA218-200 | 2.0-18.0           | 15             | 5.0            | 2.5              | 10                   |
| JCA218-206 | 2.0-18.0           | 17             | 5.0            | 2.5              | 15                   |
| JCA218-300 | 2.0-18.0           | 23             | 5.0            | 2.5              | 10                   |
| JCA218-306 | 2.0-18.0           | 22             | 5.0            | 2.5              | 15                   |
| JCA218-307 | 2.0-18.0           | 20             | 5.0            | 2.5              | 21                   |
| JCA218-400 | 2.0-18.0           | 29             | 5.0            | 2.5              | 10                   |
| JCA218-406 | 2.0-18.0           | 30             | 5.0            | 2.5              | 15                   |
| JCA218-407 | 2.0-18.0           | 30             | 5.0            | 2.5              | 21                   |
| JCA218-506 | 2.0-18.0           | 35             | 5.0            | 2.5              | 15                   |
| JCA218-507 | 2.0-18.0           | 35             | 5.0            | 2.5              | 18                   |

## Features/Options:

- Removable SMA Connectors
- Competitive Pricing
- Compact Size
- Quick Delivery
- Alternate Gain/Noise/Power/VSWR levels if required

**JCA**  
TECHNOLOGY

**DELIVERY IN 30 DAYS ARO**

1090 Avenida Acaso, Camarillo, CA 93012  
(805) 445-9888 Fax: (805) 987-6990  
email: [jca@jcatech.com](mailto:jca@jcatech.com)  
[www.jcatech.com](http://www.jcatech.com)

INFO/CARD 19

delay causes many closely spaced ripples across the channel. A short-time delay causes a small number of widely spaced ripples across the channel.

To understand why multipath cause ripples in the spectrum, consider a con

...continued on page 7

### • INST MODE

|                     |  |
|---------------------|--|
| Demodulation        |  |
| Demodulation Setup  |  |
| Demodulation Format | = 64 QAM   |
| Symbol Rate         | = 5.056941 MHz                                       |
| Result Length       | = 512 Symbols  |
| Measurement Filter  | = Root Raised Cosine                                 |
| Reference Filter    | = Raised Cosine                                      |
| Alpha/BT            | = 0.18   |
| EQ Filter           | = ON   |
| EQ ADAPT            | = Run  |
| EQ Filt Length      | = 51 symbols (this sets the time range of the AE)    |
| Convergence         | = 1e-07 (this sets the speed of adaptation SEE TEXT) |
| EQ Reset            | = (select this to restart AE)                        |

### • AVERAGE

|         |       |
|---------|-------|
| Average | = OFF |
|---------|-------|

### • TIME

|               |  |
|---------------|--|
| Result Length | = 512 symbols                                  |
| Pulse Stretch | = OFF  |
| Sync Search   | = OFF  |
| Points/Symbol | = 1 (this establishes the AE as a T spaced AE) |

### • FREQUENCY

|        |                               |
|--------|-------------------------------|
| Center | = (Center Freq of QAM signal) |
| Span   | = 6 MHz                       |

### • SWEEP

|            |        |
|------------|--------|
| Continuous |        |
| Sweep Mode | = AUTO |

### • TRIGGER

|              |       |
|--------------|-------|
| Free Run     |       |
| Trig Holdoff | = OFF |
| Ext Arm      | = OFF |

### • SOURCE

|        |       |
|--------|-------|
| Source | = OFF |
|--------|-------|

### • Res BW/Window

|             |            |
|-------------|------------|
| Main Window | = Flat Top |
|-------------|------------|

### • INPUT

|                |                                      |
|----------------|--------------------------------------|
| Input Z        | = 50 or 75 Ohm (dependent on system) |
| Ch 1 In Im     | = 50 or 75 Ohm                       |
| Ch 1 Coupling  | = AC                                 |
| Ch 1 Alias LPF | = IN                                 |

### • RANGE

|                |  |
|----------------|--|
| Ch 1 Autorange | = OFF  |
| Ch 1 Range     | = (set to the minimum value that does not indicate overload) |

### • DISPLAY

4 Grids Quad

### • A DISPLAY

|                    |                              |
|--------------------|------------------------------|
| A Measurement Data | = Equalizer Impulse Response |
| A Calculate        | = ON                         |
| A Data Format      | = Log (dB)                   |
| A X Axis           | = Linear                     |
| A Ref Lvl/Sale     |                              |
| y per division     | = 10 dB                      |

### • B DISPLAY

|                    |                              |
|--------------------|------------------------------|
| B Measurement Data | = Channel Frequency Response |
| B Calculate        | = ON                         |
| B Data Format      | = Log (dB)                   |
| B X Axis           | = Linear                     |
| B Ref Lvl/Sale     |                              |
| y per division     | = 1 dB                       |
| y Ref level        | = 6 dB                       |

### • C DISPLAY

|                    |                       |
|--------------------|-----------------------|
| C Measurement Data | = Time                |
| C Calculate        | = ON                  |
| C Data Format      | = Polar Constellation |
| C Ref Lvl/Sale     |                       |
| y Ref level        | = 0                   |
| x Ref level        | = 0                   |
| y per div          | = 180m                |
| Range Tracking     | = ON                  |

### • D DISPLAY

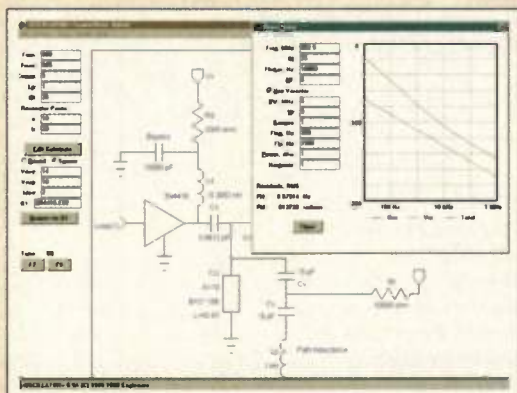
|                    |                              |
|--------------------|------------------------------|
| D Measurement Data | = Symbol Table/Error Summary |
| D Calculate        | = ON                         |

Table 1. HP 89441 configuration for measuring multipath with ITU-T J.83B signals.



# "Eagleware's approach is to **directly solve** your problem"\*

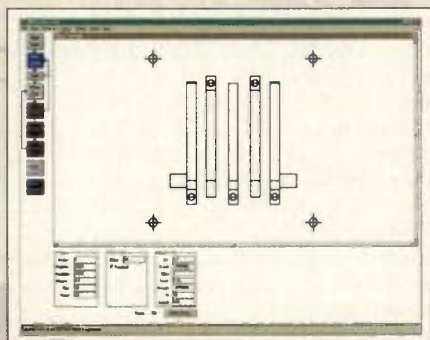
Design automation is the fast, easy, and affordable way to speed design



## SYNTHESIS

**=OSCILLATOR=**  
 L-C Colpitts, Clapp, series  
 Dielectric resonator  
 SAW hybrid, MOSFET, BJT  
 Cavity bipolar & hybrid  
 T-line and L-C VCO  
 Crystal Pierce, Colpitts, Driscoll  
 Butler overtone  
 VCO with transformer

Most design software just simulates circuits. With Eagleware's synthesis products, key parts of the design process are automated. You input your specifications and the synthesizer comes up with a design. It's fast, easy, and automatic.



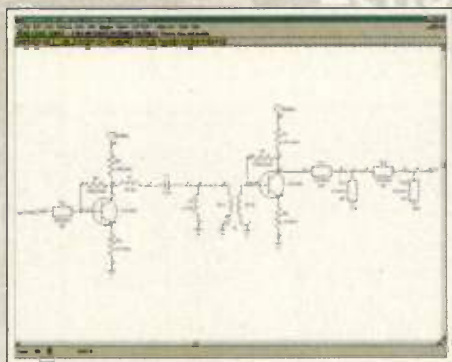
**=M/FILTER=**  
 Interdigital  
 Edge Coupled  
 Hairpin  
 Combline  
 End Coupled  
 Stepped-Z  
 Elliptic Lowpass  
 Stub Lowpass  
 Elliptic Bandpass  
 Stub Bandpass  
 Stub Bandstop  
 Edge Bandstop  
 Microstrip, Stripline,  
 Stripline and Coaxial

**=FILTER=**  
 All-pole and elliptic  
 Top-C and -L coupled  
 Shunt-C coupled  
 Tubular  
 Bunchikoff filter delay  
 Zig-Zag  
 Eagleware Symmetrical  
 6 Group Delay Equalizers

Take amplifier design. Broadband, multistage matching is sometimes tedious, sometimes frustrating, and always time consuming. But, with **=MATCH=**, you select devices, input performance parameters, and—BAM!—out comes the design. **=MATCH=** solves problems that simple optimizers will never solve.

**=A/FILTER=**  
 GIC transform  
 Single & Multiple feedback  
 State variable (bi-quad)  
 VCVS  
 Dual amplifier  
 Low Sensitivity  
 3 Group Delay Equalizers

Other synthesis products generate oscillators. And filters. Even PLLs.



**=MATCH=**  
 L-C pi and L  
 L-C tee  
 T-line quarter wave  
 T-line single/double stub  
 General order bandpass  
 L-C & T-line pseudo lowpass  
 T-line stepped-Z  
 Custom with Rs and transformers

Synthesis products start at \$999. The complete GENESYS/EM design suite is \$8990. Technical support for individual Eagleware products is **FREE**.

So don't wait. Contact us today to get your own fast and easy tools that automate your design process.

## EAGLEWARE

RF and Microwave Design Software


4772 Stone Drive • Tucker, GA 30084 USA  
 eagleware@eagleware.com • www.eagleware.com  
 Tel: 770.939.0156  
 Fax: 770.939.0157

\* Quote from a satisfied customer

INFO/CARD 87



# Get the Data Now!!

Find out information on all the products, software and literature described in this issue. Either circle the reader service number on the right and mail in the card today! 

Or go to **www.rfdesign.com** and choose from two options.

## Option 1: Home Page Links

Link directly to the home page of any of the companies listed below (where available).

## Option 2: Product Directory (advertisers only)

Link directly to the web page that relates to the data on the product advertised (where available).

### ADVERTISERS

| COMPANY NAME            | PAGE NO.  | READER SVC. NO.   | PRODUCT CAT.                  | COMPANY NAME             | PAGE NO.                          | READER SVC. NO.   | PRODUCT CAT.   |
|-------------------------|-----------|-------------------|-------------------------------|--------------------------|-----------------------------------|---|--|
| AEA a Division of       |           |                   |                               | Mercury United Elec.     | 81                                | 61  | Filters  |
| Tempo Research          | 72        | 42                | Impedance Analyzer            | Mini-Circuits            | 4,5,6,11,19,27,36,37,43,53,85,103 | 10,15,62,63,30,31,67,68,32,33,65,66,27,28,69,70,83,84,36,37,77,79 | Oscillators<br>Couplers<br>Mixers<br>Amplifiers<br>Attenuators<br>Switches |
| Amplifier Research      | 3         | 38                | Amplifiers                    | MITEQ                    | 47                                | 97  | Mixers   |
| Anritsu                 | 33        | 35                | Power Meters                  | Monitor Products         | 90                                | 78  | Oscillators  |
| ATN Microwave           | 74,82,88  | 39,64,71          | Multiport Testing<br>Switches | MTI Milliren             | 91                                | 103   | Oscillators  |
| Avnet                   | 2         | 80                | Distributor                   | M-tron Industries        | 82                                | 21  | Oscillators  |
| California Eastern Labs | 56,57,104 | 14,55             | Transistors<br>GaAs HEMTs     | Murata Electronics       | 25                                | —   | Resonators   |
| Champion Technologies   | 61        | 88,89,90,91,92,93 | Oscillators                   | Nemal Electronics        | 86                                | 29  | Connectors   |
| Communication Concepts  | 74        | 43                | Amplifiers                    | Noble Publishing         | 41                                | 34  | Books  |
| CST of America          | 17        | 2                 | Software                      | Princeton                |                                   |   |  |
| Derwent                 | 31        | 5                 | Patent Web site               | Electronic Systems       | 9                                 | 49  | Oscillators  |
| Eagle                   | 90        | 47                | Filters                       | Pulsar Microwave         | 8                                 | 100   | Mixers   |
| Eagleware               | 63,65     | 86,87             | Software                      | QMI                      | 29                                | 4   | Cable Assemblies   |
| Elanix                  | 55        | 9                 | Software                      | Rakon                    | 62,89                             | 20,22   | Crystals   |
| Electro Dynamics        |           |                   |                               | Raltron                  | 88                                | 74  | Oscillators  |
| Crystal (EDC)           | 80        | 76                | Crystals                      | RCPL                     | 72                                | 98  | Isolators/Circulators  |
| EMS Wireless            | 59        | 17                | Antennas                      | Renaissance Electronics  | 76                                | 99  | Mixers   |
| Film Microelectronics   | 22        | 105               | Substrates                    | RF Micro Devices         | 15                                | 58  | ASICs  |
| Giga-Tronics            | 12,13     | —                 | Power Meters                  | Richardson Electronics   | 48                                | 104   | Distributor  |
| Glaesteel Industrial    |           |                   |                               | RLC Electronics          | 50                                | 106   | Detectors  |
| Laminates (GIL)         | 39        | 6                 | Substrates                    | Rockwell Filter Products | 78                                | 44  | Filters  |
| Henry Radio             | 81        | 51                | Amplifiers                    | Sawtek                   | 58                                | 41  | Filters  |
| Hermetic Technology     | 78        | 46                | Component Bases               | Stanford Telecom         | 51                                | 7   | ASICs  |
| Hewlett-Packard         |           |                   |                               | Stellex Microwave        | 60                                | 52  | GaAs MMIC/RF   |
| Microwave Instruments   | 23        | 3                 | Network Analyzers             | Surcom Associates        | 22                                | 73  | Capacitors   |
| Hitachi Metals          | 87        | 60                | Transformers                  | Teledyne Electronic      |                                   |   |  |
| IFR                     | 45        | 45                | Spectrum Analyzers            | Technologies             | 73                                | 82  | Duplexers  |
| IMS                     | 84        | 75                | Resistors                     | Temex Electronics        | 87,91                             | 12,72   | Oscillators  |
| JCA Technology          | 64        | 19                | Amplifiers                    | T-Tech                   | 86                                | 59  | PCB prototyping  |
| JFW Industries          | 79        | 16                | Attenuators                   | Voltronics               | 34a                               | —   | Capacitors   |
| Johanson Manufacturing  | 46        | 102               | Capacitors                    | Voltronics International | 54                                | 40  | Capacitors   |
| Johanson Technology     | 81        | 56                | Capacitors                    | Xemod                    | 49                                | 8   | Amplifiers   |
| LG C&D                  | 14        | 18                | Filters                       | XTAL Technologies        | 86                                | 53  | Filters  |
| Marlo Electronics       | 16        | 11                | Synthesizers                  |                          |                                   |   |  |
| Matrix Systems          | 82        | 54                | Switching Matrices            |                          |                                   |   |  |
| Maxim Int. Products     | 21        | 48                | Amplifiers                    |                          |                                   |   |  |
| Maxrad                  | 44        | 101               | Antennas                      |                          |                                   |   |  |

### EDITORIAL

| COMPANY NAME                  | PAGE NO. | READER SVC. NO. | COMPANY NAME              | PAGE NO. | READER SVC. NO. | COMPANY NAME                 | PAGE NO. | READER SVC. NO. |
|-------------------------------|----------|-----------------|---------------------------|----------|-----------------|------------------------------|----------|-----------------|
| Aerotron-Repec Systems        | 88       | 149             | Ericsson Components       | 89       | 155             | National Instruments         | 92       | 115             |
| Amplifier Research            | 83       | 134             | FEI Communications        | 91       | 161             | Optotek                      | 92       | 121             |
| Analog Devices                | 93       | 128             | Flann Microwave           | 86       | 145             | Philips Semiconductors       | 84       | 140             |
| Anaren Microwave              | 87       | 146             | Frontline Test Equipment  | 92       | 118             | Piezo Technology             | 91       | 162             |
| Andrew                        | 88       | 150             | Gage Applied Sciences     | 93       | 124             | Pletronics                   | 91       | 160             |
| Anritsu                       | 83       | 135             | Harmonic Software         | 92       | 116             | Power Trends                 | 80       | 165             |
| Artech House                  | 93       | 127             | Hewlett-Packard           | 83,93    | 133,132         | Princeton Electronic Systems | 83       | 136             |
| AVX                           | 93       | 129             | Hewlett-Packard EEsof     | 92       | 117             | Programmed Test Sources      | 84       | 139             |
| Boonton Electronics           | 82       | 168             | IFR Americas              | 84,93    | 138,123         | Renaissance Electronics      | 83       | 137             |
| California Eastern Labs       | 89       | 153             | Kepco                     | 82       | 167             | RF Micro Devices             | 84       | 142             |
| California Micro Devices      | 81       | 166             | KOA Speer Electronics     | 89       | 154             | Riedon                       | 93       | 125             |
| Comtech PST                   | 90       | 157             | Kota Microcircuits        | 90       | 156             | RLC Electronics              | 86       | 144             |
| Control Concepts              | 93       | 130             | Linx Technologies         | 88       | 151             | Tanner EDA                   | 92       | 119             |
| Densitron Microwave           | 90       | 158             | Lucent Technologies       | 90       | 159             | Toko America                 | 89       | 152             |
| Electronics Surveillance Comp | 91       | 163             | Maxim Integrated Products | 88,93    | 148,126         | Wavetek                      | 92,93    | 120,122         |
| EMCA-REMEX                    | 80       | 164             | Mini-Circuits             | 84       | 141             | Z-Communications             | 87       | 147             |
| EMC Test Systems              | 93       | 131             | Narda Microwave-East      | 86       | 143             |                              |          |                 |



continued from page 64

| Echo Amplitude (dB) | Destructive Interference (dB) | Constructive Interference (dB) | Peak to Valley Delta (dB) |
|---------------------|-------------------------------|--------------------------------|---------------------------|
| -0.001              | -78.78                        | 6.02                           | 84.80                     |
| -1                  | -19.27                        | 5.53                           | 24.81                     |
| -2                  | -13.74                        | 5.08                           | 18.81                     |
| -3                  | -10.69                        | 4.65                           | 15.34                     |
| -4                  | -8.66                         | 4.25                           | 12.91                     |
| -5                  | -7.18                         | 3.88                           | 11.05                     |
| -6                  | -6.04                         | 3.53                           | 9.57                      |
| -7                  | -5.14                         | 3.21                           | 8.35                      |
| -8                  | -4.41                         | 2.91                           | 7.32                      |
| -9                  | -3.81                         | 2.64                           | 6.44                      |
| -10                 | -3.30                         | 2.39                           | 5.69                      |
| -11                 | -2.88                         | 2.16                           | 5.03                      |
| -12                 | -2.51                         | 1.95                           | 4.46                      |
| -13                 | -2.20                         | 1.75                           | 3.96                      |
| -14                 | -1.93                         | 1.58                           | 3.51                      |
| -15                 | -1.70                         | 1.42                           | 3.12                      |
| -16                 | -1.50                         | 1.28                           | 2.78                      |
| -17                 | -1.32                         | 1.15                           | 2.47                      |
| -18                 | -1.17                         | 1.03                           | 2.20                      |
| -19                 | -1.03                         | 0.92                           | 1.96                      |
| -20                 | -0.92                         | 0.83                           | 1.74                      |
| -21                 | -0.81                         | 0.74                           | 1.55                      |
| -22                 | -0.72                         | 0.66                           | 1.38                      |
| -23                 | -0.64                         | 0.59                           | 1.23                      |
| -24                 | -0.57                         | 0.53                           | 1.10                      |
| -25                 | -0.50                         | 0.48                           | 0.98                      |

Table 2. Tabulated echo amplitudes.

inuous wave (CW) signal on 2,500 MHz, for example. Also consider that multipath is present with a delay of 1 ns so that the reflected path signal is delayed by exactly 2,500 cycles of the signal. Because the delay corresponds to exactly 2,500 cycles, the peak of the delayed signal carrier will correspond to the peak of the direct signal, but is displaced by 2,500 cycles. Because the peaks of the two signals line up, this will result in constructive interference, and the amplitude of the signal at 2,500 MHz will be increased. The situation is the same at 2,501 MHz; the signals differ by exactly 2,501 cycles, so constructive interference still results. Now consider the situation at 2,500.5 MHz. Here, the signals differ by 2,500.5 cycles. The peak of the reflected signal arrives with the trough of the direct signal. This causes destructive interference, so the amplitude at 2,500.5 MHz is reduced. This pattern repeats across the entire channel, resulting in constructive interference every 1 MHz and destructive interference at the 1/2 MHz points between. When a QAM signal is transmitted, ripples in the spectrum result.

Short multipath (less than 0.2 μs) creates less than one ripple in each 6 MHz channel. This short multipath

caused by relatively close objects has the effect of attenuating or amplifying entire channels; i.e., it creates ripples across the MDS band rather than ripples across individual channels. This can actually be helpful to those channels that are increased in level, but it is harmful to those that are attenuated. If the attenuation brings the channel below the noise threshold, it will not be receivable despite the AE.

The amplitude of the multipath can be determined by measuring the magnitude of the amplitude ripples. In this case, we will measure the difference in amplitude between the peak and the valley. If, for example, the multipath is -12 dBc, this corresponds to a voltage ratio of 0.25. The constructive interference results in a peak level of  $1 + 0.25 = 1.25$  or +1.9 dB, and the destructive interference results in a valley of  $1 - 0.25 = 0.75$  or -2.5 dB. This is a peak to valley of  $1.9 + 2.5 = 4.4$  dB. The following equation can be used to calculate the magnitude (in dB) of the echo with respect to the main signal from the destructive (negative) trough and constructive (positive) peak delta from the spectrum analyzer:

$$\text{Echo Level (dB)} = 20 \log \left[ \frac{10^{\left(\frac{\text{Pk-Trough}\Delta}{20}\right)} - 1}{10^{\left(\frac{\text{Pk-Trough}\Delta}{20}\right)} + 1} \right]$$

where Pk-TroughΔ = Peak to trough delta in decibels read from spectrum analyzer. Table 2 shows tabulated results corresponding to the peak to trough delta on the spectrum analyzer.

Figure 5 shows a simulation of a normal 64-QAM spectrum along with a simulation of a spectrum effected by multipath with a 0.8 μs echo at 12 dB below the main signal. Note the frequency spacing between the peaks is 1.25 MHz, and the peak to valley amplitude is about 4.5 dB. In practice, it can be difficult to see and measure small ripples on a QAM spectrum caused by the normal random variations in the signal. These random ef-

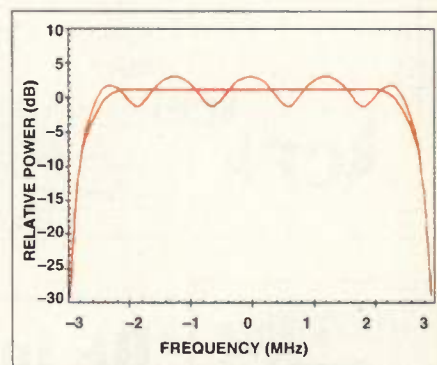


Figure 5. Multipath with 0.8 μs delay at -12 dBc.

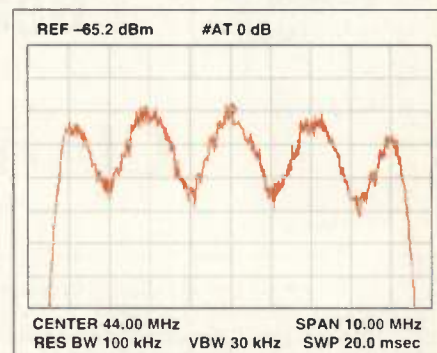


Figure 6. Spectrum analyzer plot with 0.8 μs echo at -12 dBc.

fects can be reduced by the use of the averaging function on the spectrum analyzer, allowing the ripples to be seen and measured. The span and resolution bandwidth must also be set to an appropriate value to see the ripples. It is useful to set the spectrum analyzer resolution and video bandwidth modes to AUTO. These parameters will then automatically track as the SPAN setting is varied when looking for various delays of multipath. Once ripples have been found, the span, resolution bandwidth, and amplitude settings can be varied as needed to make an accurate measurement. Table 3 shows some suggested spectrum analyzer settings useful for searching for multipath of various delays.

The spectrum analyzer plots in Figures 6 and 7 show examples of rip-

| Multipath Time Delay                     | Frequency Spacing of Peaks | Span    | RBW/VBW          |
|--|----------------------------|---------|------------------|
| 0.2 to 1 μs                              | 5 to 1 MHz                 | 10 MHz  | 100 kHz / 30 kHz |
| 1 to 10 μs                               | 1 MHz to 100 kHz           | 1 MHz   | 10 kHz / 10 kHz  |
| 10 to 100 μs                             | 100 to 10 kHz              | 100 kHz | 1 kHz / 1 kHz    |
| AVERAGE ON = 100<br>AMPLITUDE 2 dB / DIV |                            |         |                  |

Table 3. Suggested spectrum analyzer setting for searching for multipath.





## COAXIAL DUAL ISOLATOR



- Frequency: 160 MHz - 470 MHz
- Isolation: 50 dB (Min)
- Ins. Loss: .3 dB (Max)
- Bandwidth: Up to 5%

*Contract  
Manufacturing  
Welcome*

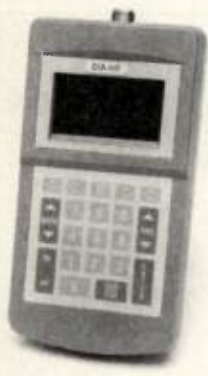
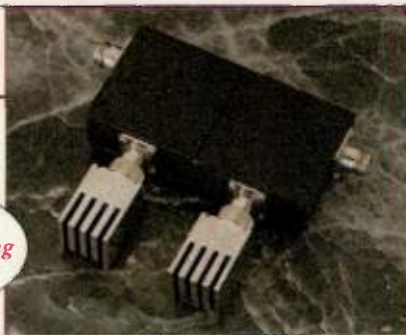


47 Gangamma Temple Road, Jalahalli P.O. Bangalore  
560013, India

Phone: 91-80-8385588 Fax: 91-80-8385988

Email: rcplin@giasbg01.vsnl.net.in Web: www.rcpl.com

INFO/CARD 98



## RF Instrumentation Requirements?

Consider This Low-Cost Portable Instrument

### CIA-HF™ Complex Impedance Analyzer

\$359.95 plus \$7.50 Shipping & Handling  
(Continental USA only)

The new AEA model CIA-HF Complex Impedance Analyzer represents a **major breakthrough** in RF instrumentation. Until now, it was necessary to spend over \$10,000 to obtain a graphical Complex Impedance Analyzer.

With the CIA-HF you can get a **graphical representation of SWR, Impedance, Resistance or Reactance** of an antenna or RF tuned circuit with respect to frequency. The CIA-HF has an internal **DDS (Direct Digital Synthesizer)** sweep or single frequency generator for excellent frequency accuracy, stability and spurious response. The keypad is a splash-proof membrane type with audible keystroke feedback. Easy for the layman production tester to use in the normal mode, or select the **Extra Features Mode** for access to all the powerful capabilities.

Packaged in a custom rugged plastic hand-held plastic enclosure, the CIA-HF is meant to be used in the field or laboratory with eight internal AA batteries or an external 12 - 16 VDC power source. The unit is small enough to take up a tower to place right at the feed-point of an antenna under test or to use on a lab bench without taking up much space. The graphical Liquid Crystal Display operates in low light or direct sunlight environments.

The frequency range for the standard CIA-HF is **400 kHz to 54 MHz in one kHz steps**. The impedance, resistance and reactance ranges are **0 to 1000 ohms in three ranges**. In addition to the graphical presentations, the CIA-HF will show the following parameters in digital format: **Relative Q factor, 2:1 SWR Bandwidth, Phase Angle (theta), Minimum SWR frequency, Sweep width/division, SWR at center frequency (Fc), Return Loss, Rough indication of Inductance or Capacitance values, DC Voltage (2 to 25 volts), (50 ohm) normalized impedance and the distance to first short or open in coaxial cable.**

A **serial port** is provided with firmware drivers to communicate with a Personal Computer for purposes of controlling the CIA-HF and for downloading data and graphs to a PC for future reference. Possible applications include but are not limited to **tuning: antennas or RF resonate circuits, feedline stubs, RF filters, MRI circuits, baluns and matching networks**. Use an external loop on the end of a short piece of coax to make the CIA-HF operate like a stable and backlash-free **grid dip oscillator** with a graphical display of the relative Q factor. A beeping tone gives **audible feedback of SWR** at a single frequency for hands-free tuning of an antenna or resonate circuit without even having to look at the CIA-HF.

We realize that to many this instrument may seem too good to be true. Order yours now and take advantage of our **two week money-back guarantee**. For full specs visit our web site or call for our brochure.



**AEA**

Division of Tempo Research Corporation

1221 Liberty Way, Vista, CA 92083 • Tel: 1-800-258-7805, FAX: 1-760-598-5634

www.aea-wireless.com, n7ml@imt.net

INFO/CARD 42

REF -69.2 dBm #AT 0 dB

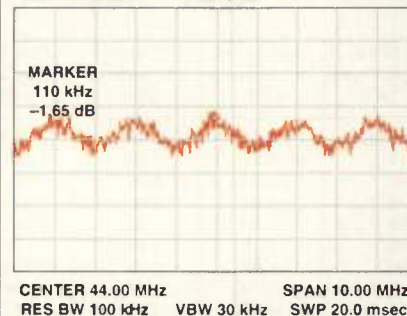


Figure 7. Spectrum analyzer plot with 5  $\mu$ s ech at -22 dBc.

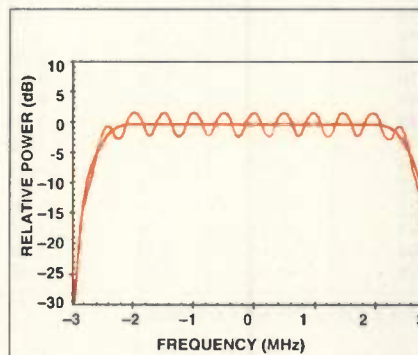


Figure 8. Simulation of a single 2  $\mu$ s echo at -1 dBc.

ples on a 64-QAM spectrum caused b multipath.

### Multiple echoes

In general there can be more than one echo at any given receiving location. On an analog signal, multiple echoes are seen as multiple ghosts, and each can be measured separately. With digital transmission, the AE compensates for each echo and the DFE values can be used to resolve multiple post echoes within the AE time range. Because the FFE itself creates additional echoes, it can be difficult to differentiate between these additional echoes and multiple pre-echoes in the propagation path.

It can also be difficult to interpret the spectrum analyzer ripples when multiple echoes are present. Figure 9 shows a simulation of a 64-QAM spectrum for the case of a single 0.8  $\mu$ s echo at -12 dBc. Figure 8 shows a single  $\mu$ s echo at -12 dBc. Although the result is simply the superposition of the two echoes, it can be difficult to recognize and separate the two patterns as seen in Figure 9.

If there are only two echoes and the



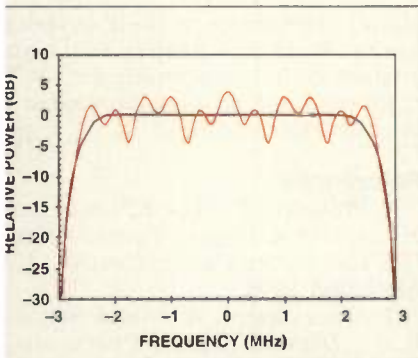


Figure 9. Simulation of double echo: 0.8  $\mu$ s @ 12 dBc and 2  $\mu$ s @ -12 dBc.

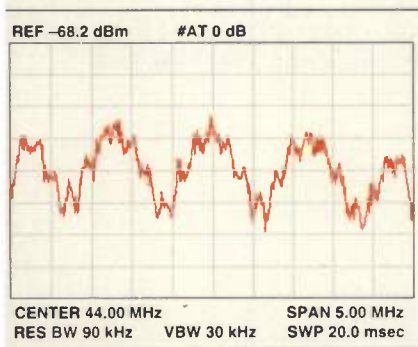


Figure 10. Multiple echoes: 0.8  $\mu$ s at -12 dBc and  $\mu$ s at -22 dBc.

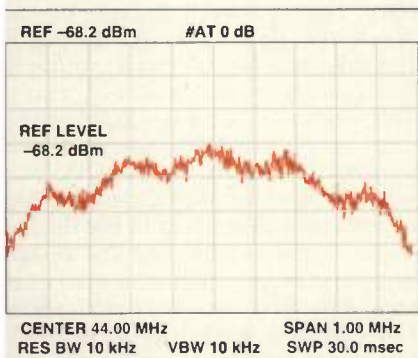


Figure 11. Zoom view of 5  $\mu$ s echo from Figure 0.

re fairly widely spaced in time, it is possible to recognize and measure the two patterns, demonstrated in Figures 0 and 11. Both the 0.8  $\mu$ s and the 5  $\mu$ s echo can be measured from the spectral plots below. Zooming in on the 5  $\mu$ s echo is required to obtain an accurate measurement.

If there are more than two echoes and they are not spaced widely in time, it can be difficult to recognize the individual ripple patterns. The discrete Fourier transform (DFT) is a mathematical technique that can be

used to reveal repetitive patterns. The fast Fourier transform (FFT) is a computer algorithm that is used to calculate the DFT in an efficient manner. The spectrum analyzer data can be captured, and an FFT algorithm can be used to resolve the individual echoes. The process of taking an FFT

of a spectrum is called Cepstral analysis [2].

### Conclusion

Various techniques for measuring multipath have been examined. The techniques presented can be used by wireless cable operators to characterize

# DUPLXERS

## for Wireless Communications



- Injection Molded Thermoplastic Technology
- 40% Mass Reduction
- Superior Thermal Stability
- Low Cost Volume Production

| Model Number                                   | Passband  |           | Insertion Loss |        | Isolation          |        | Weight (g / oz) |
|--|-----------|-----------|----------------|--------|--------------------|--------|-----------------|
|  | Rx (MHz)  | Tx (MHz)  | Rx & Tx (dB)   | VSWR   | Rx-Tx & Tx-Rx (dB) |        |                 |
| PCS  |           |           |                |        |                    |        |                 |
| 4744   | 1850-1890 | 1930-1970 | 1.0            | 1.35:1 | 55                 | 171/6  |                 |
| 4745A  | 1850-1865 | 1930-1945 | 1.0            | 1.35:1 | 65                 | 171/6  |                 |
| 4745B  | 1870-1885 | 1950-1965 | 1.0            | 1.35:1 | 65                 | 171/6  |                 |
| 4745C  | 1895-1910 | 1975-1990 | 1.0            | 1.35:1 | 65                 | 171/6  |                 |
| 4757   | 1850-1910 | 1930-1990 | 1.0            | 1.35:1 | 65                 | 475/17 |                 |
| PCS (With Integrated Diversity Receive Filter) |           |           |                |        |                    |        |                 |
| 4773   | 1850-1910 | 1930-1990 | 1.2            | 1.35:1 | 60                 | 690/24 |                 |
|  | 1850-1910 | —         | 0.9            | 1.35:1 | 60                 |        |                 |
| GSM  |           |           |                |        |                    |        |                 |
| 4777   | 880-915   | 925-960   | 1.0            | 1.20:1 | 75                 | 820/29 |                 |
| 4779   | 876-901   | 921-946   | 1.2            | 1.35:1 | 90                 | 820/29 |                 |
| DCS-1800                                       |           |           |                |        |                    |        |                 |
| 4778   | 1710-1785 | 1805-1880 | 0.9            | 1.20:1 | 75                 | 790/28 |                 |

Typical Performance @ +25°C. Operating Temperature: -35°C to +85°C



**TELEDYNE**  
**ELECTRONIC TECHNOLOGIES**  
*Microwave Components*

An Allegheny Teledyne Company

1274 Terra Bella Avenue, Mountain View, CA 94043  
 Phone: 650.962.6944 Fax: 650.962.6845  
 e-mail: sales@mview.tet.com





# HF LINEAR AMPLIFIERS - BROADBAND TRANSFORMERS



## HF AMPLIFIERS per MOTOROLA BULLETINS

Complete Parts List for HF Amplifiers Described in the MOTOROLA R.F. Device Data

|            |            |
|------------|------------|
| AN758 300W | EB63 140W  |
| AN762 140W | EB27A 300W |
| AN779L 20W | EB104 600W |
| AR313 300W | AR305 300W |

## NEW!! 1K WATT 2-50 MHz Amplifier

MOTOROLA AR347

## POWER SPLITTERS and COMBINERS

2-30MHz

|                      |          |
|----------------------|----------|
| 600 Watt PEP 2-Port  | \$ 69.95 |
| 1000 Watt PEP 2-Port | \$ 79.95 |
| 1200 Watt PEP 4-Port | \$ 89.95 |

## 2 METER VHF AMPLIFIERS

|                    |              |
|--------------------|--------------|
| 35 Watt Model 335A | \$ 79.95 Kit |
| 75 Watt Model 875A | \$119.95 Kit |

Available in kit or wired/tested

For detailed Information and prices, call or write for our free catalog.

## 100 WATT 420-450 MHz PUSH-PULL LINEAR

## AMPLIFIER — SSB-FM-ATV

|                      |          |
|----------------------|----------|
| KEB67-PK (Kit)       | \$159.95 |
| KEB67-PCB (PC Board) | \$ 18.00 |
| KEB67-I (Manual)     | \$ 5.00  |

We also stock Hard-to-Find parts

|                                  |         |
|----------------------------------|---------|
| CHIP CAPS—Kemet/ATC              |         |
| METALCLAD MICA CAPS—Unelco/Semco |         |
| RF POWER TRANSISTORS             |         |
| MINI-CIRCUIT MIXERS              |         |
| SBL-1 (1-500MHz)                 | \$ 6.50 |
| SBL-1X (10-1000MHz)              | \$ 7.95 |

## ARCO TRIMMER CAPACITORS

Broadband HF Transformers

Add \$4.50 for shipping and handling.

www.communication-concepts.com



**CCI Communication Concepts Inc.**

508 Millstone Drive • Beavercreek, OH 45344-5840 • (937) 426-8600  
FAX (937) 429-3811 • E-mail: cci.dayton@pobox.com

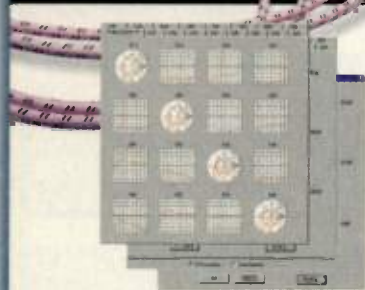


INFO/CARD 43

## Differential and multi-port device characterization just got a whole lot easier.



ATN - 4000 System



An easy-to-use windows-based graphical interface allows measurements to be displayed in a number of different ways.

### A fully loaded multi-port measurement solution

Tools to thoroughly characterize balanced circuits such as baluns and differential circuits.

Powerful user-defined display capability to calculate important parameters

True multi-port error correction

Full network analyzer functionality

Complex characterization of multi-port devices is now a whole lot easier. Devices such as couplers, baluns, transistors, differential circuits, and balanced transmission lines that were once difficult to measure using conventional two-port measuring systems, can now be completely and accurately tested with ATN's 4000 Series Multi-port Test Systems. With one connect on you can now test both single-ended or balanced topologies across the RF and Microwave range. Whether your application is for an engineering or manufacturing environment, this family of products can save you valuable time and money and help you achieve higher levels of productivity.

Call or visit our Web site for more information.

**atnmicrowave**

85 Rangeway Road, North Billerica, MA 01862-2105 USA  
978-667-4200 • Fax 978-667-8548 • www.atnmicrowave.com

signal conditions in their coverage areas. With the proper tools and analysis techniques, multipath can be minimized and possibly eliminated at the subscriber's home.

RF

## References

1. Waltrich, J., "The Effect of Long Multipath on Digital Transmission," *IBC Conference Publication No. 428*, September 1996.

2. Oppenheim, A.V. and Schafar, R.W., *Digital Signal Processing*, Prentice-Hall, 1975 Englewood Cliffs, NJ.

3. Jeruchim, Michel C., Balabar Philip and Shanmugan, K. Sam, *Simulation of Communication Systems*, Plenum Press, 1992 New York.

## About the authors

Marc Ryba is a lead engineer and supervisor with General Instrument's (GI's) Digital Special Projects/Digital Network Systems. He holds a B.S.E.E. from New Jersey Institute of Technology in Newark, NJ, and a M.S. degree in Computer Engineering from the National Technological University in Fort Collins, CO. His accomplishments include authorship of multiple publications in the field of digital transmission, and the design and implementation of a one-year trial of the first Personal Communications System operating in a CATV environment. Other achievements include the first field trial of 256QAM in a CATV environment. He can be reached at 215-323-1000 or by e-mail at mryba@gi.com.

Mark Kolber is a senior staff engineer with General Instrument (GI) in Horsham, PA. He holds a B.S.E.E. from New Jersey Institute of Technology and a M.S.E.E. from Arizona State University. Prior to joining GI, he worked as an RF Engineer for Honeywell in Phoenix, AZ, Aircraft Radio Corp. in Boonton, NJ, and Blonder Tongue Labs in Old Bridge, NJ. He can be contacted at 215-323-1000 or by e-mail at mkolber@gi.com.



# Novel designs for elliptic bandstop filters

A new way to design elliptic bandstop filters may lessen frustrations.

By Philip R. Geffe

Designers of RF bandstop filters are often frustrated by the discovery that their numerical design cannot be built as a practical lumped element filter because of extreme element spread.

The design of a 50 Ω bandstop filter

centered at 400 MHz, with a bandwidth of 20 MHz, illustrates this point. If an elliptic lowpass prototype having three ladder branches, 0.1 dB passband ripples and a 30 dB stopband is chosen, it is apparent that no choices other than those already made are available (not counting the dual circuit, which offers no improvement). Every calculation is determined in advance, so that only one

final design is possible. This design is shown in Figure 1, with the simulated ideal frequency response in Figure 2.

If this were a bandpass filter, various transformations would be available to make the circuit feasible, but that is not available here. The design is totally inflexible. Note that the element spread for both inductors and capacitors is an appalling figure of 844. At this frequency, inductors that are near 20 nH are desired, but the shunt branches of the filter use inductors that are more than 400 nH, and the series branch coils are less than 1 nH. Any coils built with these values would have a poor Q at 400 MHz.

**Making transformations possible**  
Transformations that are desirable—

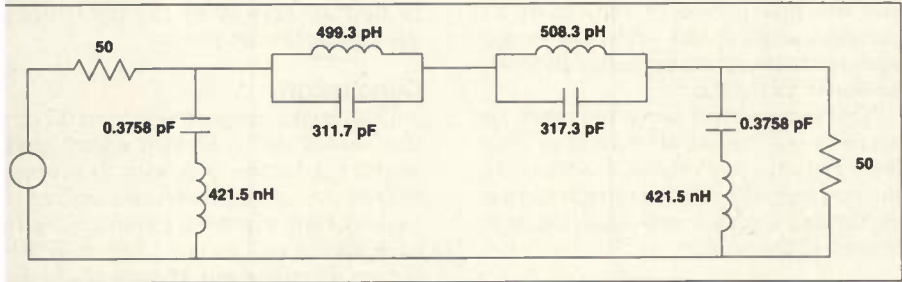


Figure 1. Conventional bandstop filter.

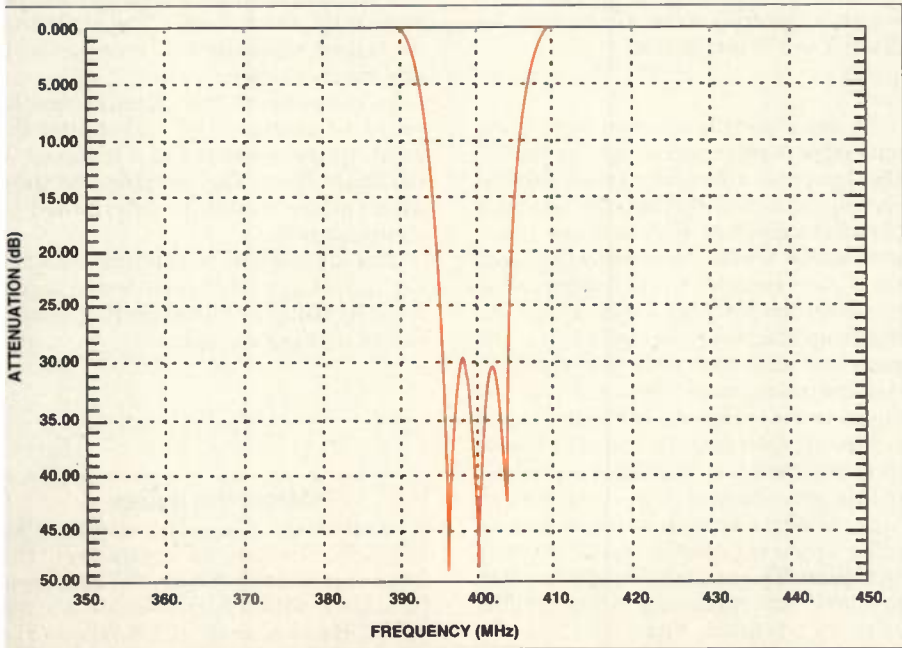


Figure 2. Bandstop filter response.

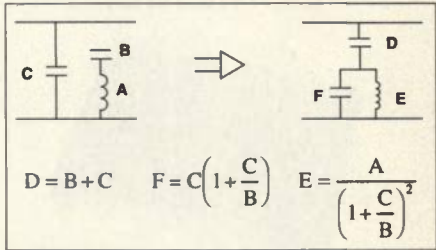


Figure 3. Shunt circuit.

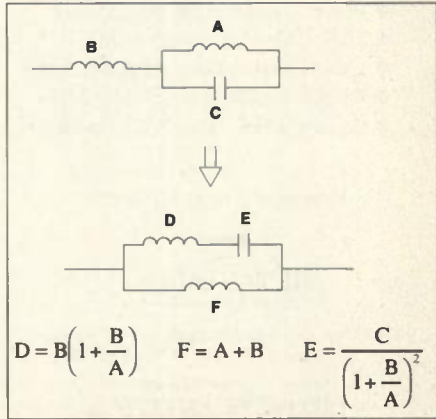


Figure 4. Series circuit.



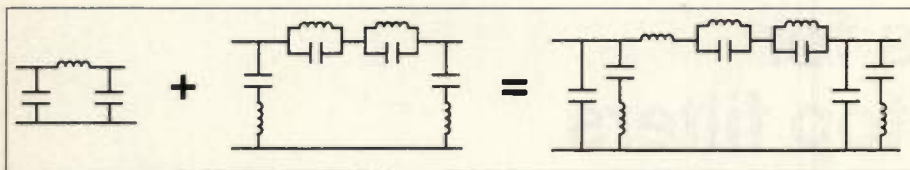


Figure 5. Example of interleaving.

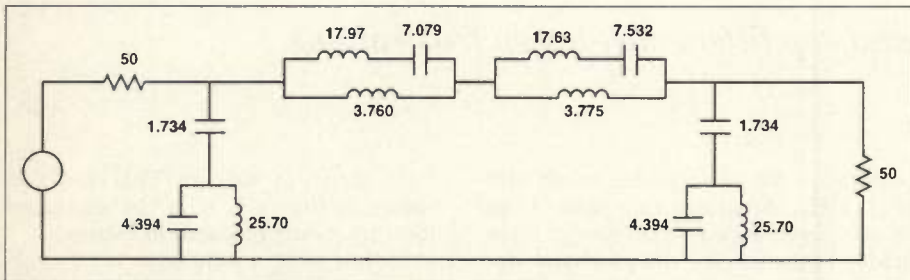


Figure 6. Filter with low inductance spread.

because they are useful in other circuitry—are the dipole transformations of Figures 3 and 4. Observe that they both require two-terminal networks containing three elements rather than two. This suggests combining the notch circuit with a lowpass or other filter cir-

cuit to obtain three-element dipoles. This method is illustrated in Figure 5: a process called “interleaving.” This means that two ladders of the same size are interleaved by combining the corresponding shunt branches in parallel, and the series branches in series, as shown in the figure.

This process will serve to embed the notch in the passband of another filter. Now that three-element branches are in the filter, the dipole transformations of Figures 3 and 4 will apply to every branch of the ladder.

### Optimizing the element spread

Now let  $y$  = inductance spread, and  $x$  = bandedge frequency of the lowpass filter.  $Y$  is a function of  $x$ :

$$y = f(x)$$

To evaluate this function for a given bandedge frequency,  $x$ , begin by finding the lowpass element values for the chosen value of  $x$ . Because the bandstop element values of Figure 5 are fixed, writing the lowpass element values into the figure completes the design. Now, partition the lowpass series coil of the bandstop filter into two equal parts, and associate each part with one of the series antiresonances. Then perform the dipole transformations of Figures 3 and 4. Finally, calculate the element spread thus obtained (i.e., the function value). If this procedure is performed enough times to plot a smooth curve, it will become apparent that it has a definite minimum. The bandedge frequency that produced this minimum is the optimal value for a practical filter.

Applying this procedure to the pre-

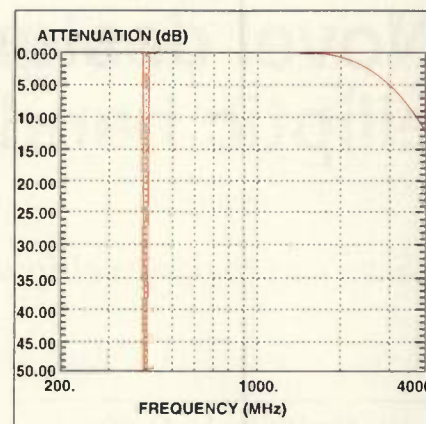


Figure 7. Attenuation of low spread filter.

vious numerical example gives the design of Figure 6, with its response shown in Figure 7. The inductance spread is reduced from 844 to 6.8, and the capacitance spread is reduced from 844 to 4. Although the upper passband is not limited, it appears to be wide enough for many applications. It would, of course, be limited anyway by the parasitics of the circuit, though less so.

### Conclusion

One might suspect that partitioning the series coil into two equal parts might not be the best way to proceed. Maybe using multivariable optimization to find the best partitioning for each series coil in the filter would be better. It turns out that a slight improvement can be achieved this way but the largest improvements obtained were only about 3–4%. The algorithm described previously is more reliable and much simpler.

It is apparent that similar results could be obtained by embedding the notch in the passband of a highpass or bandpass filter. The usefulness of these alternatives would be determined by circumstances.

The numerical minimum obtained for the design of Figure 6 was calculated by using a Golden Section search not by plotting a graph.

RF

## The Second Generation Quad Combiner



- Power: 70 Watts cw per channel
- High Isolation: 70 dB (min)
- Low Insertion Loss: <7.0 dB(max)
- Frequency Ranges: 850-870 MHz
- Compact Size: 10 x 7 x 2 (inches)

For More Information Visit

[www.rec-usa.com](http://www.rec-usa.com)

**RENAISSANCE**  
ELECTRONICS CORPORATION

1300 Mass Ave. ~ Boxborough, MA 01719, USA  
(978) 263-4994 ~ Fax (978) 263-4944

Email: [rec-info@rec-usa.com](mailto:rec-info@rec-usa.com)

**ISO 9001 CERTIFIED**

### About the author

Phil Geffe is a senior engineer at PULSE Division of Technitrol. He was once a math major, but has been working with LC filters for a long time. He is also an IEEE fellow. He can be reached at 619-674-8224.



# ECL line receivers used as amplifiers: How do they work?

The ECL differential line receiver has been used in amplifier and limiter applications. But did you know about its analog capability?

By Tom Balph  
and Bill Morgan

Figure 1 shows a circuit schematic and symbol of a traditional emitter coupled logic (ECL) line receiver. The receiver is a simple emitter-coupled current switch with emitter-follower output buffers to provide low-impedance drive. Resistors  $R_B$  are sometimes not shown because they offer low-impedance (50–75  $\Omega$ ) and are present to keep the input transistor base complex impedance a positive real value over frequency and switching conditions. An ECL line receiver is normally specified with  $V_{EE} \approx -5.2$  Vdc and  $V_{CC} @ Gnd$ , but it is not uncommon to operate an ECL with  $V_{CC} \approx +5.0$  Vdc and  $V_{EE} @ Gnd$  (commonly called positive-ECL or PECL). Although essentially the same circuit, more modern devices will vary some-

| DEVICE    | SUPPLY VOLTAGE | STAGES /RCVR | GAIN @ 100 MHz (dB) | INPUT RESISTORS | RCVRS/PACKAGE | PACKAGE |
|-----------|----------------|--------------|---------------------|-----------------|---------------|---------|
| 10H116    | 5.2            | 1            | 17                  | NO              | 3             | PLCC 20 |
| 10E116    | 5.2            | 1            | 19                  | YES             | 6             | PLCC 28 |
| 10EL16    | 5.2            | 2            | 30                  | YES             | 1             | SOIC 8  |
| 100LVEL16 | 3.3            | 2            | 29                  | YES             | 1             | SOIC 8  |
| 100LVEL17 | 3.3            | 2            | 29                  | YES             | 4             | SOIC 20 |

Table 1. Several line receiver characteristics.

what from the traditional model. Perhaps the most significant deviation is that some receivers have two DC-coupled stages (shown symbolically in Figure 2). The net result is higher gain as well as important implications on biasing techniques because of the DC-coupling. Other deviations can include devices rated for 3.3 VDC operation, better common mode range, fewer receivers per package (lower cost and smaller package) and better electrostatic discharge (ESD) protection with input re-

sistor bias and pulldown networks.

With the model shown in Figure 1, which has no input resistor network, any unused line receiver in a package should have one input tied to the provided  $V_{BB}$  bias voltage. This supplies base current to one transistor of the switch. If this is not done, the current source transistor will be starved for current that loads the internal  $V_{CS}$  voltage source and disrupts proper operation of the rest of the line receivers. Alternately, the input resistor networks on newer devices provide a known bias condition to any line receiver not in use. The switch current source is not disrupted, and the unused line receiver is in a known condition. Figure 2 also shows a typical bias network with resistor values nominally 75  $k\Omega$ . Perhaps the main implication for RF applications is the impact on input impedance.

Table 1 provides a listing of several available ECL line receivers.

### Line receiver AC test configuration

To test the response curves of the ECL line receivers, a network analyzer was used in the configuration shown in Figure 3a. The analyzer output drove a 20 dB pad, connected to the device-under-test (DUT). The output of the DUT drove a 6 dB pad that was in line with the analyzer input. The pads were required to put the test voltages in the desired range.

The test circuit for the DUT is shown in Figure 3b. The input signal from the 20 dB pad is terminated with a 50  $\Omega$  load and AC-coupled to the input of the re-

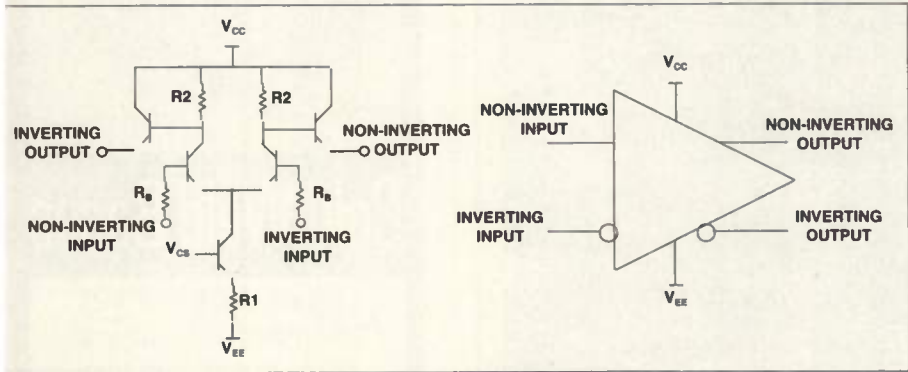


Figure 1. Simple circuit schematic and symbol of a traditional ECL line receiver.

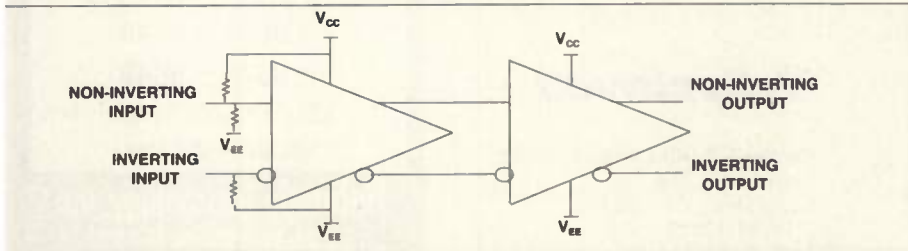


Figure 2. More recent line receivers can be comprised of two DC-coupled stages and include input bias networks.



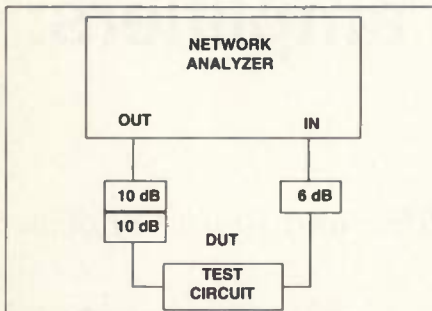


Figure 3a. ECL line receiver test configuration.

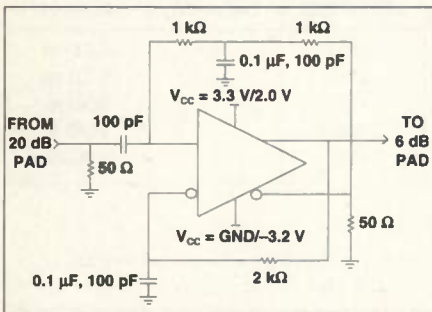


Figure 3b. Test circuit for ECL receiver.

ceiver under test. The non-inverting receiver output drives the 6 dB output pad.

The line receiver requires a proper biasing network as shown in Figure 3b for AC operation. Because of the DC-coupling of the two-stage receivers, feedback is required in the bias scheme to overcome the input differential offset voltage so that the line receiver can amplify low level signals. The bias network has a 2 kΩ feedback resistor from the non-inverting output to the inverting input, and two equivalent 1 kΩ resistors in series from the inverting output to the non-inverting input. On a DC basis, this differential feedback biases the amplifier in the center of the linear region and overcomes the input offset voltage. To allow AC operation, the AC feedback is bypassed by capacitance to ground at the inverting input and a similar network at the junction of the 1 kΩ feedback resistors. Note that the bypass networks consist of a 0.1 μF and a 100 pF capacitor in parallel. Finally, a 50 Ω resistor to ground on the inverting output is added to bal-

ance the 50 Ω loading caused by the dB pad on the non-inverting output.

The supply voltages in Figure 3b also require some comment. When testing ECL, the power supply voltages are split to allow the emitter-follower outputs to drive 50 Ω to ground. In a 5.0 VDC supply situation,  $V_{CC}$  is +2.0 VDC and  $V_{EE}$  is -3.2 VDC (equivalent to a normal total supply voltage of 5.2 VDC). For the 3.3 VDC supply devices  $V_{CC}$  is 3.3 VDC and  $V_{EE}$  is ground. The power supply voltages were altered as required by the DUT.

### Test results

Using the test configuration discussed previously, curves were run for the line receivers listed in Table 1. Both low level input voltage gain and phase angle versus frequency were obtained. Figure 4 shows low-level gain versus frequency and Figure 5 shows phase angle versus frequency. Observe that the two-stage devices have higher gain than the two single-stage devices. Also, most of the later technology devices have usable

## Collins Mechanical Filter Low-Cost Product Line Expanded

**NEW!**

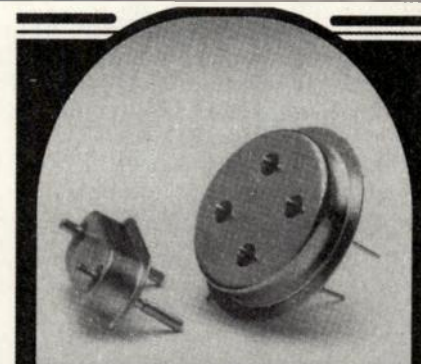


### YOUR CUSTOMER DESERVES THE BEST

- Bandwidths of 300Hz, 500Hz, 2.5kHz, 5.8kHz, 7.0kHz and 10kHz now available.
- 455 kHz Center Frequency
- Small, Reliable, Rugged
- Volume Pricing As Low As \$20.00



**Rockwell Collins Filter Products**  
2990 Airway Ave.  
Costa Mesa, CA 92626  
(714) 641-5315  
FAX: (714) 641-5320



## Cold Weld Bases

Copper clad Kovar with  
7052 glass (clear optional).  
Plated to customer spec.

- HC-18 • HC-37
- HC-35 • HC-40
- HC-36 • HC-45

Also: Resistance and  
Solder Seal Bases.

**Hermetic Technology, Inc.**  
P.O. Box 893, Windham, NH 03087  
(603) 882-1748



bandwidth as high as 0.9–1.0 GHz.

### Conclusion

Since its inception, the ECL line receiver has been useful as an economical low-level amplifier and limiter. The newer devices provide higher gain (25–30 dB) and bandwidth out to the GHz region. For many applications, the 10LVEL16 and the 10EL16 provide the best solution with a single amplifier in an SOIC 8 package; the main difference being the need for a 1.3 Vdc vs. a 5.0–5.2 Vdc power supply. All of these devices provide 50  $\Omega$  drive capability (with a maximum of about 22–25 nA drive). The user must note that the ECL outputs are limited to about 600–800 mV swings depending on the device.

For users familiar with line receivers as amplifiers, be sure to note the discussion about the bias network used in the tests. Older bias techniques that do not use feedback will not work well with the two-stage line receivers. The offset voltage of the first stage is amplified by the gain of the second stage such that simple non-feedback biasing is not suitable.

RF

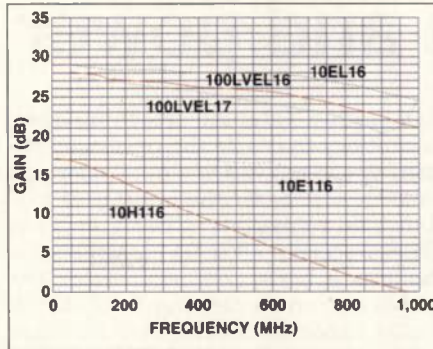


Figure 4. MECL voltage gain vs. frequency at low level input voltage (1.8 mVrms).

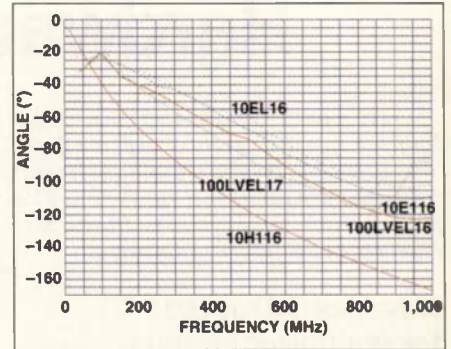


Figure 5. MECL phase angle vs. frequency high or low level.

### About the authors

Tom Balph is a senior member of the technical staff of Motorola, where he has been for 29 years. He currently defines and implements digital system functions on silicon. Other experience includes extensive work with LAN serial communications and ECL applications and design. He can be reached at 602-755-2504 or by e-mail at [rgd210@email.sps.mot.com](mailto:rgd210@email.sps.mot.com).

Bill Morgan, recently retired, spent 33 years at Motorola as an RF lab technician. He was heavily involved in the evaluation and applications support of PLL and frequency synthesizers. Other experience includes significant RF small signal device evaluation and support.

All the devices mentioned in this article are available from Motorola.

# Quality

We have designed over 7000 unique RF components.

Many of those devices are application specific for test equipment, medical, automotive and cellular/PCS requirements.

With over 18 years of experience with innovative products and consistently exceeding the expectations of our customers, JFW provides the highest quality and cost effective solutions available in the industry.

#### Attenuators:

Fixed: DC-26.5GHz  
Rotary: DC-4GHz  
Programmable: DC-5GHz

#### Power Dividers:

Wilkinson: 800-2100MHz  
Resistive: DC-4GHz

#### RF Switches:

Solid State  
Reflective  
Absorptive  
Ranges up to 3GHz

#### Accessories:

DC Blocks up to 18GHz  
Impedance Matching Pads to 3GHz  
RF Detectors  
Feed thru Terminations

## JFW Industries, Inc.

5134 Commerce Square Drive • Indianapolis, Indiana 46237  
Tele. (317) 887-1340 Fax (317) 881-6790

Internet— <http://www.jfwindustries.com>

E-mail— [sales@jfwindustries.com](mailto:sales@jfwindustries.com)

ISO 9001 Certified

See us at Booth #338 at the Wireless Symposium!

INFO/CARD 16





# Hardware and power products

*Each month, the product focus highlights a specific area of RF products and provides product announcements from that area in a special section. This month, the product focus highlights hardware and power technologies.*

### Advanced dielectric for multilayer circuits

The MULTISYST 7061D is an advanced thick-film multilayer dielectric for the construction of multilayer circuitry. The 7061D dielectric is designed to meet the needs of increasingly complex multilayer circuits, providing dense and hermetic film at a fired thickness of 40 microns. This dielectric is compatible with a wide range of gold conductors as well as silver and palladium-silver conductors. The 7061D dielectric represents the most advanced combination of high-temperature glass chemistry in conjunc-

tion with a patented screening agent technology to enable the consistent processing of 8 mil vias while still offering a smooth surface for the printing of fine-line gold connectors. Closely matched TCE properties allow for construction of complex hybrids, and the dielectric provides manufacturers the flexibility to build complex and low-cost packages with either silver or gold connectors for the inner and top layers.

**EMCA-REMEX**  
**INFO/CARD 164**

### Dual output power modules for DSPs

The PT6920 series of dual output, integrated switching regulators (ISRs) is designed to power the latest generation of dual voltage digital signal processors (DSPs) including Texas Instrument's C6000 series. These dual

25 W power modules are available with 3.3 V/6 A and 2.5 V/2.2 A fixed output voltages. The second output can also be selected for 1.8 V to accommodate the next generation of DSP chips. Both output voltages are independently adjustable with an external resistor with the second output voltage adjustable to as low as 1.2 V. The 5 V input voltage makes it easy for inclusion into existing power systems. Housed in a 23-pin SIP package, the PT6920 series is available in surface mount, vertical and horizontal through-hole configurations. The series is priced at \$24.20 in quantities of 1,000.

**Power Trends**  
**INFO/CARD 165**

### Integrated dual supply power management circuit

The CMPWR-100 is a fully integrated

WE  
'RE



COOL

We offer a full line of competitively priced, superior quality SMD and Thru-Hole quartz crystals and oscillators. Call us today for more information and a FREE Product Guide. Standard and Custom specifications available.

**Experience our "Personal Touch" Customer Service!**

ISO 9002 Certified

**EDC**

ISO 9002 Certified

electro dynamics crystal corp • [www.electrodynamics.com](http://www.electrodynamics.com) • Tel: (913) 888-1750 • (800) EDC-XTAL

INFO/CARD 76



ual supply power management circuit. Unlike other integrated products that require an external switch, the CMPWR-100 integrates the regulator, switch and controller into a single 8-pin SOIC package, eliminating the need for additional components. This component integrates all the functions required to deliver 200 mA output current from either an on-chip 5 V to 3.3 V LDO regulator or from 3.3 V auxiliary supply via an internal switch. The CMPWR-100 is priced at 95 cents in quantities of 10,000.

**California Micro Devices**  
**INFO/CARD 166**

**Linear, low-noise power supplies**

The ATE-DMG series of 1,000 W instrument-grade, linear low-noise power supplies feature a built-in IEEE 88-2 bus interface for full talk-listen test-system interact ability. These power instruments respond to both the SCPI command set and to analog inputs that range from DC to high

**VCXO; TCXO  
VCTCXO  
Quick-Turn**

- Shipped in 2~4 weeks
- ◆ 3 V or 5 V
  - ◆ Sine or square wave
  - ◆ Surface mount or thru-hole; Standard DIP; Low profile DIP; Gull wing; 9.6x11.4 leadless
  - ◆ Quick-turn from Mercury United; High volume and low cost from Mercury Taiwan and Mercury Philippines

 **MERCURY UNITED ELECTRONICS INC.**  
 Since 1973

10823 Edison Court,  
 Rancho Cucamonga CA 91730  
<http://www.mecxtal.com>  
 e-mail: mercury@mecxtal.com  
 TEL: (888) 310-8382  
 FAX: (909) 466-0762

INFO/CARD 61



**RF POWER SOURCES**

- 1.8 to 1000 MHz
- 20 to 10,000 Watts

HENRY RF Power Sources have been a standard of reliability for over 30 years. Thousands are in use in scientific, industrial, medical and semiconductor manufacturing installations around the world.

Tell us what you need. If we don't have it, we'll design it for you.

**1.800.877.7979**



# HENRY RADIO

2050 S. Bundy Drive, Los Angeles, CA 90025  
 Phone: 310.820.1234 FAX: 310.826.7790  
[www.henryradio.com](http://www.henryradio.com)

INFO/CARD 51



**WORLD'S SMALLEST  
HIGH FREQUENCY MLCC**

New 0402 sized high frequency MLCC's exhibit excellent Q and ESR performance at frequencies up to 4.0 GHz. Ideal in wireless applications like cellular handsets, wireless LAN modules, cable modems, and CATV components where small size and high performance are desired.

Visit [www.johanson-caps.com](http://www.johanson-caps.com) for more details

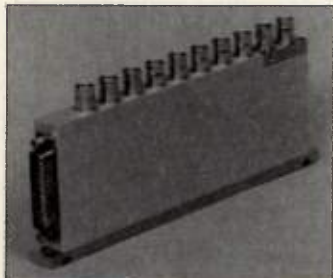
**JOHANSON TECHNOLOGY** 

Camarillo, California  
 Tel (805) 389 1166  
[www.johanson-caps.com](http://www.johanson-caps.com)

INFO/CARD 56



## FOR IMMEDIATE RELEASE



Contact: Matrix Systems, 5177 Douglas Fir Road,  
Calabasas, CA. 91302  
(818) 222-2301 FAX (818) 222-2304  
E-mail tech@matrixsystems.com  
www.matrixsystems.com

### Coaxial Relay Incorporates A Built-In R.F. or Video Amplifier

Matrix Systems Model 76A00 Coaxial Relay incorporates a built-in R.F. or Video Amplifier which is convenient when assembling Non-blocking Matrices or when simply a Gain Block is needed in conjunction with a Coaxial Relay.

The module is Self-Terminating, allowing it to mate with Power Splitters which always need to be terminated. The unit can be used independently or can be incorporated in Matrix Systems' Model 11600 Controller Chassis which provides RS-232, RS-422, IEEE-488 and Keypad Control.

The module's frequency response of DC to 800 MHz makes it ideal for Switching Wideband R.F./I.F. or Fast Rise Video/Pulse Signals.

INFO/CARD 54

audio signals. A 24-key keypad augments the rotary voltage and current controls and a two-line, 16-character liquid crystal display (LCD) replaces the meters. This display shows both the settings and actual voltage and current readings. The output ripple and peak-to-peak noise are around 100  $\mu$ V root mean squared (RMS). The source-load effects are less than 0.001% with 12-bit digital resolution. Their fast-mode bandwidth also allows users to operate them as true current stabilizers with fast load recovery. The series is priced from \$3,868-4,100.

**Kepeco**  
INFO/CARD 167

### RF peak power meter for wideband modulation formats

The 4530 series RF power meters can make high-speed peak and continuous wave (CW) power measurements from 10 kHz to 40 GHz, depending on the sensor, across a 20 MHz video bandwidth. Designed for measuring signals

based on wideband modulation format the 4530 series has the capability of having two independent channels that allow a variety of measurements to be made, including maximum power, peak power, average power, peak-to-average power ratio, dynamic range, minimum power, CW power and RF voltage. In addition, the peak power meter provides channel math functions that allow the sum ratio to be displayed, as well as the difference between channels or between a single channel and a reference measurement. The meter also includes statistical analysis features such as histograms and cumulative distribution functions (CDFs), so it can conduct fast analysis of complex signals including code-division, multiple access (CDMA) and high-definition television (HDTV). The peak power meter can also perform time domain power measurements for global system for mobile communications (GSM) and time-division multiple access (TDMA) signals.

**Boonton Electronics**  
INFO/CARD 168

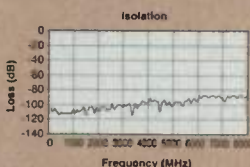
## Broadband Switch Features 100 dB Isolation

ATN 5101

The ATN-5101 SP2T Switch uses advanced GaAs and PIN diode technology to achieve 100 dB isolation and 1.4:1 max VSWR from 300 kHz to 6000 MHz. It also includes a built-in driver that is TTL controlled. This compact device is 2" x 1.5" x .8" and is ideal for next generation signal routing and test and measurement applications. Standard models and custom configurations are available for fast delivery. For a complete datasheet visit [www.atnmicrowave.com](http://www.atnmicrowave.com).



- High Isolation
- Ultra Broad Band
- Superior Match
- Non-Reflective
- Integrated Driver



**atnmicrowave**

85 Rangeway Road, North Billerica, MA 01862-2105 USA  
978-667-4200 • Fax 978-667-8548 • [www.atnmicrowave.com](http://www.atnmicrowave.com)

Mastercard and Visa Accepted

INFO/CARD 64



PORTABLE TELECOM DEVICES

PLL APPLICATIONS

WIRELESS



**MVS series**  
**SURFACE MOUNT**  
**VCXO**  
**with tristate**



### SPECIFICATIONS

- Package: 14.0 x 9.0 x 4.7mm J-leaded ceramic package utilizes a standard footprint
- Frequency: 3.00 to 50.00MHz
- Stability:  $\pm 25$ ppm over a temperature range -40° to 85°C
- Tristate output is an option in a 6-lead package
- Pullability:  $\pm 100$ ppm is achievable with a 0.5V to 4.5V control voltage
- Grounded lid provides for reduced EMI emissions
- Well suited for PLL applications in telecommunications/wireless equipment

**M-tron**  
INDUSTRIES, INC.

PO Box 630, Yankton, SD 57078-0630  
1-800-762-8800 • FAX 605-665-1709  
[www.mtron.com](http://www.mtron.com)

ISO 9001

INFO/CARD 21



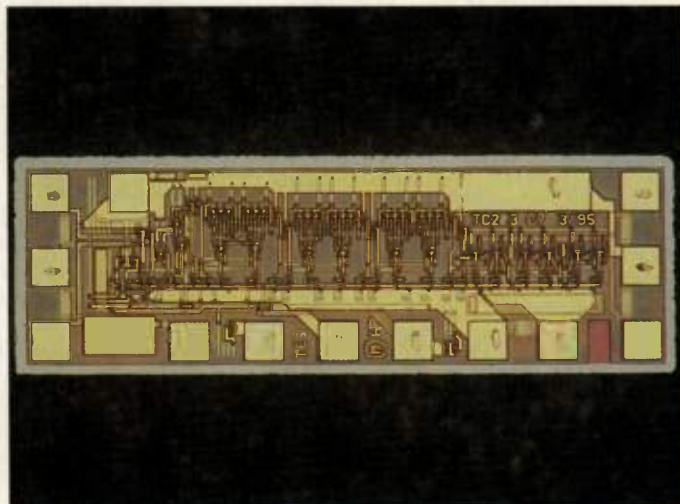
# RF products

## First microwave ICs using GaAs HBT technology available

A series of eight microwave integrated circuits (ICs) feature indium-gallium-phosphide (InGaP)-mitter, gallium arsenide (GaAs) heterojunction bipolar transistor (HBT) technology. The benefits of HBT technology include the potential for high gain per stage, operation from a single power supply voltage, low phase noise, high linearity and good uniformity and repeatability to ensure high production yields. The eight products include six prescalers, three operating at

60 mA current in low output power mode (one divide-by-two, one divide-by-four and one divide-by-eight) and three operating at 30 mA current in low power mode, and two Darlington-feedback HBT amplifier chips, one having a DC-15 GHz frequency range and the other a DC-20 GHz frequency range. Prices for the ICs are \$27.35 for the prescalers and \$15.10 and \$21.40 for the amplifiers, respectively, in quantities of 1,000-2,499.

**Hewlett-Packard**  
INFO/CARD 133



## Amplifier meets Bellcore specification

The 15T4G18 travelling wave tube (TWT) microwave amplifier tests to the higher frequency radiated RF requirements of the Bellcore specification for telecommunications. The amplifier has a frequency response from 1.2-18 GHz and offers 15 W minimum output standard, 10 W minimum in a choice

## Vector network analyzers

The MS462x family of RF vector network analyzers is the first such instrument to



incorporate noise-figure measurement capability. Features include a tune mode that maintains full 12-term calibration while optimizing sweep speed and fully error-corrected measurements that can be made at sweep speeds as high as 150  $\mu$ s per point. Four models are available. Two are equipped with non-reversing transmission reflection test sets with frequency ranges from 10 MHz to 3 GHz and 10 MHz to 6 GHz. The other two incorporate reversing test sets for automatic forward and reverse S-parameter measurements from 10 MHz to 3 GHz and 10 MHz to 6 GHz.

**Anritsu**  
INFO/CARD 135

## Fixed frequency and smart synthesizer

The PSF-2510 fixed frequency synthesizer for wireless applications consists of a basic frequency synthesizer and an internal microcontroller that is used to program the synthesizer's high-performance phase lock loop (PLL) chip. The synthesizer is suitable for applications ranging from fixed frequency operation to other complex modes without the need of external control. The synthesizer operates at a frequency of 2,510 MHz having a cur-



rent of less than 38 mA with a 5 V supply. The phase noise of the synthesizer is -105 dBc/Hz at a 10 kHz offset. The synthesizer can be built using any voltage-controlled oscillator (VCO).  
**Princeton Elec. Systems**  
INFO/CARD 136

## Boost channel capacity

This multichannel, high-power transmitter combiner



can be configured in nine combinations covering a frequency range of 850-870 MHz with no tuning required. Packaged in a standard EIA 3.5" high, 19" rack mounting, the unit has integral fan cooling for as much as 400 W dissipation with wiring provided for 18-70 VDC operation. Designed for either code-division, multiple access (CDMA) or time-division, multiple access (TDMA) applications, typical performance for the unit features greater than 70 dB isolation between transmitters with less than 7.0 dB insertion loss for the four-way and 3.8 dB insertion loss for the two-way.  
**Renaissance Electronics**  
INFO/CARD 137

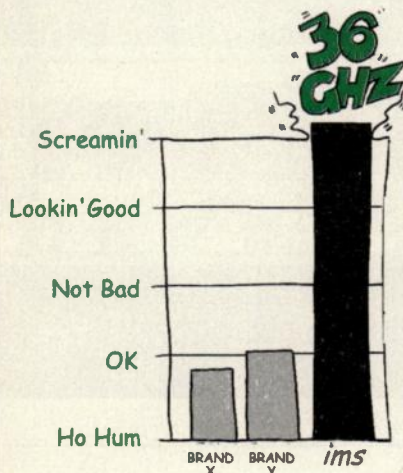


of three low-harmonic subbands. A digital front panel shows extensive system status information that can be accessed (like the subbands) through a series of menus using soft keys, or remotely via the built-in IEEE-488 interface.

**Amplifier Research**  
INFO/CARD 134



# NEED RESISTORS? WE WANNA TAKE YOU HIGHER!!



**IMS** stocks a broad line of chip resistors and attenuators for use at frequencies up to **36 GHz**.

- 0302, 0402, 0502, 0603, and 0805 partial wraps
- 0302 wraparound with single ground plane
- 0805 attenuator from 1 to 10 dB
- Custom configurations
- Highly stable over temperature and time

## IMS

It Means Stock  
It Means Service  
It Means Satisfaction

It's all in who you know.



50 Schoolhouse Lane  
Portsmouth, RI 02871  
Tel: (401) 683-9700  
Fax: (401) 683-5571  
email: [ims@ims-resistors.com](mailto:ims@ims-resistors.com)  
<http://www.ims-resistors.com>

INFO/CARD 75

## TEST EQUIPMENT

### Portable spectrum analyzer designed for TV/wireless

The 2398 portable spectrum analyzer combines high performance and portability in an instrument. Designed for use in wireless infrastructure or television broadcast field-testing or for use in laboratory environments, features include a frequency range of 9 kHz to 2.7 GHz. Other features include a split screen mode to allow for simultaneous viewing of two display functions, full marker capabilities and the ability to store traces and setups internally. The 2398 is priced at less than \$7,000.

**IFR Americas**  
INFO/CARD 138

### Frequency synthesizer with ultra-fine resolution

The PTS 620FR frequency synthesizer features ultra fine resolution. It has an operating range of 1–620 MHz, with a choice of resolution from 100 kHz down to 1 mHz. Output level is +3 to +13 dBm, single sideband (SSB) phase noise is –100 dBc at 100 Hz and –120 dBc at a 10 kHz offset, spurious outputs are –70 dBc and frequency switching speed is 5–10 microseconds. Available with remote parallel BCD control, the unit operates from an internal 10 MHz or an external 5 or 10 MHz standard. The price is a function of resolution. A typical version with 1 mHz resolution is priced at \$10,375.

**Programmed Test Sources**  
INFO/CARD 139

### Evaluation board supports wireless home networks

This wireless local area network (WLAN) frequency hopping spread spectrum (FHSS) radio evaluation board targeting home network applications supports data rates as high as 2 Mbps with a range of more than 300 meters. Designed for designers developing applications based on the HomeRF shared wireless access protocol-cordless access (SWAP) specification, the board is compliant with the IEEE 802.11 specification designed for home and office wireless network environments. The board uses a highly integrated four-chip configuration. It is designed to implement the front end of a 2.4

GHz FHSS subsystem and also includes the analog circuitry from the antennas to the analog baseband signals. The board is priced at \$250.

**Philips Semiconductors**  
INFO/CARD 140

## SIGNAL PROCESSING COMPONENTS

### Low profile splitter/combiner

Model BP2G is a low cost, low profile (0.077" high) surface mount two-way C power splitter/combiner. The unit operates in the 1.42–1.66 GHz frequency range with a typically low 0.6 dB insertion loss (above 3 dB), a high 28 dB isolation and a maximum voltage standing wave ratio (VSWR) of 2:1 on all ports. The unit can handle an absolute maximum input power of 1.5 W as divider and 0.75 W per port, divided by two, as a combiner. Additional features include 50  $\Omega$  operation and tape reel availability. The BP2G is priced at 99 cents each in quantities of 10–49.

**Mini-Circuits**  
INFO/CARD 141

### Dual-mode upconverter for CDMA/FM cellular

The RF2628 is a complete dual-mode code-division multiple access (CDMA)/FM upconverter that can also be used as a direct bipolar phase shift keying (BPSK) modulator. Operating from a single 2.7–5.0 V power supply, the RF2628 features a +9 dBm output intercept point with 0 dB conversion gain. The unit contains a double-balanced mixer stage and an output buffer amplifier. The RF2628 is priced at \$1.75 in quantities of 10,000.

**RF Micro Devices**  
INFO/CARD 142

### Cellular and PCS VSWR alarm modules

Models 8460-N1 and 8480-N1 are voltage standing wave ratio (VSWR) monitors for use in cell site transmission antenna cables. These monitors continuously measure root mean square (RMS) forward and reflected RF power and trigger an internal single pole, double throw (SPDT) form "C" latching alarm relay when the antenna VSWR exceeds a user adjustable threshold.



# NEW PRODUCTS

**no.56**

## RF/IF MICROWAVE COMPONENTS



FROM  
\$19.95

### 5V SHIELDED VCO'S HAVE CELLULAR APPLICATIONS

ROS-1000PV 900MHz to 1000MHz voltage controlled oscillators from Mini-Circuits work with 5V supply voltage and 0.5V to 5V minimum to maximum tuning voltage, which make them suitable for integration with monolithic PLL chips and commercial synthesizers. Measuring only 0.5"x0.5"x0.18" in size, these VCO's provide excellent tuning linearity with -104dBc/Hz phase noise typical at 10kHz offset. 3dB modulation bandwidth is 1000kHz. Ideal for cellular use.



FROM  
\$54.95

### 20dB DIRECTIONAL COUPLER FOR 75 OHM SYSTEMS

Mini-Circuits has introduced a rugged 800MHz to 1750MHz coaxial directional coupler for instrumentation applications. The high performance ZADC-20-18-75 features a nominal coupling value of 19.8dB  $\pm$ 0.6dB with maximum  $\pm$ 0.7dB flatness and is capable of handling up to 1W. Band wide, mainline loss is 0.4dB (typ), and typical directivity and VSWR are 22dB and 1.2:1 respectively. The unit is equipped with BNC connectors and can be operated and stored within a maximum temperature range of -55°C to +100°C. Value priced and available from stock.

### 2WAY SPLITTER/COMBINER FOR CB/AMATEUR RADIO

The JYPQ-30 from Mini-Circuits will split an RF signal 2ways, 90 degrees in the 16MHz to 30MHz frequency range. In 50 ohm environments, this device typically provides very high 28dB isolation, very low 0.2dB insertion loss, and excellent 1.20:1 in/1.15:1 out VSWR while delivering 0.5dB amplitude and 1 degree phase unbalance. Maximum power input as splitter is 1W and uses include IF signal processing. Tape with up to 500 units can be supplied on one 13 inch reel.



J-LEAD

FROM  
\$14.95

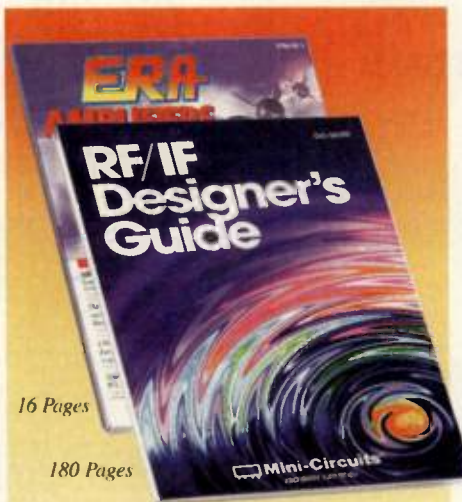


J-LEAD

FROM  
\$29.95

### 180° VOLTAGE VARIABLE PHASE SHIFTER FOR VHF

Mini-Circuits new JSPHS-26 is a 180° (min.) voltage variable phase shifter designed for VHF receiver applications in the 18MHz to 26MHz frequency range. Important characteristics of this unit include 0 to 12V control voltage with a control bandwidth range from DC to 50kHz typical and low 1.2dB (typ) insertion loss. VSWR is good at 1.2:1 typical. The surface mount package is equipped with solder plated J leads for superior mechanical integrity over temperature. Available in tape and reel.



16 Pages

180 Pages

## FREE!



Call Today

718 934-4500

Fax 718 332-4661



it

FROM  
\$3.45

### LEVEL 7 (LO) MIXERS FOR ISM AND WIRELESS/SAT SYSTEMS

Measuring only 0.108" in height, Mini-Circuits ultra-slim 2300MHz to 2700MHz ADE-3G frequency mixers allow engineers to develop smaller surface mount wireless products. Open case design also allows water wash to thoroughly drain and eliminates the possibility of residue entrapment. With electrical performance superior to previous generation mixers, this 50mW (max.) level 7 (LO power) model displays low midband conversion loss of 5.6dB typical, +13dBm IP3 typical at midband, and good 36dB L-R, 26dB L-L isolation typical band wide. Patent pending.

# Mini-Circuits®

US 36 INT'L 37  
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](http://WWW.RFGLOBALNET.COM)

ISO 9001 CERTIFIED

F 293 Rev Org



# 800-522-2253

**This Number  
May Not Save  
Your Life...**

But it could make it a lot easier!  
Especially when it comes to  
ordering non-standard connectors.

## RF/MICROWAVE CONNECTORS

- Specials our specialty virtually any SMA, N, TNC, BNC, SMB, or SMC delivered in 2-4 weeks
- Cross reference library to all major manufacturers.
- Large inventory of piece parts for all types of coaxial connectors.
- Experts in supplying "hard to get" RF connectors.
- Connectors supplied to your drawings and specs.
- Our 56 Standard adapters can satisfy virtually any combination of requirements, between SMA, TNC, N, 7mm, BNC and others.
- Extensive inventory of passive RF/Microwave components including attenuators, terminations and dividers.

**NEMAL**  
Cable & Connector  
for the Electronics Industry

NEMAL ELECTRONICS INTERNATIONAL, INC.

12240 N.E. 14TH AVENUE  
NORTH MIAMI, FL 33161  
TEL: 305-899-0900 • FAX: 305-895-8178  
E-MAIL: INFO@NEMAL.COM  
URL: WWW.NEMAL.COM

INFO/CARD 29

The alarm level can be set from 1.2:1 to 2.5:1. They also feature a one-second alarm activation time that eliminates false alarms caused by rapidly fluctuating RF transmit power. The modules come with built-in, dual-directional sampling couplers for monitoring the transmit line. Model 8460-N1 is designed for advanced mobile phone service (AMPS) band applications while the 8480-N1 covers personal communications service (PCS) band applications.

**Narda Microwave-East**  
INFO/CARD 143

## Surface-mount transfer switches

A miniature surface-mount transfer switch combines high performance in a compact configuration. The switch is available with a choice of four operating frequencies and two coil voltages. The SR-TMIN-MIN-X-X features an impedance of 50  $\Omega$ , a power rating of 10 W and a switching time of 15 ms maximum. Frequency options range

from DC to 18 GHz, insertion loss ranges from 0.2–0.7 and isolation ranges from 40–70.

**RLC Electronics**  
INFO/CARD 144

## Fixed attenuator for radio applications

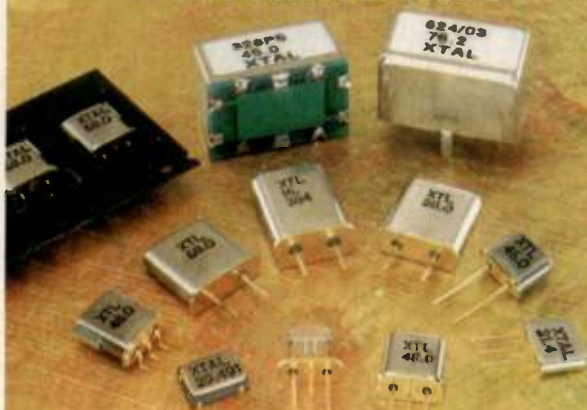
The 22081-06 WT is a 6 dB fixed attenuator that offers  $\pm 0.2$  dB frequency sensitivity over the full WG 22 (W 28) band. Features include an attenuation loss variation with temperature of  $\pm 25$  dB and a return loss of better than  $-28$  dB. 3, 6, 10, 20 and 30 dB attenuation models are available.

**Flann Microwave**  
INFO/CARD 145

## 4 x 4 hybrid matrix for power amplifier applications

A 4 x 4 hybrid matrix is available that uses four amplifiers in parallel typically to cover three channels, providing reliability and performance for the user with

## High-Frequency Fundamentals



As a former unit of one of the world's communications technology leaders, XTAL has been producing high-frequency, tight-spec. frequency devices for over thirty years. Our depth of experience can be seen in our high-performance communications crystals, crystal filters and packaged filter products. If your design calls for precision-performance, specify XTAL for tight-spec. crystals and filters in fundamental frequencies to 75MHz and overtones to 155MHz.

**XTAL**  
TECHNOLOGIES LTD.

28 Mill Race Drive • Lynchburg, VA 24502 USA  
Telephone: 800-365-0850 Fax: 804-385-8100  
Website: www.xtaltech.com

INFO/CARD 53

## 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

INFO/CARD 59



ess overall amplifier capacity. Features include a minimum isolation of 20 dB and a maximum insertion loss of 0.5 dB, which means increased efficiency and channel isolation for the user. The unit also has a maximum voltage standing wave ratio (VSWR) of 1.25:1, a peak amplitude balance of 0.50 dB and a peak phase balance of 3.0 degrees. It operates in the 750–960 MHz frequency range and measures 2.0" x 2.5".

**Anaren Microwave**  
INFO/CARD 146

**VCO enhances up/downconverters**

The V844ME01 is a low-cost, high-performance voltage-controlled oscillator (VCO) designed for low noise up/downconverter applications. This VCO generates frequencies from 1,200–3,400 MHz within a control voltage range of 0.4–4.5 VDC. Features include spectral purity of –88 dBc/Hz typically at a 10 kHz offset while operating off a 5 VDC supply and drawing

22 mA typically. Other features include a 1.1:1 linearity over frequency and temperature, output power of 5±3 dBm into a 50 Ω load while suppressing the second harmonic to better than –15 dBc, and pulls less than 25 MHz with a 14 dB return loss, any phase. The V844ME01 is priced at \$15.95 each in prototype quantities.  
**Z-Communications**  
INFO/CARD 147

**SUBSYSTEMS**

**Transceivers extend distance and increase data rate**

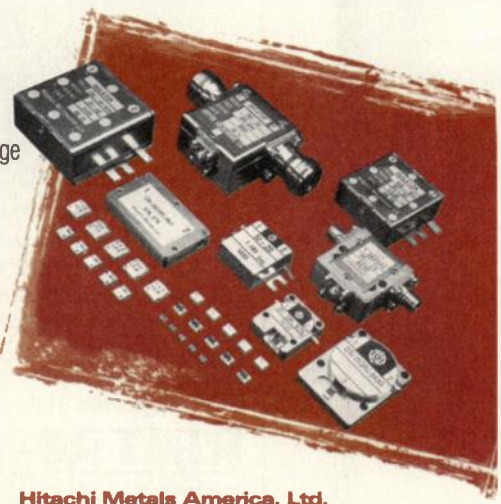
The MAX3291/MAX3292 RS-485/RS-422 transceivers feature driver preemphasis circuitry, which increases the maximum distance and data rate for reliable communications by reducing intersymbol interference (ISI)—a form of data-dependent timing jitter caused by cable parasitics. Typically, preemphasis allows either double the data rate at

# Cellular — Satellite — Mobile Communications...Hitachi Metals Has The Solution!

**The world's gone mobile. Your design demands top performance. Specify Hitachi Metal's microwave components and get your design moving today.**

The international mobile marketplace demands high performance. Your design requires microwave components with low losses, superior response characteristics, and minimum volume. You need components from Hitachi Metals.

Need to save circuit board area and package volume? Designed with our superior "Multi-Layered" technology, Hitachi components require minimal volume and circuit board area. Specify Hitachi. Specify Hitachi, a major international supplier of electronic components. Hitachi, setting the highest quality and reliability standards in the world.



- RF TRANSFORMERS
- CIRCULATORS, ISOLATORS
- COMBINERS AND SPLITTERS
- COUPLERS
- DOUBLE AND SINGLE BALANCED MIXERS
- LOW PASS FILTER, BAND PASS FILTER
- ANTENNA SWITCHES, DIPLEXER

**Hitachi Metals America, Ltd.**  
2101 S. Arlington Heights Rd., Suite 116  
Arlington Heights, IL 60005  
Tel: (847) 364-7200 Fax: (847) 364-7279  
www.hitachimetals.com

INFO/CARD 60

## 10 MHz OCXO MOTAC 511



2" x 2" x 1.5"  
(50mm x 50mm x 38mm)

The MOTAC 511 has a glass sealed SC Cut crystal for fast warm-up and low aging. It utilizes double oven technology for improved frequency vs. temp. performance.

Applications:

- CDMA & GSM Base Stations
- Test & Measurement
- GPS Timing

**STANDARD SPECIFICATIONS at 10 MHz**

|                                     |                        |
|-------------------------------------|------------------------|
| Stability 0 to +70°C                | ±1 x 10 <sup>-10</sup> |
| Aging/year*                         | <3 x 10 <sup>-8</sup>  |
| Supply                              | +12 Vdc                |
| Output                              | +7 dBm                 |
| *After 2 weeks continuous operation |                        |

Custom specifications welcomed.



**Crystals, Filters, Oscillators, VCXO's, TCXO's, OCXO's & Rubidium Atomic Clocks**

PH: 602-780-1995  
FAX: 602-780-9622  
e-mail: sales@temex-az.com  
www.temex-az.com

TEMEX ELECTRONICS, INC.  
3030 W. Deer Valley Rd. Phoenix, AZ 85027

INFO/CARD 12



a given distance or double the distance at a given data rate as compared to other RS-485/RS-422 transceivers. The MAX3291 is optimized for data rates of 5-10 Mbps, while the MAX3292 is programmable for data rates as high as 10 Mbps using a single external resistor. Each device operates from a single +5 V supply and features a shutdown mode that reduces the supply current to 100 nA. Prices for the transceivers start at \$2.70 in quantities of 1,000.

**Maxim Integrated Products**  
INFO/CARD 148

### Spread-spectrum radio modem

The Blue Streak is a high-speed digital communications spread-spectrum radio modem capable of linking various electronic devices. Features include unlicensed operation, frequency hopping spread spectrum (FHSS) technology, 50 user selectable sequences, adjustable data rates from 1,200-115,200 baud operations and

multiple repeater capabilities.  
**Aerotron-Repco Systems**  
INFO/CARD 149

### Aluminum feeds enhance performance of antennas

Aluminum feeds featuring wideband (7.1-8.5 GHz) capabilities are available on terrestrial microwave antennas. Formed from heavy duty aluminum, the feeds feature improved cross polarization (35 dB), a low 1.06 voltage standing wave ratio (VSWR), a return loss of -30.7 dB, gain improvements from 0.1 to 0.5 dBi and front-to-back ratio improvements from 2 to 3 dB.

**Andrew**  
INFO/CARD 150

### Planar antenna for portable products

The Splatch is a low-cost planar antenna that uses a proprietary grounded-line technique to extract outstanding performance from a tiny sur-

face-mount element. The Splatch is immune to proximity effects, making it suitable for handheld applications such as remote controls. The antenna measures 1.1" x 0.5" x 0.062", exhibits a 5  $\Omega$  characteristic impedance, a voltage standing wave ratio (VSWR) of less than 1.9 and is available in standard or custom frequencies within the 300-900 MHz range. The Splatch is priced at less than \$1 in production quantities.

**Linx Technologies**  
INFO/CARD 151

### Low-profile GPS antenna module

The TMM869 global positioning system (GPS) front-end antenna is packaged in a compact low-profile radome of less than 13 mm that houses the entire front end of the antenna element, the low-noise amplifier (LNA) and the preselect bandpass filter. The right hand circular polarized antenna receives the GPS signal of 1,575.42 MHz with

## Bias T Reduces Device Oscillation

### ATN-5110 Series

Unwanted device oscillation associated with capacitor and inductor roll off in Bias T's is now a thing of the past. ATN Bias T's employ a unique diplexer technique which improves low frequency match and nearly eliminates oscillation. In addition, these devices combine broadband performance with high current and extreme power handling capability. They're ideal for load pull, pulsed and many other device biasing applications.

For a complete data sheet visit  
[www.atnmicrowave.com](http://www.atnmicrowave.com).



- **Handles up to 10 Watts & 4 Amps**
- **Provides Superior Match**
- **Insertion Loss as Low as 0.6 dB**
- **3 Models in Stock**  
ATN-5111 0.8 - 4 GHz  
ATN-5112 2 - 8 GHz  
ATN-5113 4 - 18 GHz
- **Custom Models Available**

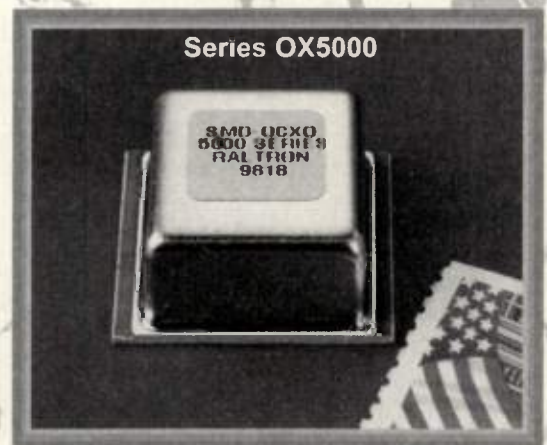
**atnmicrowave**

85 Rangeway Road, North Billerica, MA 01862-2105 USA  
978-667-4200 x22 • Fax 978-667-8548 • [www.atnmicrowave.com](http://www.atnmicrowave.com)

Mastercard and Visa Accepted

INFO/CARD 71

## Only Raltron has it all... New SMD OCXO



- **Frequency Range 10.00 MHz to 60.00 MHz**
- **$\pm 0.1$  PPM over 0° C to +60° C**
- **Low power consumption of 500 mW at steady state**
- **Typical warm-up time in less than 2 minutes**
- **SC Cut option in development**
- **Laser trim option for final system calibration**
- **Low profile SMD package of 25.4 x 22.0 x 11.5 mm**

**RALTRON**

A Worldwide Manufacturer of:

- Microprocessor Crystals and Clocks
- VCXO's, TCXO's and OCXO's
- Crystal Filters
- Ceramic Resonators
- SAW Devices
- VCO's

2315 NW 107<sup>th</sup> Avenue  
Miami, FL 33172 USA  
Tel: 305-593-6033  
Fax: 305-594-3973  
email: [sales@raltron.com](mailto:sales@raltron.com)  
Internet: <http://www.raltron.com>

INFO/CARD 74



passband width of 9 MHz. The antenna gain is +5.0 dBi typical with an elevation angle of 90°. Operating off 5 V, the module has a low current consumption of 15 mA with no signal. The power gain of the gallium arsenide (GaAs) field effect transistor (FET) LNA is 31 dB, and the noise figure is 0.9 dB typical. Several mounting methods are available. The TMM869 is priced starting around \$18 in quantities of 1,000.

**Toko America**  
INFO/CARD 152

## DISCRETE COMPONENTS

### 100 W GaAs MESFET for L-band transmitters

The NES1823P-100 is a twin-transistor device consisting of two pairs of gallium arsenide (GaAs) metal semiconductor field effect transistor (MESFET) chips that can be externally combined in either a push-pull or balanced configuration. The unit is designed for 2.1–2.2 GHz base stations, but can be modified to be used in 2.3–2.4 GHz wireless local loop (WLL) and digital audio broadcast (DAB) applications. The NES1823P-100 delivers 100 W of output power with a linear gain of 11.0 dB typical and drain efficiency of 50% typical at  $V_{DS} = 10$  V,  $I_{DSS} = 6$  A and  $f =$

2.2 GHz. The NES1823P-100 is priced at \$306 in quantities of 100.

**California Eastern Labs**  
INFO/CARD 153

### Open type inductor for signal line filtering

The KQ 0603 is an 0603 size chip inductor that features a high Q factor and is used in signal line filtering. The inductor's flat top design allows for increased placement and its electrical and mechanical characteristics offer the ability to be used as a direct replacement for other open-type inductors. The inductor is available in both  $\pm 5\%$  and  $\pm 10\%$  tolerances, with a nominal inductance range of 1.8–120 nH.

**KOA Speer Electronics**  
INFO/CARD 154

### High power RF transistor

The PTF10112 is a high-power, high-frequency RF transistor intended for code-division, multiple access (CDMA) and time-division, multiple access (TDMA) applications in the personal communications service (PCS) band. This laterally diffused metal oxide semiconductor (LDMOS) device typically has a gain 3 dB higher than bipolar equivalents, with a minimum output power of 60 W at 1 dB compression. Designed to

operate from a 28 V supply, this device has a typical power gain of 12 dB while exhibiting a gain flatness of  $\pm 0.2$  dB over the 1.93–1.99 GHz PCS band. Class AB two-tone third-order intermodulation distortion is  $-40$  dBc at 25 W. Efficiency is typically 41%.

**Ericsson Components**  
INFO/CARD 155

## AMPLIFIERS

### Low distortion hybrid operational amplifiers

The KH232 and KH207 are two low distortion hybrid operational amplifiers designed specifically for wide dynamic range systems. Using current feedback topology and offering high slew rates and fast settling times, the KH207 is designed for high-gain applications while the KH232 is designed for low-gain applications. The KH207 features a gain range of +7 to +50 and  $-1$  to  $-50$  V/V. Other features include a small signal bandwidth of 170 MHz and a large signal bandwidth of 100 MHz at a gain of 20V/V. It operates on supply voltages of  $\pm 5$  V to  $\pm 15$  V and provides a maximum output current of 150 mA. The KH232 features a gain range of  $\pm 1$  to  $\pm 5$  V/V. Other features include a small signal bandwidth of 270 MHz and a large signal bandwidth of 95 MHz at a

# Search, request, modify . . .



Unlimited crystal specification and product detail options will soon be yours, 24 hours a day

*It doesn't get any more convenient than this . . .  
Watch this space.*

### RAKON LIMITED

1 Pacific Rise, Mt Wellington, Auckland, New Zealand.  
Private Bag 99943, Newmarket.

Fax: 64-9-573 5559, Phone: 64-9-573 5554 (64 IS THE COUNTRY CODE, 9 IS THE AREA CODE)





gain of 20V/V. It operates on supply voltages of  $\pm 5$  V to  $\pm 15$  V and provides a maximum output current of 100 mA.

**Kota Microcircuits**  
INFO/CARD 156

## Class A linear amplifier

Model AR88258-50 is a class "A" linear amplifier that operates over the full 800–2,500 MHz frequency range with 50 W of output power at the 1 dB compression point. Gain is 47 dB minimum with typical two-tone intermodulation distortion at –30 dBc. The unit measures 8.75"  $\times$  19"  $\times$  22".

**Comtech PST**  
INFO/CARD 157

## Power amplifier for intermodulation testing

The DMS 7055 is a high power amplifier that delivers 50 W of RF output power over the 2,000–2,000 MHz frequency range. Designed for inter-

modulation distortion measurements, the amplifier operates in class "A" from a 240 V AC power supply with integral output isolator for added protection. Features include a small signal gain of 48 dB minimum, saturated output power of 47 dBm typical and spurious outputs of –60 dBc maximum.

**Densitron Microwave**  
INFO/CARD 158

## SEMICONDUCTORS

### Chip set for spread spectrum digital cordless phones

The Everest 900 MHz digital cordless chip set will enable cordless phone manufacturers to deliver products with world-class clarity and range at as much as half of today's typical costs. The chip set provides digital cordless phones with 200 MIPS of processing power. The set consists of two B900 digital signal processor (DSP) chips, two, four-channel codec CSP1009 com-

munications signal processor chips and two W9009 RF transceiver chip designed for the 900 MHz industrial, scientific and medical (ISM) band. On of each chip is placed in the handset while the other is placed in the base station. The chip set enables six hour of talk time and seven days of standby time, and is priced at \$14.95 in quantities of 100,000.

**Lucent Technologies**  
INFO/CARD 159

## SIGNAL SOURCES

### Line of surface-mount VCXOs

A line of surface-mount voltage controlled crystal oscillators (VCXOs) are available for the frequency range from 1.5–60 MHz. Part numbering is VC2XXX for the non tri-state parts and VC3XXX for the tri-state parts. Features include frequency stability from  $\pm 15$  ppm to  $\pm 100$  ppm over a

## Monitor Products' SO-1300 THERMAL STABILITY OXCO



CALL FOR MORE INFO!

Monitor Products' new SO-1300 OXCO combines high stability with a small package, providing the frequency tolerances normally associated with larger OXCOs. With long term stabilities as low as  $\pm 0.075$  ppm per year (SC option), and frequency output ranges from 5.0 MHz to 66.66 MHz, the SO-1300 is designed for use in base stations, frequency counters, and switching applications.

- ▲ Small package size
- ▲ Low phase noise ( $-110$  dBc @ 10 Hz)
- ▲ High stability
- SC and AT crystal options
- ▲ Extremely low aging rate
- ▲ Square wave HCMOS output
- ▲ Surface mountable option
- ▲ Mechanical trim option
- ▲ Electronic frequency control standard
- ▲ Low power consumption (5W max)

Monitor Products has a proven 70-year track record as a manufacturer in the frequency control market. If our extensive selection of standard and engineered crystals and oscillators does not meet your spec, we will work with you towards a customized solution.

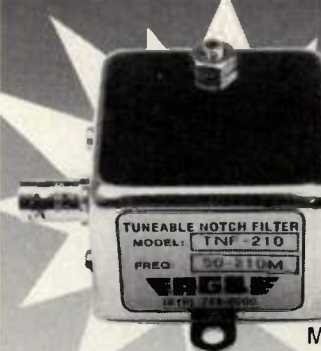
**MONITOR PRODUCTS**  
PC COMPANY INC  
A BOWTHORPE company

CORP OFFICE/FACTORY REGIONAL SALES OFFICE  
502 Via del Monte 3415 Custer Rd, Ste 117  
Oceanside, CA 92054 Plano, TX 75023  
Tel : 760 433-4510 Tel : 972 758-8687  
Fax : 760 434-0255 Fax : 972 758-7574  
www.monitor-products.com

Designers and manufacturers of quality frequency control devices since 1927

INFO/CARD 78

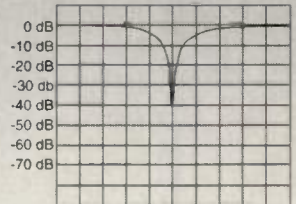
## TUNEABLE NOTCH FILTERS



### FEATURES:

- Low VSWR: <1.2:1
- Low Loss: <0.5 dB
- 25 Watt pass band
- Deep Notch to 35 dB
- Pass band to 3.0 GHz
- Rugged Construction
- Low Cost: starts at \$125
- Models from 0.5 to 850 MHz

The TNF200 filters are available in nine models from 0.5 MHz to 850 MHz. While primarily designed to improve the dynamic range of spectrum analyzers, these filters can also be used to reduce parasitics; or to eliminate or identify out of band interference in communications systems.



Plot of Typical Notch

Please call for FREE application note:  
"Spectrum Analyzer Measurements"

**EAGLE**

VOICE: (520) 204-2597 ♥ FAX: (520) 204-2568  
P.O. BOX 4010 ♥ SEDONA, ARIZONA 86340

INFO/CARD 47



operating temperature range of -70°C. Pullability is from 25-300 ppm. Input voltage can be either 5 or 3.3 V ± 5%. Pricing starts at \$12.75.

**Pletronics**  
INFO/CARD 160

### Low phase noise crystal oscillators

The FE-103A series of low phase noise crystal oscillators is designed for wireless applications such as cellular phone base stations. Available in the 5-20 MHz frequency range, features include typical phase noise of -142 dBc at a 10 Hz offset, -148 dBc at a 100 Hz offset, -155 dBc at a 1 kHz offset and -158 dBc at a 10 kHz and 100 kHz offset.

**FEI Communications**  
INFO/CARD 161

### Low profile, high performance OCXO

Model XO5008 is a low profile, high performance oven compensated crystal

oscillator (OCXO) that features a height of 0.75" with a footprint of 1.5" x 1.5". The standard center frequency is 10 MHz with options available over the 3-50 MHz frequency range. The unit features an SC-cut resonator, sinewave output, five-minute warm up and moderate current consumption. AT-cut options are also available.

**Piezo Technology**  
INFO/CARD 162

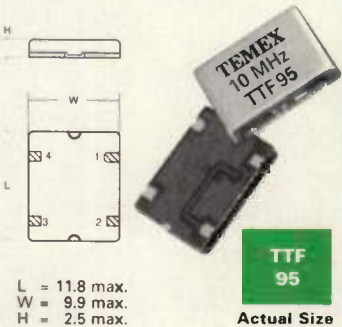
### Low noise 13 GHz oscillator

The ESC 206-121 is a 13 GHz dielectric resonator oscillator that has a typical phase noise of -90 dBc/Hz at an offset of 10 kHz. Output power is 19 dBm minimum. Pulling into a 1.5:1 voltage standing wave ratio (VSWR) is less than 0.01% and harmonics are -20 dBc. The oscillator is housed in a low profile flanged package measuring 1.6" x 1.7" x 0.6" including the flange.

**Electronics Surveillance Components**  
INFO/CARD 163

## LOW COST SURFACE MOUNT TCXO

### TTF 95



The Temex Time & Frequency TTF 95 is a low cost TCXO or VCTCXO available in many standard frequencies from 10 MHz to 26 MHz. Parts are available on Tape and Reel and may be reflow soldered, using no clean processing.

**Applications:**  
Wireless Communications  
Test & Measurement  
GPS receivers

**Specifications at 10 MHz**  
Stability Options  
± 2.5 ppm -30° to +75°C  
± 1.5 ppm -20° to +70°C  
± 1.0 ppm 0° to +50°C  
Input ..... +3.3 or +5.0 Vdc  
Clipped Sinewave or TTL output  
Phase Noise ..... -125 dBc at 100 Hz

Custom specifications welcomed



**TEMEX**  
TIME & FREQUENCY

**Crystals, Filters,  
Oscillators, VCXO's,  
TCXO's, OCXO's &  
Rubidium Atomic Clocks**

PH: 602-780-1995  
FAX: 602-780-9622  
e-mail: sales@temex-az.com  
www.temex-az.com

TEMEX ELECTRONICS, INC.  
3030 W. Deer Valley Rd. Phoenix, AZ 85027

OCXO Redefines Industry Standard

210 SERIES  
220 SERIES  
230 SERIES  
240 SERIES  
250 SERIES

260 SERIES  
400 SERIES  
500 SERIES  
ENTER

PRODUCT PROFILE

Stratum III, IIIe --- Thermal stability of 1.00E-008 over -30°C to +70°C --- Power consumption of 0.8W at 25°C --- Warm-up <3 min --- Ultra high reliability --- SMT or 16 PIN pkg. --- Available on tape and reel --- Call: 978-465-6064 --- Fax: 978-465-6637

MTI

Frequency Range4.8 MHz to 125 MHz  
Aging2.00E-010/day  
3.00E-008/yr  
Phase Noise, 10Hz offset-125 dBc/Hz  
100 kHz Offset-155 dBc/Hz  
Crystal CutSC or AT  
Welded Hermetic Package0.975" x 0.800" x 0.500"  
24.77mm x 20.32mm x 12.7mm

INFO. SOURCE

www.mti-milliren.com

INFO/CARD 103

INFO/CARD 72



**RF Design**  
**Online**  
**now has**  
**three ways**  
**to link**  
**to companies**  
**mentioned**  
**in this issue:**  
**advertiser links,**  
**product directory**  
**links**  
**and editorial links.**  
**Check out**  
**our website at**  
**[www.rfdesign.com](http://www.rfdesign.com)**

## RF software

### Development software updated with Web apps

National Instruments' Labview 5.1 offers users an improved application development by streamlining the creation of Web-enabled applications. The new modular application architecture allows users to create smaller executables that improves system performance and decreases memory usage. The software also extends the use of Active X (COM) to allow for seamless integration of the math and interactive analysis capabilities of the Mathworks Matlab and National Instruments HiQ. **National Instruments**  
**INFO/CARD 115**

### Design software can be client or server

O-Matrix 4, from Harmonic Software, offers a client/server capability that enables O-Matrix to communicate with other Windows programs and perform interprocessing computing. The interprocessing capabilities enable the software to act as either a computing client or server with other applications. Both data and programs can be transferred between instances of O-Matrix or other applications. The process allows the users to develop a Mathlink package for communicating with Mathematica. **Harmonic Software**  
**INFO/CARD 116**

### Software designed for EM, layout, linear analysis

Hewlett-Packard (HP) EEsos introduces its Momentum circuit designer. The software enables engineers to perform electromagnetic (EM) analysis as well as layout and linear analysis in a single, integrated environment. The software includes strip-slot computation, adaptive frequency sampling, edge mesh and other capabilities. It is designed for use with PCs using Windows 95 and Windows NT 4.0.

**Hewlett-Packard EEsos**  
**INFO/CARD 117**

### PC-based asynchronous data and protocol analyzers

Frontline Test Equipment has released its Serialtes Async and Serialtes Spy asynchronous data and protocol analyzers for Windows NT environments. Previous releases support Windows 95/98. The software is

designed to allow a PC to function as full-featured serial data and protocol analyzer, enabling the user to troubleshoot asynchronous data transmissions on the fly, reviewing and searching the data as it is being captured.

**Frontline Test Equipment**  
**INFO/CARD 118**

### Circuit design tool updated with optimization options

Tanner EDA's T-Spice Pro is an integrated circuit design capture, simulation and data viewing system for Windows NT/95/98. The software has been updated to include new optimization options, remote simulation over network, parameter sweeping, more flexible behavioral modeling and advanced post processing support.

**Tanner EDA**  
**INFO/CARD 119**

### CDMA developed for base station test platform

Wavetek has developed version 2.0 code-division multiple access (CDMA) software for the Model 4032 base station tester. Technicians using the software with the Model 4032 can determine the PN offset of a sector within 30 seconds.

**Wavetek**  
**INFO/CARD 120**

## Software on the Web

### Design software demo offered on Web

Optotek offers a demonstration version of its MMICAD suite of CAE/CAT software. The suite allows for precise circuit simulation and device modelling, contributing to design realization and high-yield, affordable manufacturing of RF and microwave circuits.

**Optotek**  
**INFO/CARD 121**

To access this Web site, and other Web sites offering downloadable software, check out **RF Design Online** for direct links.



## Booklet describes CDMA history, growth, technology

Wavetek offers a booklet that offers readers an overview of code-division multiple access. *CDMA Introduction* describes the history of CDMA, its growth and the differences between CDMA, time-division multiple access (TDMA) and frequency-division multiple access (FDMA). The booklet also describes advantages of CDMA, codes in CDMA, logical channels in CDMA and basic CDMA specifications.

**Wavetek**  
INFO/CARD 122

## Short form catalog features testers and power supplies

IFR Americas' 1998/1999 short form catalog features a quick reference to Tekkui power products and detailed product descriptions. Products include Tekkui's full line of safety testers, DC power supplies, AC power supplies, electronic loads and battery testers.

**IFR Americas**  
INFO/CARD 123

## Catalog and application notes offered on CD-ROM

Gage Applied Sciences has issued its first full line catalog and application notes CD-ROM. The CD-ROM contains descriptions, specifications and technical information on Gage products. Up to 100 application notes, articles, and white papers are offered as well as a question and answer section. All files are saved in the PDF format and are readable on Windows 95, Windows NT, Macintosh and Unix computers.

**Gage Applied Sciences**  
INFO/CARD 124

## Catalog features foil and film resistors

Riedon's new line of foil and film resistors are described in a 12-page catalog. The catalog features as many as 35 power and precision resistors and networks using advanced metal foil, metal film and thick film elements. Included are precision low ohm foil resistors for current sensing and shunt applications.

**Riedon**  
INFO/CARD 125

## Design guide offers A/D converters

Maxim offers an analog design guide that features the company's 18-bit sigma-delta analog digital converters (ADC). The MAX1400 family of ADCs can sample to 4.8 ksp/s and can maintain 16-bit performance at 480 samples per second. The devices also offer a 4.8 ksp/s max sample rate.

**Maxim**  
INFO/CARD 126

## Guide offers insights into DECT, PWT

*Personal Wireless Communications with DECT and PWT*, from Artech House, is a guide to two personal wireless communications systems: digital enhanced cordless telecommunications (DECT) and personal wireless telecommunication (PWT). The book offers background material and technical principles, basic protocols and implementations, plus features and a wide range of applications. For more information visit Artech House's Web site.

**Artech House**  
INFO/CARD 127

## Newsletter dedicated to digital communications

Analog Devices "Communications Direct" is dedicated to digital communications issues. The current 8-page edition, Vol 3, No. 3, presents an overview of ADSL and cable modem technologies and the viability of each in the marketplace. To request a copy visit Analog Devices Web site.

**Analog Devices**  
INFO/CARD 128

## Catalog highlights circuit protection products

AVX offers its TVS catalog, featuring the company's Transguard, Staticguard and Multiguard multilayer ceramic transient voltage suppressors. The catalog provides users with detailed product specifications in addition to information on applications. Schematic diagrams for typical circuits and application notes are also provided.

**AVX**  
INFO/CARD 129

## Product catalog features filters, surge suppressors

Control Concepts' product catalog features the company's line of power conditioning equipment. Included are a variety of high-performance filters and surge suppressors designed to help eliminate power fluctuations at the source. The 20-page catalog offers technical specifications, typical installation, test results and other information.

**Control Concepts**  
INFO/CARD 130

## Catalog offers SMT, thru-hole PCB components

Keystone's 16-page catalog supplement offers information on the company's surface mount (SMT) and thru-hole printed circuit board (PCB) components and hardware. Product groups include coin cell holders, retainers and clips, vertical 20mm coin cell holders, surface mount battery clips, SMT and thru-hole test points, and PC screw terminals. The catalog also addresses surface mount tape and reel packaging availabilities.

**EMC Test Systems**  
INFO/CARD 131

## Online

**HP offers end-of-production equipment on its Web site—** Hewlett-Packard (HP) has listed end-of-production equipment and more than 1,200 refurbished test and measurement products on its Web site. The refurbished equipment comes with a one-year limited warranty covering all components covered by HP's warranties on new products. To access the site go to [www.hp.com/go/refurbished](http://www.hp.com/go/refurbished).  
**Hewlett-Packard**  
INFO/CARD 132

## RF Design Online

For direct access to those companies offering information through their Web sites, go to [www.rfdesign.com](http://www.rfdesign.com).



Solutions-oriented, Application-driven.  
**PROBLEMS SOLVED.**

Intelligent satellite network  
solutions for your business.



**SCEC'99**

25-27 August 1999  
Washington Convention Center  
Washington D.C. USA

For more about attending or exhibiting,  
call 1-800-288-8606 or  
1-303-741-2901

[www.scec.com](http://www.scec.com)



# RF LITERATURE/PRODUCT SHOWCASE

## MICROWAVE ISOLATORS/CIRCULATORS

Freq. 0.45 to 26.5 GHz  
Insertion loss <0.3 dB  
Isolation >23 dB  
VSWR 1.25:1



### Low Cost/High Volume Production Capability

- Drop-in Packages • High Power Coaxial packages
- Surface Mount Packages • Multiple connector options
- High Isolation/Multi-junction • MIL-I-45208 Qualified
- Four port custom designs • Just in Time delivery
- Reflection sensing tabs • Custom design capability



380 Tennant Ave., Morgan Hill, CA 95037  
<http://www.novamicro.com>  
Tel. 408-778-2746 • Fax: 779-5967  
email: novamic@msn.com

INFO/CARD 200

## QUALITY PRODUCT DESIGN



### RF POWER GENERATORS

- RF Excited Plasma for Deposition, Sputtering, Etching, & Ion Implant
- Induction Heating

### AMPLIFIERS / XMTR'S

- Commercial
- Industrial
- HF / VHF Bands
- Mobile / Base Station

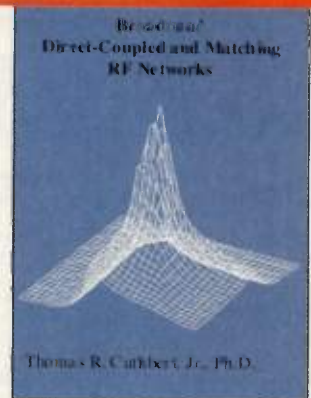
IF YOU CAN'T FIND IT, WE'LL DESIGN IT!

### T&C Power Conversion, Inc.

110 Halstead Street E-Mail: TCPOWER1@AOL.COM  
Rochester, New York 14610, USA Phone: 716-482-5561  
<http://members.aol.com/tcpower1> Fax: 716-482-8487

INFO/CARD 201

## Cuthbert's New Book!



New and Useful Direct-Coupled Filters  
Optimal Broadband Matching  
TRCPEP@AOL.COM or FAX 501-996-5618

INFO/CARD 202

RF Design is the place to reach prime prospects—more than 40,000 readers who are design and R&D engineers, engineering managers and corporate staff in the wireless, military, communications and electronics industries.

## RF design

For rates and closing dates, call Jody Schrader at 1-888-234-0448

## Pin-Diode Switches



- All Frequencies from 100 Mhz to 18 Ghz
- Reflective or Absorptive Types
- TTL, CMOS, ECL, Control Logic families
- Switching speed as fast as 10ns (Rise/Fall)
- Miniature Outlines with Removable Connectors
- Numerous factory options for any applications

### Universal Microwave Components Corp.

5702-D General Washington Drive  
Alexandria, Virginia 22312  
Tel: (703) 642-6332  
Fax: (703) 642-2568

E-Mail: UMCC111@AOL.COM



INFO/CARD 204

## Wireless Simulation



<http://www.tesoft.com>

INFO/CARD 205

## Reach an exclusive audience of buyers in RF Design!

### New & Current Products Promoted in our Product Showcase

For \$650 or less you can promote your products to thousands of interested buyers. Four-color is included in the price. Simply provide us with a copy of your sales brochure or a photograph of the product and 40-50 words of copy. We'll do the rest!

For more information contact: Jody Schrader at 1-888-234-0448

## Reach Thousands of Potential Buyers in RF Design!



# RF marketplace

## CLASSIFIEDS

### Fax

Jody Schrader  
Classified Ad  
Manager  
1-720-489-3253

### Phone

Jody Schrader  
Classified Ad Manager  
1-888-234-0448  
or 1-720-489-3290

### Mail

ad materials to:  
Annette Hulsey  
9800 Metcalf  
Overland Park, KS  
66212



Jody Schrader

E-mail: jody\_schrader@intertec.com

**Toll-Free: 1-888-234-0448**

## At a glance...

|                            | Page    |
|----------------------------|---------|
| Buyers' Source .....       | 100-101 |
| Career Opportunities ..... | 96-99   |
| Literature/                |         |
| Product Showcase .....     | 95      |
| Products & Services .....  | 100     |

## RFdesign

## CAREER OPPORTUNITIES

### TAD Telecom, Inc.

Whenever, Wherever, TAD Telecom provides premier personnel and project services worldwide.

#### ENGINEERING OPPORTUNITIES AVAILABLE

- Sr. Project Engineers
- RF Engineers
- Project Engineers
- RF Design Engineers
- Field Engineers
- RCDD & Project Engineers
- LAN/WAN Network Engineers
- Switch Engineers/Technicians

Retiree's Welcome!

Health Insurance,

401 (k), Holiday/Vacation

Call or fax resume to:

### TAD Telecom, Inc.

National Recruiting Office  
4405 International Blvd., Suite B-102  
Norcross, GA 30093

Ph: 800-843-6910

Fax: 800-545-1988

Email: tadtelecom@adecco.com  
(rtf or txt format preference)

Web site at

<http://www.tadtelecom.com>

### R.F. ENGINEERS: NATIONWIDE

R.F./WIRELESS/RECEIVERS/AMPS  
CDMA/TDMA/SPREAD SPECTRUM  
SATELLITE & ANTENNA DESIGN

Respond to: GTH, Ltd.

2204 Bahia Vista #D7, Sarasota, FL 34239  
Phone: 941/362-2773 • Fax: 941/362-0217  
E-mail: <cth@mindspring.com>

### CDI

CDI Telecommunications is part of a large public corporation (NYSE) serving customers nationwide.

We are seeking experienced personnel for the following positions:

#### CELLULAR & PCS

Program Managers  
Network Engineers  
RF Engineers  
Installers

Construction Managers  
Real Estate Specialists  
Salespersons - Testers  
Technicians

Fax resume to:

**CDI Telecommunications, Inc.**

800-669-1890, Ext 798  
Fax: 800-875-1904

2800 N. 44th Street, Suite 800,  
Dept. RFD, Phoenix, AZ 85008-1500  
E.O.E.

Phone: 800-527-0373  
Fax: 800-784-0499

2425 N. Central Expressway, #101  
Richardson, TX 75080  
E.O.E.

**Do you live in Florida or  
would you like to?**

### RF Design Engineer

Tired of winter snow? Wish for a warm winter and a job that fills a void in the CATV industry? We have the answer for the right person qualified to design wideband RF communications products for the cable television industry.

Qualified applicant should have familiarity with Tango circuit board design software. EE degree or equivalent design experience. Send resume to Quality RF Services, Inc., 850 Parkway Street, Jupiter, Florida 33477; Phone: 800-327-9767 or 561-747-4998; Fax: 561-744-4618.



...your connection to the best opportunities nationwide!

**National Engineering Search®** is the leading search firm placing Engineers nationwide. Contact us for immediate access to today's most exceptional career opportunities! Our clients range from the Fortune 500 to the most successful emerging technology companies.

#### DESIGN/DEVELOPMENT ENGINEERS:

#### IMMEDIATE OPPORTUNITIES IN:

Communications (Data, PCS Cellular, Networks, Satcom GPS), CATV, Computers Medical, Security, Defense Semiconductors, Software Consumer Electronics

#### Skills in any of the following

Wireless Design, Digital Analog Design, ASIC, FPGA SiBipolar/BiCMOS/GaAs Mixed Signal, MMIC, Spread Spectrum, DSP, Antenna: Passive Components, PLL Synthesizers, Simulation Verification, Embedded SW

800/248-7020  
FAX: 800/838-8789  
email: nes@nesnet.com

3700 East Avenue • Rochester, NY 14618  
1235-E East Blvd. 146 • Charlotte, NC 28227

See many of our current opportunities on-line at:  
[www.nesnet.com](http://www.nesnet.com)

**What are you worth?**  
See our on-line Salary Survey!

**MR MANAGEMENT  
RECRUITERS®  
OF BOULDER, INC.**  
The search and recruiting specialists

### WINDY BRADFIELD RF / MICROWAVE SPECIALIST

CONTINENTAL BLDG., SUITE 301  
1401 WALNUT STREET, P.O. BOX 4657  
BOULDER, COLORADO 80306  
(303) 447-9900  
FAX(303) 447-9536

We can create a **custom reprint** for any marketing effort without breaking your budget

For a quote call: **Jenny Eisele**  
Phone: 913-967-1966 • Fax: 913-967-1898



Combine  
with an fast technology  
**exciting  
lifestyle.**

Be part of the leading-edge excitement at Raytheon Systems Company! With multi-million and billion dollar contracts and state-of-the-art facilities in Tucson, Arizona and Portsmouth, Rhode Island, we're taking missile systems and Naval & Maritime systems technology deep into the next millennium. You can be part of the excitement working and living at either of these fabulous locations:

#### **Tucson, Arizona**

With year-round sunshine and breathtaking mountain and desert landscapes, Tucson is an outdoor-lover's paradise. And equally attractive is the city's growing cultural attractions, including fine restaurants, a world-class symphony, numerous museums and abundant community events.

#### **Portsmouth, Rhode Island**

Surrounded by sparkling water and fresh air, Portsmouth, Rhode Island offers the best of historic New England living in a rich colonial setting. Residents in Portsmouth and in the surrounding towns have easy access to sailing, fishing, skiing, biking and much more.

Portsmouth, RI

Tucson, AZ

The  
reason  
is

# **Raytheon**

We're looking for experienced engineers and recent graduates with BS/MS/PhD degrees in EE/ME/Physics/Math/CS in the following categories:

- Software Engineering
- Digital Design
- Electrical Design
- Design and Analysis of Sensors and Systems
- Signal/Image Processing and Algorithms
- Antenna Design
- Analog Design
- RF/IF Hardware Design
- Microwave Hardware Design/EMI/EMC
- Fuze Design and Analysis
- RF Subsystems and Integration
- Guidance, Navigation and Controls
- Simulation and Modeling
- Electro-Optical Subsystem Design

- Opto-Mechanical Design
- Mechanical Design
- Optical Design
- Systems Integration and Test
- Test Equipment Design
- Product Support - Logistics
- Ship Systems
- Combat Systems

Make this your opportunity to explore the timeless beauty of America's southwest or the rich cultural heritage of colonial New England. E-mail your resume, indicating **Source Code AMRFD**, position and geographical preference, to: [resume@rayjobs.com](mailto:resume@rayjobs.com) Or mail your resume to: **Raytheon Resume Processing Center, Source Code AMRFD, 13510 N. Central Expressway, Dallas, TX 75243.**

We are proud to be an Equal Opportunity Employer. Proof of U.S. citizenship is required. Applicants selected are subject to a security investigation and must meet eligibility requirements for access to classified information.



# www.heavymetal.com

## Work on the edge of everything.

### ...YOUR CAREER

**Wireless IC Design Centers:** Major corporation seeks several key Sr. Technologists to staff wireless design centers located throughout the US. Technical expertise in the area of Si RF IC's for wireless communication applications (AMPS, ISMPS, GSM, DECT POS). Si RF IC design experience in the 400-2400 MHz. Past RF PLL synthesizer design experience. BS/MS/PhD.

**Sr. Systems Architecture, Wireless Handsets & Base Stations:** Define RF system architectures in low-cost receiver-transmitter design on discrete circuit level. Knowledge of integrated circuit architecture, modulation theory and digital signal processing.

**Director of Operations:** Responsible for existing operation and growth of division into new business opportunities.

**Process Manager/Staff Engineers:** Responsible for technical support in wafer fabrication, process development and sustaining engineering in device manufacturing. Directs the development and implementation of new wafer fabrication process formulas and establishes operating equipment specifications.



**CATV Designer:** RF Design experience should include LC filter, microstrip, amplifier, circuit modeling and system analysis in the 5-1000MHz range. BS/MS/EE fiber optics a plus.

**RF Test Engineer:** You will develop automated test software and procedures for RF/analog circuits. Experience using cellular test equipment. GPIB/HP VEE/LabVIEW programming and CDMA/AMPS knowledge a plus. Will consider highly motivated entry-level RF Engineers with BSEE.

**Regional Field Sales:** Aggressive individuals to create and serve new accounts. Positions are located throughout the U.S.A. An engineer who wants to enter sales world is acceptable. Base salary, commission and car. BSEE.

**Applications Engineers:** Responsible for providing customers with RF technical product development, developing application notes and data sheets. Requires BSEE/MS/EE with minimum 3 years RF design/product experience, strong RF/Microwave measurement skills, design experience with analog and digital modulation schemes (AMPS, GSM, TDMA, CDMA), and strong communication and customer relation skills.

**RF Engineer:** RF circuit design and development for wireless phones. Develop radio architectures and RF circuit design for systems operating in the 800-900MHz and the 1800-2000MHz regions.

**Sr. Project Antenna Design:** Lead the conception, design and development of a wide variety of antennas and antenna systems, including both reflector and array systems using microstrip, stripline and waveguide technologies. BS/MS with 5 years experience.

**RF Design Manager:** Lead a team of RF engineers from initial design and implementation through product integration and testing into high volume production. 8+ years of RF design with emphasis on low cost radio design. BS/MS.

**Sr. MMIC Designer:** Design highly integrated GaAs MMICs for advanced cellular products. Circuits to be designed include: power amplifiers, LNAs, mixers, IF amplifiers, buffer amplifiers. RF frequencies are 900 and 1800 MHz.

**Product Line Manager Wireless:** Specific responsibilities include product line strategic planning, establishing revenue and price objectives, setting internal cost targets and oversight of internal product realization schedules.

**RF PA Engineer:** Requires 3+ years experience in design, test and manufacturing of high efficiency GaAs MESET and HBT class A and C power Amplifiers (C-verts) in the frequency range 1-2GHz. Experience in both discrete and MMIC design a plus.

**Sr. Analog IC Designers:** Responsibilities for conceptual circuit design and developing new analog/mixed signal IC's. BS/MS experience in A/D D/A, ASIC's bipolar and BiMOS.

**Filter Design Engineer:** Development of microwave high Q coaxial cavity and machine filter designs for PCS base stations. BS/MS familiar with simulation and modeling tools, three plus years filter design experience with direct Q designs (6-8000 Q's).

**RF Systems Engineers:** You will analyze, design, develop and simulate RF systems architecture (DC to 2 GHz) for next generation of cellular phones, working in a multi-disciplinary team environment using integrated product development approach. Requires a minimum of seven years' experience in RF communication systems. BSEE or MSEE preferred.

**Senior RF Engineer:** Design RF and Microwave components for microwave digital communication links. Develop RF hardware block diagrams and perform analysis for communication systems. BSEE or MSEE with 5+ years experience in Microwave circuit design such as microstrip, low noise amplifiers, power amplifiers, mixers, oscillators and RF circuits.



**MICRO COMMUNICATIONS**  
EXECUTIVE SEARCH

We specialize in the placement of wireless, RF, microwave communications nationally.  
FOR THESE AND OTHER OPENINGS  
CALL COLLECT: TEL: 978-685-2272 800 Turnpike St. • North Andover, MA 01845  
E-mail: micsearch@aol.com FAX: 978-794-5627

### SENIOR RF DESIGN ENGINEER

At Morrow, Inc., an expanding division of UPS, the worlds leading courier, designs, tests and manufactures aviation communications and navigation systems in Salem, OR, one of the most attractive mid-size cities you will ever find. They seek an experienced **RF Design Engineer** to design and develop advanced aviation RF systems. You will need a BSEE, or equivalent, and 5+ years related experience, which should include any of: Avionics RF systems, RF circuit simulation/design, VDL Mode-2/Mode-4 (STDMA) aviation datalinks.

### RF IC DESIGNERS

Are required by two semiconductor firms, both of whom design chips for Wireless communications applications. One is a top-ten world player with 6000+ employees across four continents and needs in CA, CO, TX; the other is a successful start-up niche player with operations in both AZ and CA.

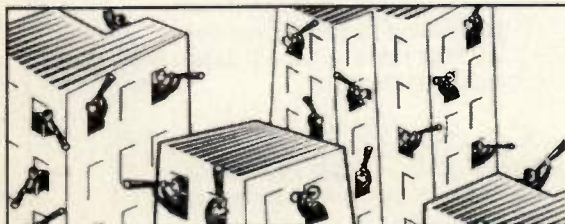
For more information on these and other AzTech positions visit our web site at [www.aztechjobs.com](http://www.aztechjobs.com) where you can post your resume on-line, or e/mail it to [resumes@aztechjobs.com](mailto:resumes@aztechjobs.com).

**AzTECH**  
Recruitment Co.

4131 N. 24th Street, Suite A122,  
Phoenix, AZ 85016  
Call (602) 955-8080 or Fax (602) 955-9639  
[www.aztechjobs.com](http://www.aztechjobs.com)

## Looking to fill a position in your company?

Advertise in the Career Opportunities section of **RF Design!**  
Call Jody at 888-234-0448 for more information.





# Landing Gear

After we brainstorm for hours, we like to be well-equipped for easing back into the atmosphere.



*Nokia people work in teams of savvy modern day wizards, brainstorming, collaborating, and creating high impact technology that continually evolves. We define communication and inspire talent, connecting people, ideas, and the known universe.*

## HERE'S YOUR CHANCE!

If you live to conquer the challenge of 'what's next', get in touch with Nokia. We have significant opportunities for the following individuals:

### RF Circuit Design Engineers (Mid through Senior Level)

These positions will design and develop new RF products for Base Station R&D. Specific responsibilities will include: design, development and analysis of circuits, as well as development and analysis of subcontracted modules. This will involve actively sourcing local component suppliers. Additional responsibilities include RF CAD-based design and simulation; development, tracking, analysis and evaluation of RF performance requirements; circuit test, evaluation and analysis; design and test of RF test plans; and supporting the product in manufacturing and during field trials.

Requirements include 5+ years of RF circuit design experience with a BSEE or equivalent experience; hands-on RF circuit design and lab prototyping; circuit debugging and integration; and demonstrable RF circuit analysis abilities. (Code: RFCDE)

### RF Circuit Design Engineers - Synthesizer/VCOs (Mid Level)

These positions are responsible for the design and development of synthesizers and Voltage Controlled Oscillators for PCS Base Stations. Candidates should be qualified in the following areas: developing, analyzing and tracking RF performance requirements; analysis, circuit testing, and evaluation; developing, executing and tracking RF test plans; and supporting the product in manufacturing and in the field with customers.

Positions require 2+ years of solid RF circuit design experience with a BSEE or equivalent experience; hands-on RF circuit design and lab prototyping; circuit debugging and integration; and demonstrable RF circuit analysis abilities. (Code: RF-VCO)

### RF Design Engineers - Integrated Circuits (Mid through Senior Level)

These positions are responsible for design and development of new RF Integrated Circuits (IC's) within the Base Station Research and Development Group. Candidates should be qualified to: analyze, design, develop, and test RF ICs; manage the acquisition of parts from outside foundries; develop, track, and execute RF IC test plans; support test and evaluation of RF IC devices; support testing the end product in manufacturing.

All positions require, in addition to a BSEE or equivalent experience, a minimum of 2 years of RF circuit design and testing experience. A minimum of 5 years of related experience is preferred for Senior positions. (Code: RFDE-IC)

### RF Design Engineer - Receivers (Mid Level)

The selected candidate will be involved with the development of RF receiver systems and circuit design and should have the qualifications to perform those functions. Requires 5+ years of experience and overall understanding of receiving system function and performance requirements. Hands-on experience with RF circuit design and lab prototyping, as well as integration and debug is essential. (Code: RFDE)

### RF Development Engineers (Mid through Senior Level)

These positions will develop suppliers for new base station products. Applicants should be qualified to specify, analyze, test, track, and evaluate modules and assemblies supplied by subcontractors. Successful candidates will monitor and aid in the development of new base station products. The ability to perform Computer Aided Circuit Design and Simulation of RF systems and components is also required. All positions require 2+ years of relevant experience with a BSEE or equivalent experience.

Experience in Transceiver, Synthesizer, RF filter, PA, VCO, Design for volume production, and PCS/Wireless/Cellular is a definite plus. (Code: RF-LNA)

### RF Engineers - Filter Systems (Entry through Senior Level)

These positions are responsible for the design and development of new RF products within the Base Station R&D group. Candidates should be qualified in the following areas: RF filter systems analysis, development, test and evaluation; interfacing closely with subcontractors; actively developing local sources and suppliers; supporting products and implementing product improvements; developing, tracking and executing RF test plans; supporting the product in manufacturing and in the field with customers.

Entry-level positions require a BSEE or equivalent plus understanding of RF filter system functions and performance requirements. All other positions require, in addition to a BSEE or equivalent, a minimum of 2 years of RF filter systems development experience to include testing, integration, and analysis experience. A minimum of 5 years of related experience preferred for Senior positions. (Code: RF-FILTER)

### RF Test Engineers (Mid through Senior Level)

These positions require 2-5+ years of solid experience in RF systems and test engineering. Must have experience in understanding RF system functions and performance requirements. Hands-on experience with RF testing in a lab environment with controlled environment conditions, as well as RF test integration and debugging is essential. Must have RF circuit analysis abilities. (Code: RFTE)

### RF Resourcing Manager

This position will be responsible for assisting/managing RF TC tasks including recruiting, hiring, and staff development/training. In addition, staff planning, tracking, and review/evaluation will also be required. Extensive budgeting and expansion planning for CAD/CAE system upgrades will be expected, as is maintenance and acquisition of new equipment. Requirements include a technical degree in Engineering, or equivalent experience. Three years R & D experience necessary, with working knowledge of RF and product development. Strong interpersonal and organizational skills necessary, supervisory experience and Finnish language are a plus. (Code: RFRM)

When you join Nokia, your health care coverage, medical and dental, and 401(k) begin on your very first day of employment. We provide many additional benefits and a competitive plan that only a leader in it's field could provide. Please forward your resume to: NOKIA, Attn: RFD(Insert Code), 6000 Connection Dr., Dallas, TX 75039; Fax (972) 894-4600; E-mail: recruiter.ntcusa@ntc.nokia.com. Equal Opportunity Employer.

# NOKIA

CONNECTING PEOPLE

Visit us at [www.nokia.com](http://www.nokia.com)



# Filters to 40 GHz!

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

For more information, ask for our RF Catalog.

**MC**

**MICROWAVE FILTER COMPANY**

6743 KINNE STREET, E. SYRACUSE, NY 13057

(315)438-4700 • 800-448-1666 • FAX: (315)463-1467

E-MAIL: mfcsales@microwavefilter.com



## Discover the Advantages of Reprints!

For a quote or to discuss how reprints from this magazine can work for you--call me!

**Jenny Eisele, PRIMEDIA Intertec**

Phone: 913-967-1966 Fax: 913-967-1898

**RFdesign**

**BUYERS' SOURCE**

### ANTENNAS



**M<sup>2</sup> ANTENNAS** 1.6 - 3000 MHz  
Positioners & Pedastals

We Specialize in High Gain Arrays  
Standard & Custom Designs

7560 N. DEL MAR AVE., FRESNO, CA 93711

Ph: (209) 432-8873 Fax: (209) 432-3059 Website: m2inc.com

### AMPLIFIERS

**TE SYSTEMS**

PO Box 25845  
Los Angeles, CA  
90025

**RF Power Amplifiers**  
...VHF/UHF/Microwave  
Custom Designs

TEL 310.478.0591  
FAX 310.473.4038

### DISCRETE COMPONENTS

#### CAPACITORS

**Mica High Power**

**SURCOM ASSOCIATES, INC.**

2215 Faraday Avenue, Suite A, Carlsbad, CA 92008

Phone: (760) 438-4420 Fax: (760) 438-4759

E-mail: link@surcom.com Web: www.surcom.com

**Vacuum**

**SURCOM ASSOCIATES, INC.**

2215 Faraday Avenue, Suite A, Carlsbad, CA 92008

Phone: (760) 438-4420 Fax: (760) 438-4759

E-mail: link@surcom.com Web: www.surcom.com

### DISCRETE COMPONENTS

#### CAPACITORS

**Variable**

**SURCOM ASSOCIATES, INC.**

2215 Faraday Avenue, Suite A, Carlsbad, CA 92008

Phone: (760) 438-4420 Fax: (760) 438-4759

E-mail: link@surcom.com Web: www.surcom.com

### DISCRETE COMPONENTS

#### CRYSTALS/RESONATORS

**Varactor**

Knox Semiconductor, Inc.

13 Quarry Rd., P.O. Box 609, Rockport, ME 04856

Phone: (207) 236-6076

Fax: (207) 236-9558

Crystals • Oscillators • VCXOs • TCXOs

**SaRonix**

141 Jefferson Dr • Menlo Park • CA 94025

650-470-7700 • 800-327-4032

saronix@saronix.com

**www.saronix.com**

**RFdesign**

**Jody Schrader**

1-888-234-0448

Classified Advertising Manager

### DISCRETE COMPONENTS

#### CRYSTALS/RESONATORS

**West Crystal Company Ltd.**

Since 1980

- 1 to 200 MHz custom crystals
- Tight spec, quick turn
- Lifetime warranty
- ISO 9002 certified

Tel: 250-765-4833 Fax: 250-765-3308

Email: wcrystal@silks.net

10 - 2550 Acland Rd, Kelowna, BC  
V1X 7L4 Canada

### ELECTRONIC COMPONENTS/EQUIPMENT

#### TRANSFORMERS

- RF TRANSFORMERS UP TO 300 MHZ
- POWER SPLITTERS & COMBINERS 2-30 MHZ AND 88-108 MHZ
- TRANSFORMER DESIGN CONSULTATION



17827 N. 26th. Street  
Phoenix, AZ 85032

Ph:(602)867-0389•Fax:(602)971-9295•www.rfpowersystems.com

**Get Noticed**

for a price you'll hardly notice.

**1-888-234-0448**

**RFdesign**



## ELECTRONIC COMPONENTS/EQUIPMENT

### EMI SUPPRESSION COMPONENTS



#### Fair-Rite Products Corp. Your Signal Solution™

P.O. Box J 1 Commercial Row,  
Wallkill, NY 12589  
Phone (914) 895-2055 • FAX (914) 895-2629  
E-Mail ferrites@fair-rite.com

Fair-Rite Products Corp., a QS9000 registered company, is a leading full-line ferrite component manufacturer offering a wide variety of components for EMI suppression and power applications utilizing innovative processes and materials.

## MATERIALS/HARDWARE/PACKAGING

### SHIELDING MATERIALS

#### EMI/RFI Shielding Tapes

Conductive Adhesives & Tapes  
Foils/Fiber/Fabric/Gasketing/Laminating

#### Venture Tape Corp.

30 Commerce Road, Rockland, MA 02370  
Tel: (800) 343-1076 Fax: (781) 871-0065  
Visit us at: [www.venturetape.com](http://www.venturetape.com)

## MODULAR COMPONENTS

### OSCILLATORS



#### Wenzel Associates "Quietly the Best"

- Standard and Ultra Low Noise Crystal Oscillators
- New Low Noise RF Modules
- Ultra Low Noise Frequency Standards

PH 512-450-1400 Fax 512-450-1490 [www.wenzel.com](http://www.wenzel.com)

## PRODUCT DEVELOPMENT

### SYSTEM OEM PRODUCT DEVELOPMENT/SUPPLY

Locus, Inc.  
142 Hoffman St., Madison, WI 53704

Phone: (608) 244-0500  
mail: [www.locusinc.com](http://www.locusinc.com)

**Take control of your advertising dollar!**

Advertise in  
RF Design Marketplace!

Call Jody Schrader at 888-234-0448

## RF TRANSMISSION COMPONENTS

### INDUCTORS AND CHOKES



- Lightning Suppressors
- D.C.-26GHz Coaxial
- Powerline • Digital

FISCHER CUSTOM COMMUNICATIONS, INC.  
2917 W. Lomita Blvd., Torrance, CA 90505

Phone: (310) 891-0635  
Fax: (310) 891-0644  
E-mail: [sales@fischercc.com](mailto:sales@fischercc.com)

Custom Inductors and Chokes For  
VLF, LF, MF and HF Applications

Kintronic Labs  
144 Pleasant Grove Rd., Bluff City, TN 37618  
Phone: (423) 878-3141 • Fax: (423) 878-4224  
Email: [kti@kintronic.com](mailto:kti@kintronic.com)  
Web Site: [www.kintronic.com](http://www.kintronic.com)

## DESIGN AND MANUFACTURING

#### RF/Microwave Design Designs that Work!

Transmitters, Receivers, Up/Downconverters

#### WAVECON

PO Box 2697, Escondido, CA 92033  
Phone: (760) 747-6922 • Fax: (760) 747-5270

## SOFTWARE & SYSTEMS, CAD/CAE

### SYSTEM SIMULATION

#### Circuit Simulation

ingSoft Ltd. -the providers of the RF Designer® Solution  
213 Dunview Ave., North York, Ontario M2N-4H9  
Canada

Phone: (416) 730-9611  
Fax: (416) 226-0861

**Rf Intercept.** Increase your design confidence by simulating and optimizing entire systems: IM, noise, S/N, BER, eye pattern, spectral occupancy.

RHR Laboratories, 207 Harding Blvd. W.  
Richmond Hill, ON, L4C 8X6, Canada  
Tel.: (905) 884-2392 • Fax: (905) 884-6843  
104673-3110@compuserve.com  
<http://ypn.com/rhrlaboratories>

Tesoft, Inc.  
205 Crossing Creek Ct., Roswell, GA 30076  
Makers of TESLA for Windows Simulator

Phone: (800) 631-1113  
Fax: (770) 664-5817  
Intl: (770) 751-9785

## TEST EQUIPMENT

### RF TEST & MEASUREMENT EQUIPMENT

Coaxial Dynamics, Inc.  
15210 Industrial Pkwy., Cleveland, OH 44135

Phone: (216) 267-2233  
Fax: (216) 267-3142

### Lone Mountain Electronics

Bargain RF & Microwave Test Equipment  
New - Used - Surplus Visit our website:

[www.lonemtn.com](http://www.lonemtn.com)

## TEST EQUIPMENT

### SPECTRUM ANALYZER

#### SPECTRUM ANALYZER in a probe \$249

Display on your inexpensive scope

Measure  $\mu\text{V/m}$ ,  $\mu\text{V}$ ,  $\text{mA}$

[www.spectrumprobe.com](http://www.spectrumprobe.com)

## TEST LABORATORIES/CONSULTANTS

### LABORATORIES



Product testing and certification for Telecoms (TTED),  
EMC, ISO 9000 & more.

1-800-609-1287

[www.babtps.com](http://www.babtps.com) • Fax: 408-919-0585

# Because it works.

The RF Design direct mail maintains a clean, qualified subscriber list.

RF Design magazine meets the tough audit standards of BPA International. So when we say you'll reach over 40,000\* professionals in radio frequency design — we mean it.

When you're ready to reach this qualified group of professionals call Lori Christie and let our names work for you!

**Call Lori at 913-967-1875**

fax 913-967-1897

e-mail [lori\\_christie@intertec.com](mailto:lori_christie@intertec.com)

website [www.interteclists.com](http://www.interteclists.com)

\*Based on the June 1998 BPA International Circulation Statement



# RF A moment with...

## Dr. Bami Bastani

Chief Executive Officer, Anadigics

*Dr. Bastani has previously worked with a number of semiconductor companies including Intel, National and Fujitsu. He joined Intel in 1980 as the senior device engineer where he was involved in memory and microprocessor technology development.*

*In 1985 he joined National Semiconductor where he served in several executive positions. In 1996, Dr. Bastani joined Fujitsu Microelectronics as executive vice president for System LSI Group, where he lead semiconductor business units in networking and processing information for worldwide markets.*



*Dr. Bastani holds a B.S.E.E. from the University of Arkansas College of Engineering. In 1977, he received his M.S.E.E. and earned his Ph.D. in 1980 from Ohio State University.*

*Dr. Bastani has written over a dozen publications on semiconductor devices, and holds three US patents in semiconductor technology.*

*Anadigics manufactures high-performance gallium arsenide integrated circuits (GaAs ICs) used in a variety of high-volume communications applications.*

*The interview was conducted by Senior Associate Editor Roger Lesser.*

**RF Design:** *Where is third generation (3G) headed?*

**Bastani:** I was at the worldwide conference. It was interesting how 3G is a "beauty in the eyes of the beholder." While one company sees it as an evolutionary path others see it as a common standard. Yet, others are saying we already have dual-mode, triple-mode, dual-band and we can accommodate diversity. There is room for diversity. We don't have to have everything under the same standard. So, I think the only thing that will be common is the name. However, I would like to see us converge on a standard.

**RF Design:** *How does a company, like Anadigics, prepare?*

**Bastani:** First of all, 3G gives us opportunity. But you also have to have good partnership with industry leaders. We have worked with companies like Ericsson and Qualcomm in the past. We will be using them as sounding boards and then positioning Anadigics. We also will be participating in the standards bodies and conferences to make sure we are well prepared.

**RF Design:** *What does this hold for the future of Anadigics chip technology?*

**Bastani:** I think it will just be an evolution of what we do. It is going to be a digital and linear standard. Coupled with our gallium arsenide (GaAs) capability, which lends itself to linearity and efficiency and power management. These are all the elements required for the RF deck of the third generation handsets.

**RF Design:** *While GaAs technologies offer benefits, isn't there room for silicon-based technologies within 3G?*

**Bastani:** When you're dealing with the high end, the linearity and efficiency you get out of gallium arsenide will still be leading the pack. Especially in the critical transmitter side of the radio module.

**RF Design:** *When do you anticipate producing 3G chip technology?*

**Bastani:** At least a couple of years. We are keeping abreast of developments. But I think what is going to be developed is industry leader dependent. And we are fortunate to have the strong ties with these players.

**RF Design:** *How can you do this?*

**Bastani:** There are two things we are doing. One is to ensure we understand what the customer wants. This is where we need to be part of the roadmap, part of the interface with the company we are supporting. The second part is to anticipate the future. There is nothing unique about the gallium arsenide industry compared to the rest of the semiconductor industry. But, you need to move up the integration and performance path. So, what you will see will be modules that can integrate multiple functions into the substrate. Also, higher performance FETs (field-effect transistors) where you can move up the performance bridge. Another area is shrinking the gate so you can get higher performance and higher gain. As development tools progress, we will progress our performance.

**RF Design:** *What higher perfor-*

*mance areas can we anticipate?*

**Bastani:** The biggest will be in linearity and efficiency. This is especially true for power amplifiers. Also, another area will be how fast a raw transistor runs. In this area, we see a tremendous amount of interest from our broadband customers. For example, when we deal with 10 Gbits per second transimpedance amplifiers. We are introducing new pseudomorphic high-electronmobility transistor (pHEMT) technology. This will drive our 10 Gbits per second product developments and offerings. In the broadband area, 2.5 Gbits per second is the sweet spot of our current MES-FET (metal semiconductor field-effect transistor) technology. So, broadband is pushing transistor performance.

**RF Design:** *What is wireless pushing?*

**Bastani:** Wireless is heavily pushing linearity, power efficiency and cost.

**RF Design:** *How do you view Anadigics place in the market?*

**Bastani:** When you look at wireless from Anadigics perspective, power amplifiers have been our dominant place. I view Anadigics as an analog RF company in the communications market. We have segmented the market into wireless, and broadband communication. Cable addresses set top boxes, cable modems, and digital TV broadcast, while fiber represent our participation in telecomm and data-comm. 40% of our revenue is wireless, and 60% is broadband communication with 40% in cable and 20% in fiber market segments.

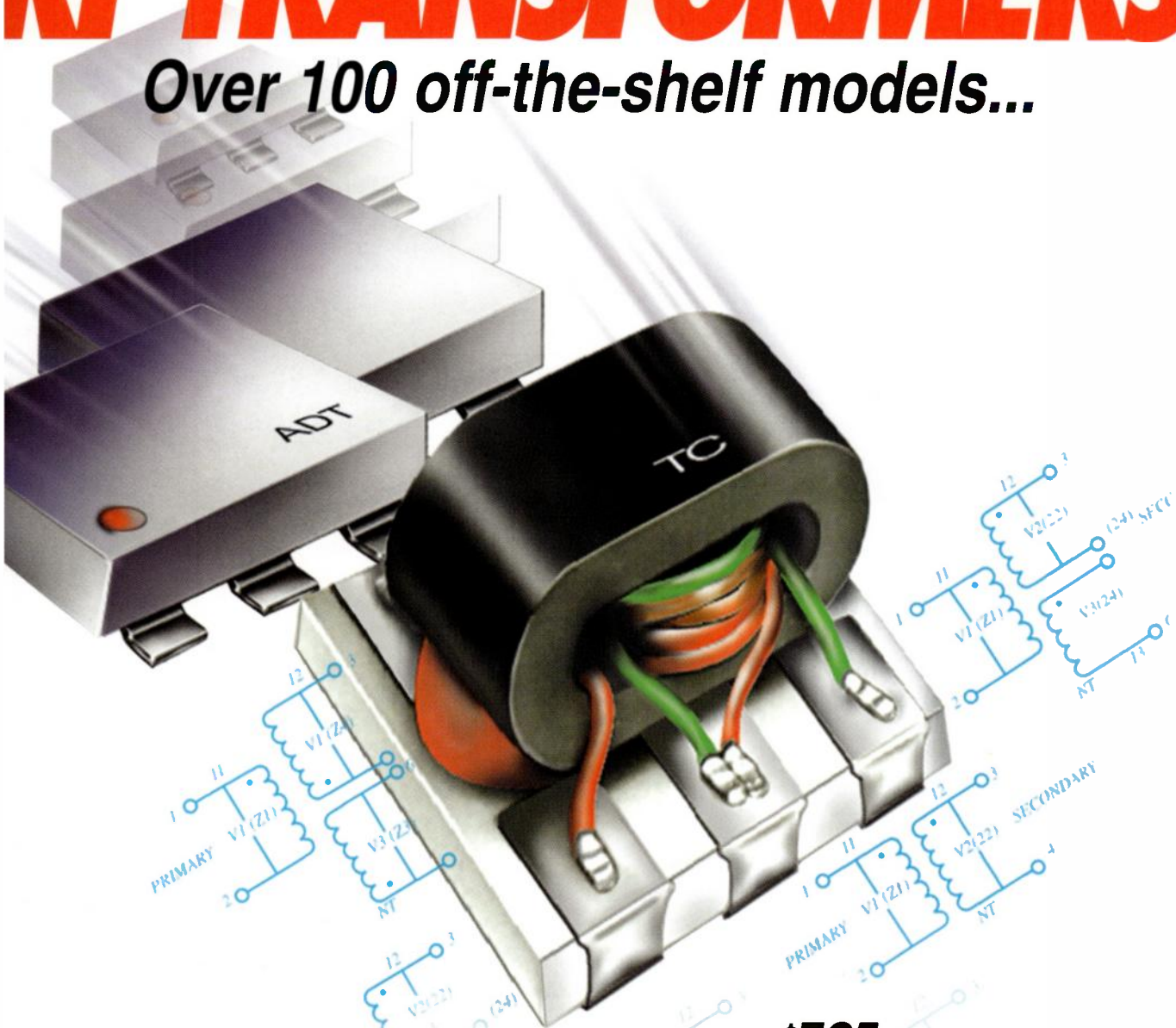
RF



**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<sup>™</sup>** 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<sup>®</sup>**

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](http://WWW.RFGLOBALNET.COM)

**ISO 9001 CERTIFIED**

US  INT'L   
CIRCLE READER SERVICE CARD

F 290 Rev Orig



# IMPROVE Your PCS Receiver's PERFORMANCE With NEC's New, Miniature Low Cost FETs

## NE34018 HEMT FETs:

### GREAT PERFORMANCE, NEW LOW PRICE...

- +23 dBm Output  $IP_3$  @ 2 GHz
- 0.7 dB NF, 15 dB Gain @ 2 GHz
- Ultraminiature SOT-343 package
- 70¢ in 100K quantities



Housed in SOT-343 packages (right), these NEC HEMTs are nearly half the size of conventional SOT-143 devices.

## VERSATILE NE76118 MESFETs:

- 0.8 dB Noise Figure @ 2 GHz
- 13.5 dB Associated Gain @ 2 GHz
- Use as an oscillator, 2nd stage LNA, or buffer amp
- 61¢ in 100K quantities

## SUPER LOW NOISE NE334S01 HJ FETs:

- 0.25 dB Noise Figure @ 4 GHz
- 16 dB Associated Gain @ 4 GHz
- Miniature plastic four pin package
- 99¢ in 100K quantities

# NEC

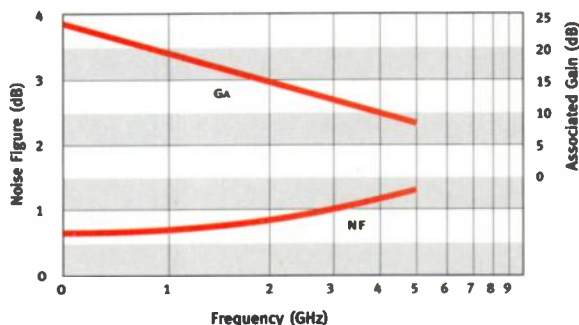
See us at Wireless Symposium San Jose, Feb 23-25  
Booth # 617

Need a high performance first stage LNA for your PCS, GPS, or WLAN receiver? Our NE34018 GaAs HEMT delivers! You get low noise and high output  $IP_3$  all in a low cost, superminiature SOT-343 plastic package. Nearly half the size of a conventional SOT-143 device, the NE34018 can help miniaturize your handheld wireless receiver design — while maximizing its performance. The NE34018 is just one in a family of

miniature plastic transistors from NEC.

Want more information? Visit our website or call our 24-hour automated Fax Hotline. We'll get you data in minutes!

## NE34018 NOISE AND GAIN PERFORMANCE



For instant Product Data visit us at:  
**[www.cel.com](http://www.cel.com)**

Or call our 24-hour Fax Hotline  
at 800-390-3232 and request  
Document #144  
(U.S. and Canada)



**CEL** California Eastern Laboratories

4590 Patrick Henry Drive ■ Santa Clara, CA 95054 ■ 408 988-3500 ■ [www.cel.com](http://www.cel.com)

DISTRIBUTORS: Repton Electronics (888) REPTON Bell Industries (800) 525-6666

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