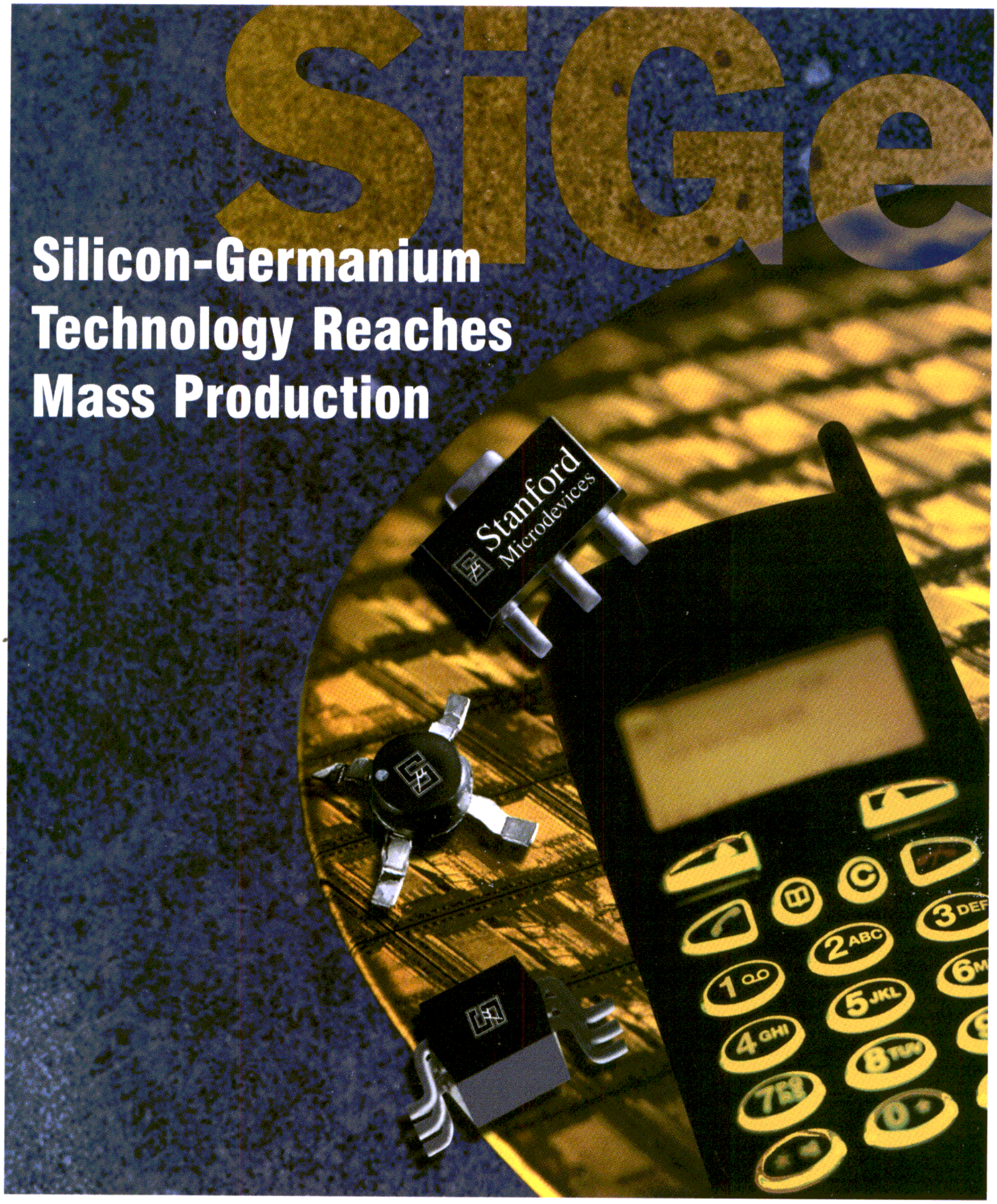
September 1999

Applied MICROWAVE & WIRELESS

SiGe

Silicon-Germanium Technology Reaches Mass Production



Circuit Design

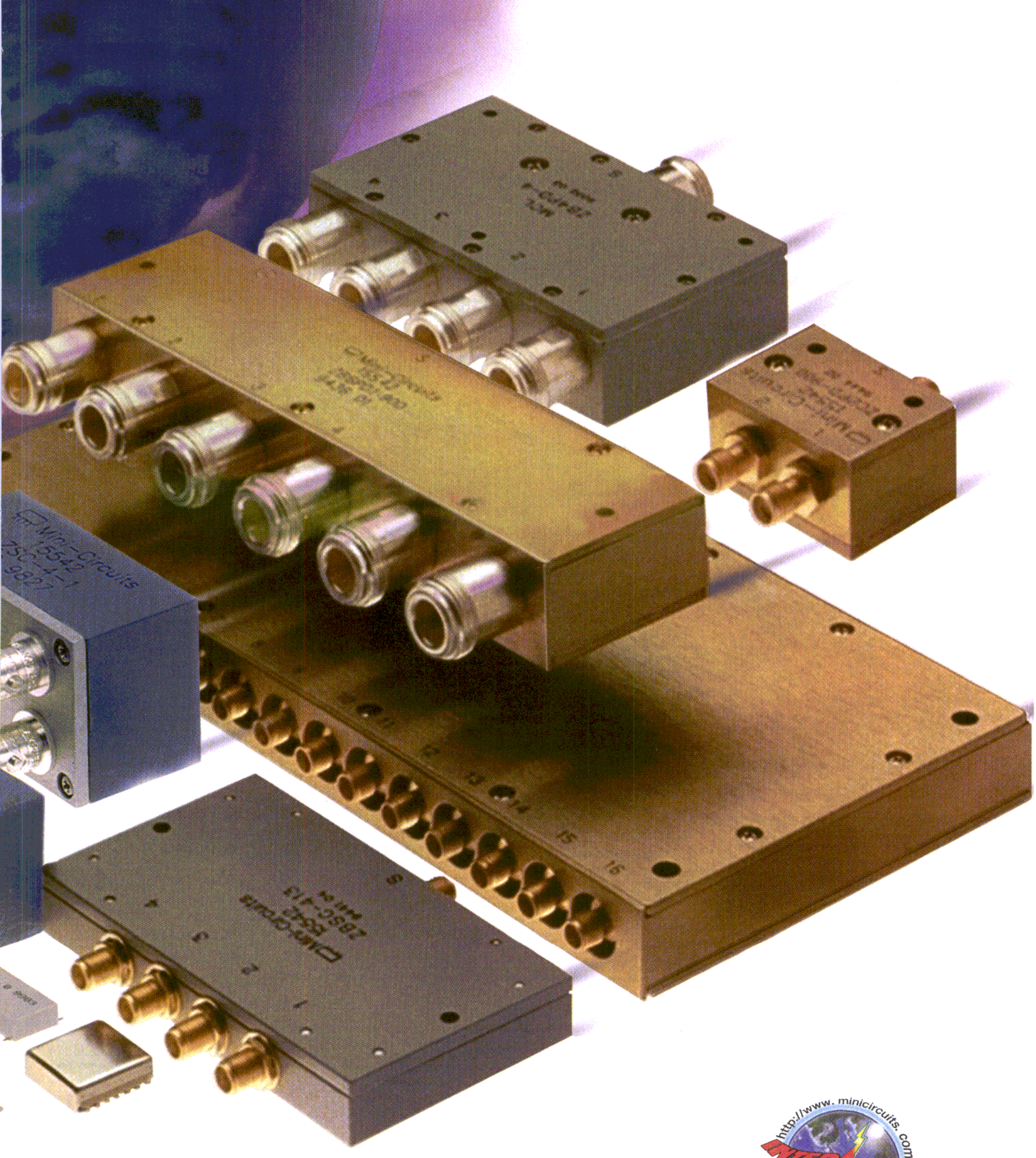
Broadband Transmission Line Hybrid Design

Wireless Systems

Requirements for Sharing Microwave Sites

Design Ideas

Mechanical Design Tips for EMI Shielding


Mini-Circuits
15542
ZSC-4-1
9827

Silicon Germanium (SiGe), Stanford Microdevices' latest RF semiconductor process, offers benefits not attainable by conventional silicon-bipolar technologies: lower noise figures, lower power consumption, high output power at high efficiency, and high integration level.

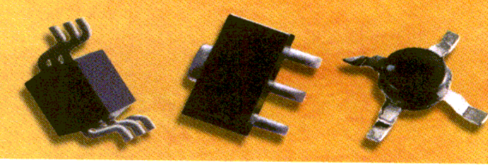
As part of a series of Stanford Microdevices' initiatives to apply silicon germanium technology to a broad spectrum of communications applications, we are now offering the wireless market devices built using a patented silicon germanium manufacturing process. As these devices enter the marketplace, consumers will benefit from cellular phones, pagers, and other wireless communications devices that have extended battery life, carry out multiple functions, and are smaller, lighter, and less expensive.

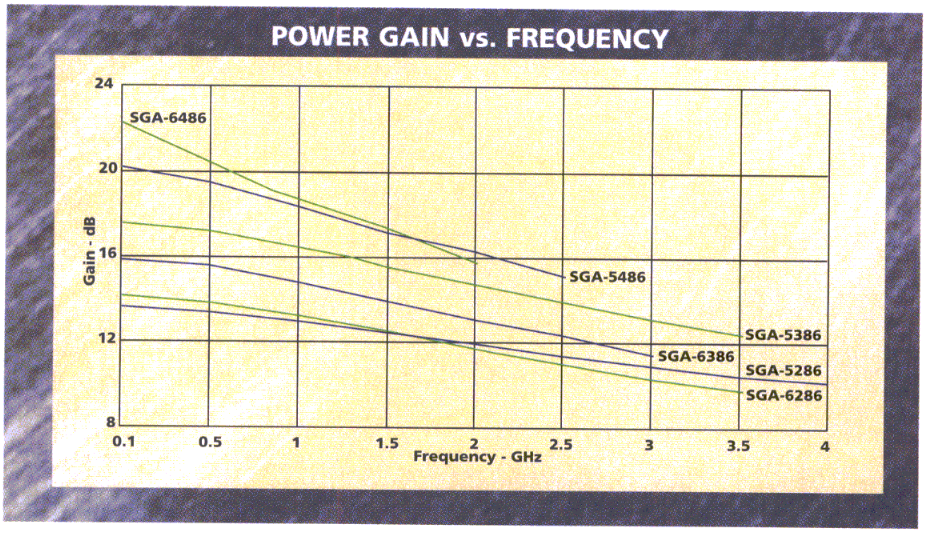
PRODUCT SELECTION GUIDE

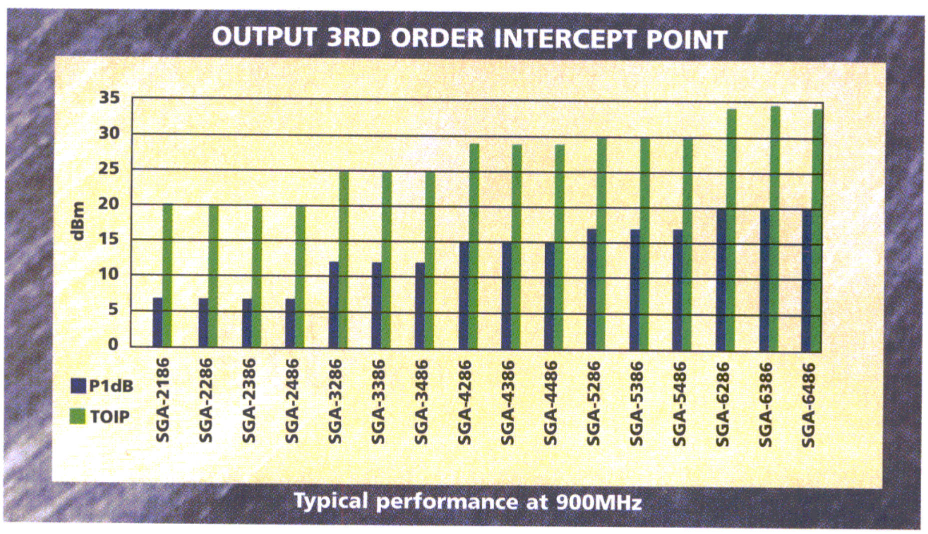
General Purpose Amplifiers

Part Number	Vd (V)	Id (mA)	3dB BW	P1dB (dBm)	IP3 (dBm)	Gain@ 1 GHz	Gain@ 2 GHz	NF 50 Ohm
SGA-2186	2.2	20	DC-5.0	+7.0	+20.0	10.5	10.2	4.1
SGA-2286	2.2	20	DC-3.5	+7.0	+20.0	15.0	14.0	3.2
SGA-2386	2.7	20	DC-2.8	+7.0	+20.0	17.4	16.4	2.9
SGA-2486	2.7	20	DC-2.0	+7.0	+20.0	19.6	18.0	2.5
SGA-3286	2.7	35	DC-3.6	+12.0	+26.0	14.8	13.4	3.5
SGA-3386	2.5	35	DC-3.6	+12.0	+25.0	17.4	16.2	3.0
SGA-3486	2.9	35	DC-2.0	+12.0	+25.0	21.5	19.4	2.6
SGA-4186	3.2	45	DC-6.0	+15.0	+29.0	10.4	10.2	4.6
SGA-4286	3.2	45	DC-3.5	+15.0	+29.0	13.8	12.6	3.3
SGA-4386	3.3	45	DC-2.5	+15.0	+29.0	17.0	15.2	2.8
SGA-4486	3.2	45	DC-2.0	+15.0	+29.0	19.0	16.8	2.5
SGA-5286	3.5	60	DC-4.0	+17.0	+30.0	13.5	12.7	4.1
SGA-5386	3.6	60	DC-3.2	+17.0	+31.0	17.3	16.0	3.5
SGA-5486	3.5	60	DC-2.4	+17.0	+31.0	19.7	18.0	2.8
SGA-6286	4.2	75	DC-3.5	+20.0	+34.0	13.8	12.4	3.9
SGA-6386	5.0	80	DC-3.0	+20.0	+34.5	15.4	13.8	3.8
SGA-6486	5.2	75	DC-1.8	+20.0	+34.0	19.7	16.7	2.9

SGA 2000 through 4000 series are also available in SOT-363
SGA 5000 and 6000 series are also available in SOT-89 & SOT23-5







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September 1999
Vol. 11 No. 9

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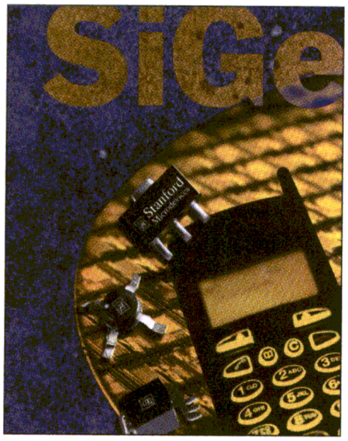

TECHNICAL FEATURES

PRODUCTS & TECHNOLOGIES

September 1999
Vol. 11 No. 9

Applied MICROWAVE & WIRELESS

PRODUCTS & TECHNOLOGIES

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Editorial

Visit Our Redesigned and Expanded Web Site

By Gary A. Breed
Publisher

Linguistics scholars and *Wheel of Fortune* fans know that the most common letter in the English language is the letter "e." Of course, that was in the past. Now the most common letter on the whole planet is "w" — as in www.anything.com!

As part of that trend, we have completely redesigned www.amwireless.com to include more information resources for our readers and advertisers, along with the potential for expansion to add many more features as the need arises. Here are some the things you can find:

Index of past articles and archives — Did you see an article from 1995 referenced in a recent paper? Do you want to see what was published before you became a subscriber? Just point your browser to our web site and take a look. All recent articles and many popular past articles are downloadable as PDF files. We will continue to add articles to the archives until the entire ten-year collection is online.

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Of course, some of the above features have been in place for more than two years. And, there are more improvements and new features in the works as we further develop our web site. Among the new features we are preparing are selected links to other sites with technical resources for our readers and a convenient way to obtain new product information.

Our web site is meant to be entirely service-oriented. We think you'll agree that it adds value to our magazine beyond its printed pages. ■

Mixer transformers can be baluns

Editor:

I read the July 1999 issue and found the article on page 80 to be somewhat misleading to your readers. I'd like to present my views on the subject to help expand on the topic.

The article is titled "Understanding Transformer Operation in Double-Balanced Mixers," by Jerry Sevick. In it, the author states that, while both T1 and T2 are commonly called baluns in this application, they are not baluns. I'd like to point out this interpretation is true for the narrow viewpoint his article presents, but a double-balanced mixer is a very versatile device, able to be used in many capacities besides its well-known use as a downconverter. It can, for example, be used equally well as a bi-phase modulator.

In this alternative application, the IF port is used to input the diode bias signal (a function usually assigned to the signal at the LO port). Operated in this manner, the diodes that simultaneously conduct are either the D1/D3 pair or the D2/D4 pair. One can quickly see that this either connects the back-to-back pair of baluns in-phase (D1/D3 biased on), or directly out-of-phase (D2/D4 biased on). T1 and T2 are hence operating exactly as transmission line baluns.

Thanks for your attention, and for an excellent publication.

Jim Luschen
REMEC, Inc.

A further clarification is that true transmission line balun operation is limited to the IF connection to the diodes. Signals at the other two ports are coupled by conventional transformer action — Editor.

A reminder that diodes are both linear and nonlinear

Editor:

I sure have enjoyed your magazine over the past years, and especially appreciate the good review of basics.

In the brief article on page 80 of July 1999, the statement "... due to the diodes' nonlinearity" reminded me that this aspect of diode modulators/demodulators is often greatly misunderstood. A prevalent misunderstanding is that the "nonlinearity" is that of the diode's forward characteristics, which couldn't be farther from the truth! It is the *forward* vs. *reverse* conduction which makes up the nonlinearity in these circuits. Even a simple diode detector is linear due to $R_L >> R_{diode}$ in the standard detector.

Franklin Swan

Mr. Swan is correct, and we should note that he was not accusing the author of making this mistake, just taking a cue from his seemingly simple statement. The issue of diode nonlinearity in the on/off transition region has been covered very well in the literature, yet it was not until around 1985 that its effect in mixers was widely discussed. An example of that discussion was the suggested use of square-wave LO signals to minimize the time that the diode operates in its nonlinear on/off transition region, thus maximizing mixer linearity. — Editor

Letters should be addressed to:

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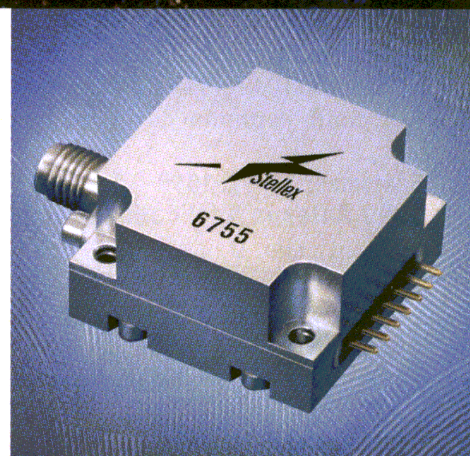

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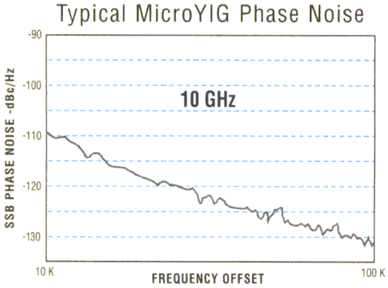

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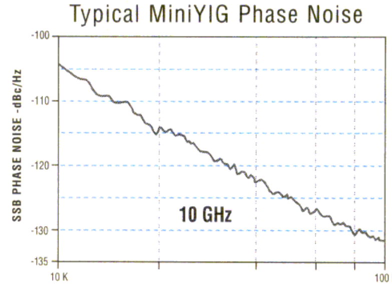
- SMA Connectorized
- Heaterless design

Typical MiniYIG Phase Noise



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Calendar

CONFERENCES

SEPTEMBER

September 8-10, 1999
ART '99 — Second Annual International Symposium on Advanced Radio Technologies
Boulder, CO
Information: Dr. John Lemmon
Tel: (303) 497-3414; Fax: (303) 497-3680
E-mail: jlemmon@ntia.its.bldrdoc.gov

September 15-17, 1999
1999 Antenna Applications Symposium
Monticello, IL
Information: Ann Wilson
Tel: (413) 545-0779
Fax: (413) 545-4652
E-mail: awilson@ecs.umass.edu

September 20-21, 1999
1999 CDMA Technology Conference
New Orleans, LA
Information: WIT
Tel: (210) 344-6660
Fax: (708) 570-3825
E-mail: witmail@bigfoot.com
Internet: http://www.bigfoot.com/~witmail

September 21-24, 1999
PCS '99 — Personal Communications Showcase
New Orleans, LA
Information: Registration
Tel: (800) 759-0300 (U.S., Canada); (703) 739-0300
Fax: (708) 344-4444
Internet: http://www.pcs99.com

September 22-27, 1999
WCNC '99 — IEEE Wireless Communications and Networking Conference
New Orleans, LA
Information: WCNC '99
E-mail: wcnc99@comsoc.org
Internet: http://www.comsoc.org/confs/wcnc/99

OCTOBER

October 4-8, 1999
European Microwave Week — European Wireless '99, European Microwave Conference and GAAS99
Munich, Germany
Information: Nicola Jedrej
Tel: +44 171 861 6391
Fax: +44 171 861 6251
E-mail: eumw@unmf.com
Internet: http://www.eumw.com

October 11-13, 1999
ICECOM '99 — 15th International Conference on Applied Electromagnetics and Communications
Dubrovnik, Croatia
Information: Mrs. Nena Stambuk-Borsic
Tel: +385 1 612 9 869
Fax: +385 1 612 9 870
E-mail: korema@fer.hr
Internet: http://www.rasip.fer.hr/korema

October 13-15, 1999
TELSIKS '99 — 4th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services
Nis, Yugoslavia
Information: Dr. Bratislav Milovanovic
Tel: +381 18 529 320; Fax: +381 18 46 180
E-mail: telsiks@elfak.ni.ac.yu
Internet: http://www.telsiks.org.yu

October 17-20, 1999
1999 IEEE GaAs IC Symposium
Monterey, CA
Information: Brad Nelson
Tel: (650) 852-6843; Fax: (650) 852-7128
E-mail: nelson.brad@ssd.loral.com
Internet: http://www.gaasic.org/

October 29, 1999
1st European Workshop on Conformal Antennas
Karlsruhe, Germany
Information: Mrs. Lehmann
Tel: + 49 721 608 6262; Fax: + 49 721 691865
E-mail: wca@ihesamoa.etec.uni-karlsruhe.de
Internet: http://ww-ihe.etec.uni-karlsruhe.de/wca_index.html

NOVEMBER-DECEMBER

November 15-17, 1999
MOMUC '99 — 6th IEEE International Workshop on MobileMultimedia Communications
San Diego, CA
Information: MOMUC '99
Tel: (212) 854-3109
E-mail: campbell@comnet.columbia.edu
Internet: http://cwc.ucsd.edu/momuc99

December 13-17, 1999
ISRAMT '99 — 7th International Symposium on Recent Advances in Microwave Technology
Malaga, Spain
Information: Banmali Rawat
Tel: (702) 784-6927; Fax: (702) 784-6627
E-mail: rawat@ee.unr.edu
Internet: http:// www.isramt99.ic.uma.es/

Calendar

SHORT COURSES

University of Missouri-Rolla

Grounding & Shielding Electronic Systems — How to Diagnose and Solve Electrical Noise Problems

Detroit, MI . . . . September 13-14, 1999
Denver, CO . . . . September 21-22, 1999
Austin, TX . . . . November 3-4, 1999
Houston, TX . . . . November 8-9, 1999

Circuit Board Layout to Reduce Noise Emission and Susceptibility

Denver, CO . . . . September 23, 1999
Austin, TX . . . . November 5, 1999
Houston, TX . . . . November 10, 1999

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

RTT Programmes Limited

Digital Cordless Design

Burnham, UK . . . . September 13-15, 1999

Digital Cellular Design

Burnham, UK . . . . September 20-22, 1999

RF Power Amplifier Design

Burnham, UK . . . . October 11-13, 1999

RF Oscillator Design

Burnham, UK . . . . October 18-20, 1999

Rx/Tx RF/IF Processing

Burnham, UK . . . . November 1-3, 1999

RF System Engineering

Burnham, UK . . . . November 15-17, 1999

3G Technology

Burnham, UK . . . . November 22-24, 1999

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

The George Washington University Continuing Engineering Education Program

Spread Spectrum Communications Systems: Commercial and Government

Washington, DC . . . . September 13-17, 1999

Satellite Communications Systems Planning, Design and Operation at C and Ku Bands

Washington, DC . . . . September 14-17, 1999

Microwave Radio Systems

Washington, DC . . . . September 20-22, 1999

Fundamentals of Video Technology for Communications and Broadcasting

Washington, DC . . . . September 27-30, 1999

Satellite and Wireless Telecommunications: Strategic Planning Issues

Washington, DC . . . . October 4-7, 1999

Digital Cellular and PCS Communications: The Radio Interface

Washington, DC . . . . October 4-8, 1999

Analyzing Communications Systems Performance

Washington, DC . . . . October 4-7, 1999

Satellite Network Planning Essentials

Washington, DC . . . . October 18-20, 1999

Mobile Wireless Telephony

Washington, DC . . . . October 25-29, 1999

Communications Satellite Systems: The Earth Station Practical Approach to Implementation

Washington, DC . . . . October 26-29, 1999

Satellite Communications Engineering Principles

Washington, DC . . . . October 26-29, 1999

Interoperability in Military Tactical Communications Using MIL-STD-188-220 and VMF

Washington, DC . . . . November 1-3, 1999

Global Positioning System: Principles and Applications

Washington, DC . . . . November 2-5, 1999

Wireless Telecommunications: An Introduction

Washington, DC . . . . November 15-17, 1999

Multiple Access Techniques for Wireless Communications Systems

Washington, DC . . . . November 15-17, 1999

Modern Receiver Design

Washington, DC . . . . November 15-19, 1999

Digital Television

Washington, DC . . . . November 17-19, 1999

Information: The George Washington University Continuing Engineering Education Program, Tel: (800) 424-9773; Fax: (202) 872-0645; E-mail: ceepinfo@ceep.gwu.edu.

Besser Associates

Mixed-Mode and Four-Port S-Parameters: Theory, Measurement and Applications

Boston, MA . . . . September 14, 1999

High-Efficiency Power Amplifiers

Boston, MA . . . . September 13-15, 1999
Mountain View, CA . . . . . . November 1-3, 1999

Wireless Digital Communication

Boston, MA . . . . September 13-15, 1999

Applied RF Techniques I

Boston, MA . . . . September 13-17, 1999
Mountain View, CA . . . . . . October 25-29, 1999

RF and Wireless Made Simple

Boston, MA . . . . September 16-17, 1999
Mountain View, CA . . . . . . October 14-15, 1999

Frequency Synthesis and PLL Design

Boston, MA . . . . September 16-17, 1999

Signal Integrity of High-Speed Digital Design

Mountain View, CA . . . . . . Sept. 30-Oct. 1, 1999

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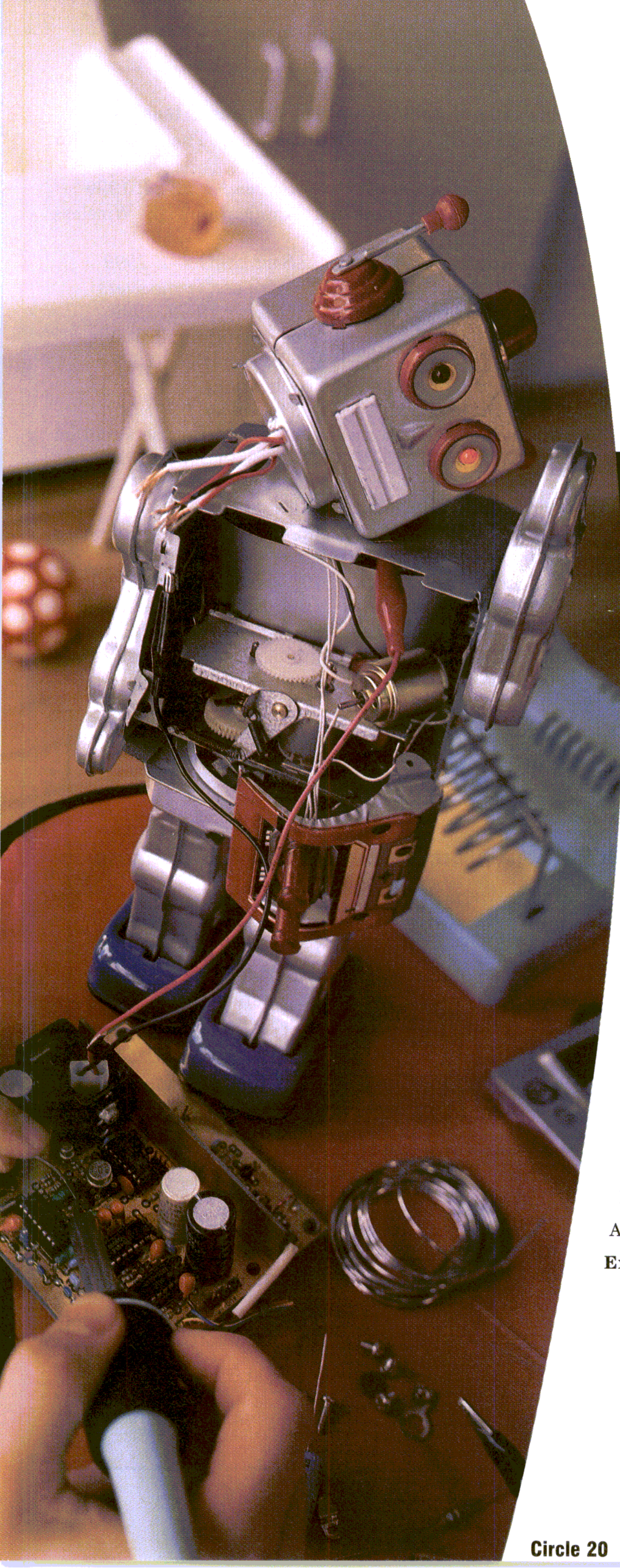

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Calendar

RFIC Techniques for Wireless Applications
Mountain View, CA . . . . . .October 6-8, 1999
RF Wireless System Design Fundamentals
Dallas, TX . . . . .October 18-20, 1999
Behavioral Modeling
Dallas, TX . . . . .October 18-20, 1999
DSP Made Simple for Engineers
Dallas, TX . . . . .October 18-20, 1999
Mountain View, CA . . . . . .December 6-8, 1999
Multitone Amplifier Design
Dallas, TX . . . . .October 21-22, 1999
RF Circuit Design Using EM Field Simulators
Dallas, TX . . . . .October 21-22, 1999
RF Test Equipment Operation (laboratory course)
Mountain View, CA . . . . . .November 3, 1999
RF Testing for the Wireless Age (laboratory course)
Mountain View, CA . . . . . .November 4-5, 1999
RF Transceiver Design
Mountain View, CA . . . . . .November 8-11, 1999
Short-Range Wireless Communications
Mountain View, CA . . . . . .November 15-16, 1999
Information: Annie Wong, Tel: (415) 949-3300; Fax: (415) 949-4400; E-mail: info@bessercourse.com; Internet: http://www.bessercourse.com/

University of California at Los Angeles Extension
Advanced Digital Communications: The Search for Efficient Signal Methods
Los Angeles, CA . . . . .September 22-24, 1999
Digital Signal Processing Applications in Wireless Communications
Los Angeles, CA . . . . .Sept. 29-Oct. 1, 1999
Integrated Circuit Design for Wireless Tranceivers
Los Angeles, CA . . . . .October 19-22, 1999
Charge-Coupled Devices, Cameras and Applications
Los Angeles, CA . . . . .October 25-29, 1999
MEMS for Optical and RF Applications
Los Angeles, CA . . . . .November 1-3, 1999
Information: UCLA Extension, Short Course Program Office, Tel: (310) 825-3344; Fax: (310) 206-2815.

University of Wisconsin at Milwaukee
Testing Surface Mount Technology: Practical Bareboard Vision and In-Circuit Strategies
Milwaukee, WI . . . . .September 22-24, 1999
SMT Implementation: New and Emerging Technologies
Milwaukee, WI . . . . .September 27-29, 1999
Introduction to EM Compatibility Design Practices
Northbrook, IL . . . . .October 7-8, 1999

Design Techniques for Controlling Radiated Emissions
Northbrook, IL . . . . .October 11-12, 1999
Information: Mark Schmidt, Program Assistant, Tel: (888) 545-4700; Fax: (888) 545-4600; E-mail: dschmidt@uwm.edu; Internet: www.uwm.edu/dept/ccee

University of California at Berkeley Extension
Phase-Locked Loop (PLL) Systems
San Francisco, CA . . . . . .October 14-16, 1999
Design of Analog Integrated Circuits for Mixed-Signal Integrated Systems
San Francisco, CA . . . . . .October 28-30, 1999
Information: Continuing Education, Tel: (510) 642-4151; Fax: (510) 642-6027; E-mail: course@unx.berkeley.edu; Internet: http://www.unex.berkeley.edu/enroll

Henry Ott Consultants
Electromagnetic Compatibility Engineering
Palo Alto, CA . . . . .October 25-27, 1999
Information: Henry Ott Consultants, Tel: (973) 992-1793; Fax: (973) 533-1442.

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RF and Wireless Engineering
Atlanta, GA . . . . .October 25-29, 1999
Information: Georgia Tech Distance Learning, Tel: (404) 894-2547; Fax: (404) 894-7398; E-mail: conted@gatech.edu; Internet: http://www.conted.gatech.edu/

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Submit a 2,000- to 3,000-word draft including examples of dates and illustrations to be presented. The draft should be typed, double-spaced, and the cover page should include title, names of authors, contact person, address, telephone and fax numbers, e-mail address and organizational affiliation. Preferred submission format is by e-mail attachment in Microsoft Word format.

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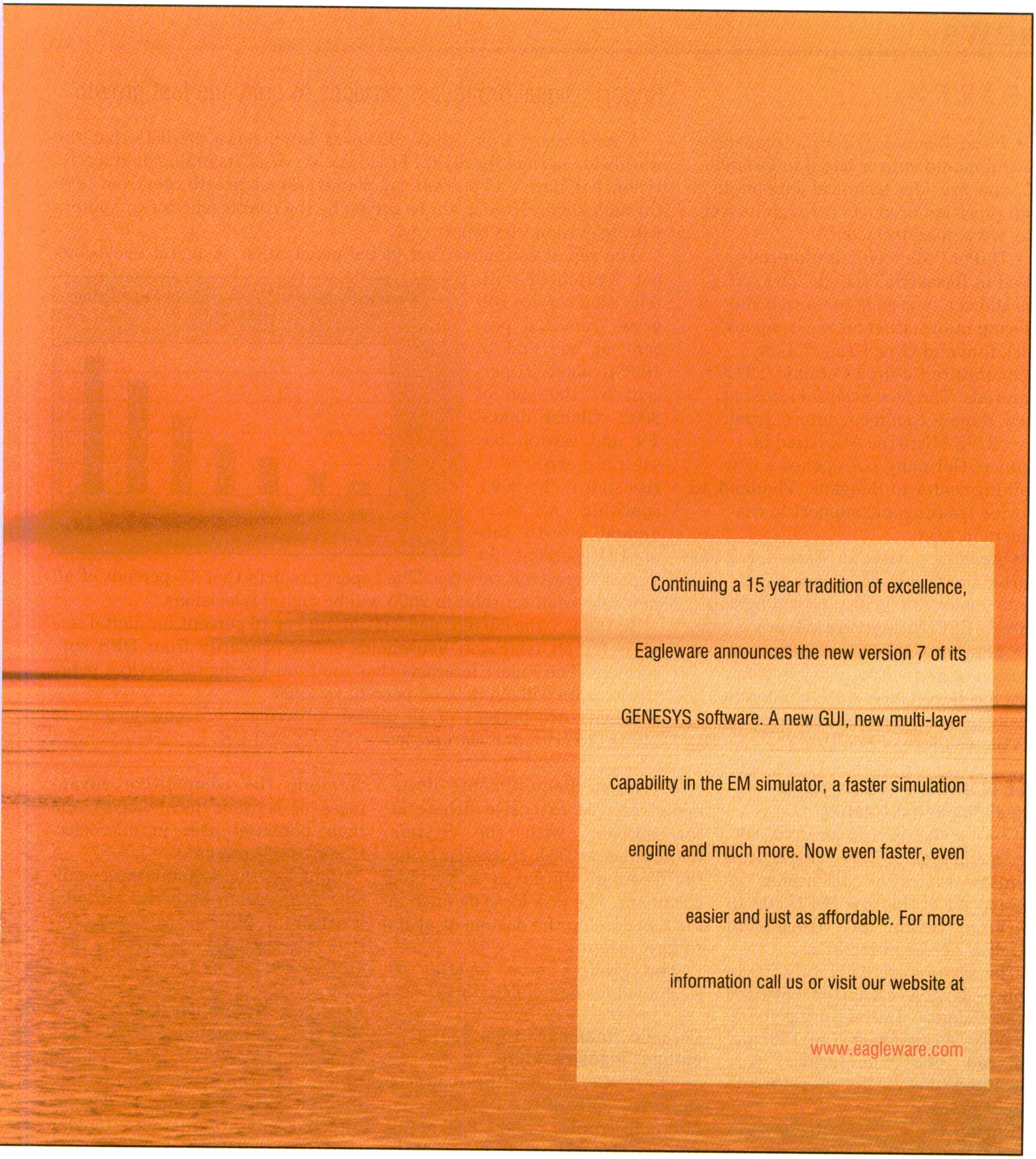
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BRIEFS

• Piezo Technology Inc., a frequency control manufacturer based in Orlando, FL, now provides technical data on its high precision products through its web site, www. piezotech.com.

• DuPont Microcircuit Materials, based in Research Triangle Park, NC, has added a new page to its web site offering information on the company's thick film and Green Tape™ Low Temperature Co-fired Ceramic (LTCC) materials. The new page is located at www. dupont.com/mcm/autosol.html.

• SUSS MicroTec AG, based in Munich, Germany, has opened a new training center in Bangkok, Thailand, to provide training and support to customers in Asia.

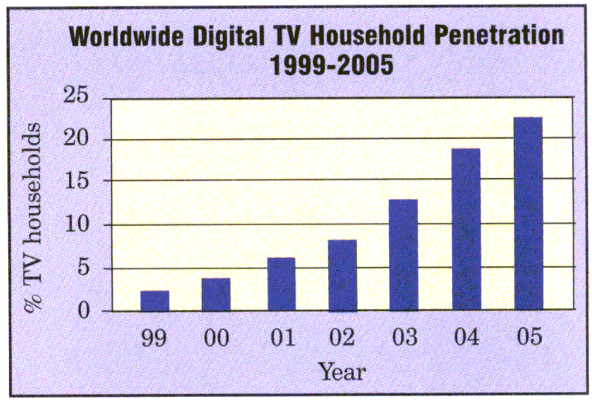
• Anadigics, based in Warren, NJ, has started operations at its new 6-inch GaAs analog fab facility, providing both GaAs MESFET and PHEMT processing.

• Marlboro, NJ-based Celwave, a division of Radio Frequency Systems Inc., has begun base station antenna production at a new facility in Embu, Brazil, a suburb of Sao Paulo.

Report: Digital broadcast services to continue fast growth

A new report from Allied Business Intelligence predicts that the worldwide market for digital broadcast services, including digital television, will have a 43 percent compound annual growth rate from 1999 through 2005. Growth will be driven by the convergence of computers with television, the report says.

The report estimates that global penetration of digital televisions per household with television service will grow from 2.5 percent at the end of 1999 to about 21 percent by the end of 2005. Global digital TV and set-top box sales are expected to rise sharply by 2003, sparking a sharp annual growth rate of 121 percent for digital terrestrial services. The report predicts that 15 percent of all new television set sales in 2005 will be digital televisions.



In the US, the current penetration rate of 16 percent for digital services for all television households stems primarily from DBS subscribers. The report forecasts that the total US digital services penetration rate will climb to 60 percent by 2005.

Ninety-two percent of all digital subscribers are now located in North America and Europe, led by the US and UK.

IEEE broadband access group completes initial meeting

Charter details and an inital voting membership were among the primary topics of discussion at Session #1 of the new IEEE 802.16 Working Group on Broadband Wireless Access Standards.

The session was held July 6-8 in Montreal, Quebec, Canada, with 130 in attendance. Initial voting membership was established at 106, and two ad hoc committees were appointed to cover IF interface and patent procedures.

During the session, the group's charter was defined as "to develop standards and recommended practices to support the development and deployment of fixed broadband wireless access systems." The group also approved a project authorization request to formally establish an IEEE standards project titled "Coexistence of Broadband Wireless Access Systems."

A System Requirements document received extensive debate at the session, with the System Requirements Task Force approving the meeting's output as a working document. The task force planned to further develop the document at its August meeting.

The group's next meeting is scheduled for September 13-17.

Ceramic "roadmap" from IMAPS outlines industry future

The Ceramic Interconnect Initiative (CII) of the International Microelectronics and Packaging Society (IMAPS) has developed a 10-year ceramic industry "roadmap," a document that describes how ceramic technology can benefit a variety of electronic packaging and interconnect appliances.

The roadmap analyzes the current state of the industry and forecasts future requirements. It is intended as a reference document detailing the competitive advantages of ceramic technologies and their potential uses in microelectronics applications.

Copies of the document are available online from both the National Electronics Manufacturing Initiative, at www.nemi.org, and the IPC, at www.ipc.org.

Anadigics, GCS to develop HBT wafer production

Anadigics Inc. and Global Communications Semiconductors Inc. (GCS) have teamed to develop internal heterojunction bipolar transistor (HBT) capabilities.

Under the agreement, GCS will provide Anadigics with 4-inch GaAs HBT fully processed wafers. All products developed will be designed and tested at the Anadigics facility in Warren, NJ.

Anadigics manufactures RFICs for the broadband and wireless communications markets.

BUSINESS AND FINANCE

HP unveils new Agilent Technologies brand identity

Hewlett-Packard has launched a new technology company, Agilent Technologies, which will incorporate HP's Test and Measurement, Chemical Analysis, Healthcare Solutions and Semiconductor Products groups. The new company will be headquartered in Palo Alto, CA.

Agilent Technologies offerings will include test systems for semiconductors and electronic printed-circuit boards; communications network infrastructure products and services; test and measurement instrumentation; analytical instrument systems for chemical analysis; clinical measurement and diagnostic products and services; and semiconductor components, modules and assemblies for communications.

Hewlett-Packard, based in Palo Alto, will continue to provide computing and imaging solutions under the Hewlett-Packard brand name.

Motorola awarded contracts for GSM networks

Motorola Inc's Network Solutions Sector (NSS) has been awarded two new contracts worth more than $57 million to provide GSM network improvements in both Germany and Oman.

Under a $47 million agreement with German network operator T-Mobil, Motorola NSS will upgrade and enhance the company's T-D1 GSM mobile communications network, enabling the introduction of high-peed data applications over General Packet Radio Service (GPRS). In addition, Motorola NSS will upgrade T-Mobil's existing countrywide mobile data network, doubling its capacity to handle growing demand.

Under a separate $10.5 million contract from Oman's Ministry of Posts, Telegraphs and Telephones General Telecommunications Organization (GTO), Motorola NSS will deploy GSM infrastructure to provide extra capacity and enhance coverage in the Batinah Coast area of Oman.

Motorola, based in Schaumburg, IL, provides semiconductors, electronics systems and components.

ProTek acquires wafer fab facility

ProTek Devices of Tempe, AZ, has announced the acquisition of Silica Tek, a wafer fab facility also located in Tempe. Terms of the transaction were not disclosed.

ProTek manufactures silicon Transient Voltage Suppression (TVS) products. Silica Tek can process 4-, 6-, 8- and 12-inch silicon wafers, and will be used primarily for new products currently under development at ProTek. The facility also has complete thin film capability.

Srico awarded contract for modulator component

Columbus, OH-based Srico Inc. has won a $100,000 contract from the U.S. Air Force to develop a unique optical chip-based modulator component that will reduce the noise figure of high frequency communications systems to almost 0 dB.

Srico manufactures optical modulators, sensors and fiber optic links for communications systems and test and measurement equipment.

Catapult announces 3G test product order

Catapult Communications has received an order for a third generation wireless protocol test product from Fujitsu Ltd. of Tokyo, Japan, a provider of information technology and network solutions.

Catapult, based in Mountain View, CA, provides software-based test systems for telecommunications.

Nokia, Protection One Mobile to develop "smart car" services

Nokia and Protection One Mobile Services Group have entered into an agreement to jointly develop wireless-based emergency, navigational and information products and services for both the automotive industry and consumers.

The "smart car" telematics industry allows car manufacturers to provide consumer safety, security and information services, as well as voice communications. Automatic and manual emergency calls, roadside assistance, traffic information and route guidance are some of the services that can be offered.

Wireless-based telematics services can offer advantages over other options because of the existing wireless network infrastructure, lower car terminal costs and real-time location-specific information.

Nokia, based in Helsinki, Finland, supplies mobile phones, mobile, fixed and IP networks and related services. Protection One Mobile Services Group, headquartered in Irving, TX, is a division of Protection One of Culver City, CA, and provides technology and response for the delivery of emergency, navigation and information services in mobile applications.

Companies preview new E911 technology

Six wireless industry companies have unveiled a new network-based technology that makes it possible to pinpoint the origin of emergency calls made by wireless users.

The new technology, called Enhanced 911 Phase II, works by allowing local authorities to home in on the signal emitted by the wireless phone iteself. No user intervention is required, and the system works regardless of the wireless provider and handset used. Because it is network-based, the new system also represents a significant advance over emerging handset-based technologies that require wireless subscribers to install a spe-

BUSINESS AND FINANCE

Bowthorpe adds DLS Testworks

Bowthorpe plc has announced the puchase of the xDSL simulator division of Consultronics Limited. The transaction is valued at $25 million.

The new division will be restructured as a separate company, DLS Testworks, within the Bowthorpe Telecoms Group. Other companies in the group include Telecom Analysis Systems Inc. of Eatontown, NJ, and Global Simulation Systems inc. of Paignton Devon, England.

Bowthorpe, based in Sussex, Engalnd, supplies advanced test instruments and systems for telecommunications testing. DLS Testworks, located in Ottawa, Ontario, Canada, develops xDSL test solutions.

Berkeley Varitronics receives Motorola contract

Berkeley Varitronics Systems Inc. has been awarded a contract by Motorola to provide CDMA test transmitters that will be used to aid in CDMA system build-out in Buenos Aires, Argentina.

Berkeley Varitronics is based in Metuchen, NJ.

MCE adds DML to company holdings

MCE Companies Inc., based in Ann Arbor, MI, has announced the acquisition of DML Microwave Ltd., formerly Densitron Microwave Ltd., of Essex, England. Terms of the transaction were not disclosed.

DML, a supplier of ferrite isolators, circulators, solid state low noise and power amplifiers, will be restructured as a wholly-owned subsidiary of MCE. Other MCE companies include Inmet Corporation, KDI/Triangle Corporation, Metelics Corporation and Weinschel Corporation.

Zetron acquires Helper Instruments

Zetron Inc. of Redmond, WA, has announced the acquisition of a majority share of Helper Instruments, a manufacturer of test instruments for the wireless industry. The transaction included rights to the Helper Instruments name and brand name rights to the company's products.

Helper Instruments will operate as a division of Zetron, with products being manufactured as Zetron's headquarters facility.

Link forms Advanced Microtek subsidiary

Link Microtek Ltd. of Basingstoke, England, has created a new wholly-owned subsidiary, Advanced Microtek Ltd., to manufacture waveguide components for military and commercial applications.

Link Microtek is a specialty supplier of RF and microwave components.

Ericsson forms unit for wireless internet services

Ericsson has announced the formation of Ericsson Wireless Internet Solutions, a new business unit targeting wireless data communications. The new unit, based in Research Triangle Park, NC, will develop wireless Internet solutions for cellular operators, service providers and enterprises.

Ericsson, based in Stockholm, Sweden, provides communications products and services worldwide.

ITT combines Roanoake operations

ITT GaAsTEK has announced the merger of its operations with the ITT Microelectronics Center (MEC), a fully automated module manufacturer. Both companies are located in Roanoke, VA.

ITT GaAsTEK provides GaAs products and services. ITT MEC produces commercial, military and space-qualified modules.

cial device in their phone in order to help police track their location.

The system also uses traditional Public Safety Answering Point (PSAP) equipment and technology and requires the addition of only limited equipment by the 911-dispatch center. Enhanced 911 Phase II is expected to be phased in over time on a state-by-state basis.

The companies, Rural Cellular Corporation, CML Technologies, 911 Datamaster Inc., GeoComm Inc., Independent Emergency Services LLC. and KSI Inc., previewed the technology at the International Association of Public-Safety Communications Officials (APCO) '99 Conference.

The Federal Communications Commission has mandated that all cellular service providers deploy Automatic Location Identification (ALI) as part of E911 services by October 1, 2001. The commission is in the process of determining requirements regarding E911 Phase II services.

Ansoft offering seminars in European cities

Ansoft Europe has scheduled a series of high frequency seminars in five European cities from September 28 through October 7.

The workshops will focus on the application of Ansoft's EDA software tools in high frequency circuit and system design. Topics will include optimization, layout analysis and parametric analysis.

The seminars will be led by Dr. Zol Cendes, Ansoft founder and Chief Technical Officer, and Dr. Lawrence Williams, director of high frequency products.

For information, contact Ed Lewis, Tel: + 44 181 891 6106; E-mail: seminars@ansoft.co.uk ■

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

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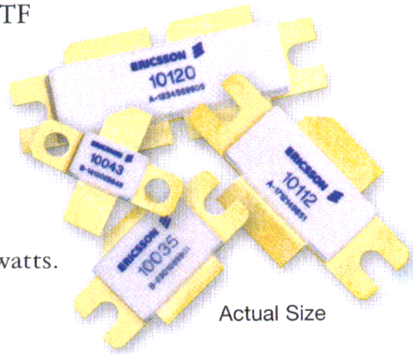

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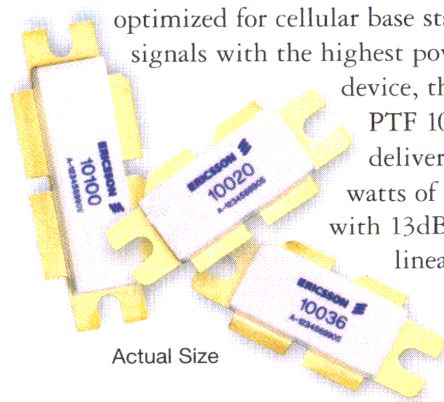

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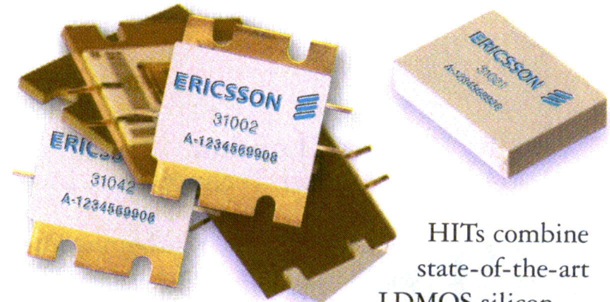

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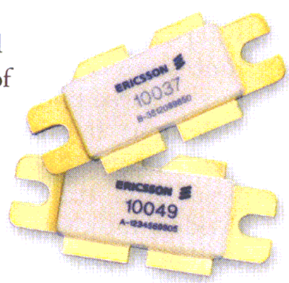

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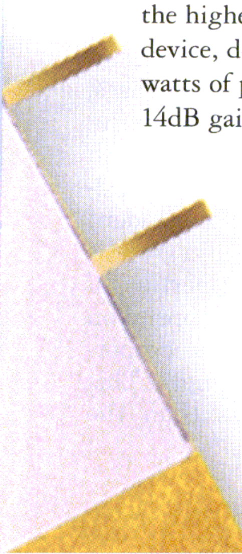

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Circle 23

A New Approach To Broadband Transmission Line Hybrid Design

A third winding increases the bandwidth of RF transformers

By Simon Y. London
Advanced Power Technologies, Inc.

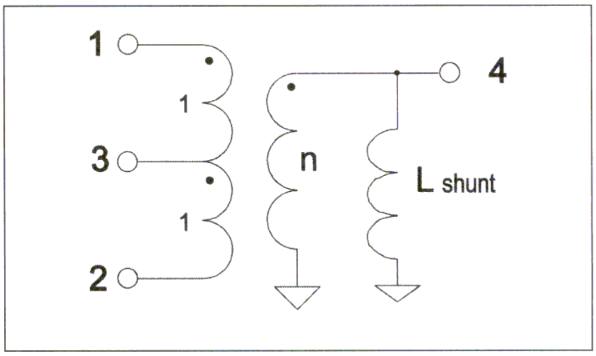
This article describes the maximum bandwidth transmission line 180 degree hybrid with unbalanced ports and a single shunt inductance. This inductance determines the lowest operating frequency of the hybrid. The performance over the entire frequency band is determined by the distributed parameters of the transmission lines.

Properly connected three-conductor transmission lines aid in overcoming the principal limitations of other hybrids. All magnitude versus frequency characteristics of the hybrid are independent of the line lengths. Stray elements and line parameter tolerances are practical limitations at the highest operating frequency. The achieved bandwidth is more than twice that of other types of hybrids. The proposed approach is validated experimentally.

Introduction

An 180 degree hybrid is a well-known four-port hybrid that provides equal amplitude in-phase signals at its two mutually isolated ports when fed from its sum port (Σ), and provides two equal amplitude 180 degree out-of-phase signals at these ports when fed from its difference port (Δ). The sum and difference ports are also mutually isolated. These properties permit the use of hybrids in various applications, such as power combiners/dividers, beam-formers and baluns, and as major components of applications such as RF switches and phase shifters. Several hybrids may be incorporated into multi-port beam-forming networks or in N-way power combiner/ dividers.

The wide range of hybrid applications and their dominant role in many systems has lead to the development of many different types of hybrids [1, 2, 3]. To increase their bandwidths, these devices are designed to operate as magnetic, tightly-coupled transformer-type units at low frequencies and as properly interconnected transmission lines at high frequencies. Interwinding capacitances and leakage inductances are included in the propagation parameters of these lines.



▲ **Figure 1. Schematic model of typical hybrid at lowers frequencies.**

Various hybrids have special properties as well as advantages and disadvantages. These broadband transmission line hybrids can be divided into two categories: those with non-matched transmission lines and, in most cases, a single shunt inductance, as in the classical configuration (Figure 1); and those with matched transmission lines for increasing bandwidth, but having two or more independent shunt inductances [2, 4].

The matching and isolating properties of hybrids in the first category strongly depend on the length of the hybrids' lines. These properties deteriorate with increasing line length. This length should be significantly less than the

wavelength of the highest operating frequency. As a result, the first category has serious limitations on bandwidth and power handling capability.

Hybrids in the second category do not have principal line length limitations and operate over a broader frequency band. On the other hand, they generally have greater size, are more expensive, and usually have less efficiency at low frequencies because two or more separate shunt inductances should be used [2, 3, 4]. Moreover, in real designs, undesirable resonances may occur due to the influence of stray elements and line parameter tolerances. Practically, the maximum electrical length of each line should be less then $\lambda/4$ at the highest operating frequency.

The low performance of existing broadband hybrids in various practical cases, especially at high and very high power applications, asks the question: What are the maximum achievable properties of hybrids having classical low frequency circuit models with single shunt inductances, as shown in Figure 1? More specifically, is it possible to achieve a hybrid having the low frequency circuit model (Figure 1) and that permits theoretically unlimited line lengths? At high frequencies, the scattering matrix describes such a hybrid as:

$$S_{4\times4} = \begin{bmatrix} 0_{2\times2} & S_{12(2\times2)} \\ S_{21(2\times2)} & 0_{2\times2} \end{bmatrix}$$

Considered in Figure 2 is a hybrid with a single shunt inductance having the circuit model shown on Figure 1 at lowest frequencies and admitting unlimited line lengths. It is described by matrix (1) at high frequencies where we have neglected the influence of stray elements. It also has flat transfer characteristics and, as a result, may be called a maximum bandwidth hybrid.

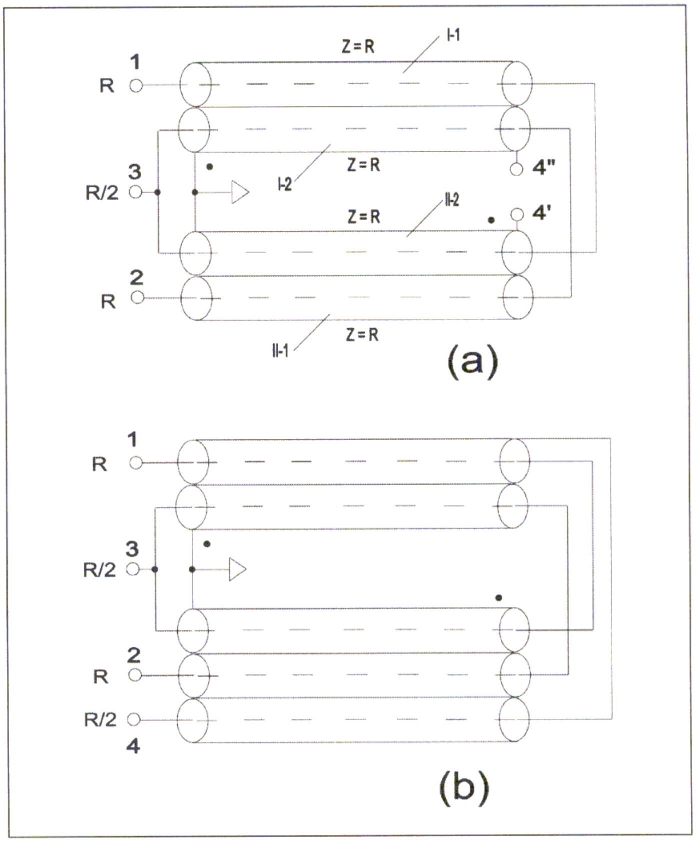
Design principle of maximum bandwidth hybrid

Consider the transmission line hybrid shown in Figure 2a [2, 5]. It has two isolated unbalanced ports 1 and 2, an unbalanced sum port 3, and a balanced difference port.

The inner conductors of the four coaxial cables form the differential winding, shown in Figure 1, with port 3 at the center tape. The outer conductors of the two paired sets of cables form the secondary winding, with the balanced port 4, having terminals 4' and 4". By using an additional coaxial line operating as an "internal balun," this port is transformed to the unbalanced ones, as shown in Figure 2b.

Uni-polarity ends of lines

The hybrids shown in Figure 2 have two properties that follow from the symmetry of their structures (if lines I and II are identical): The characteristics at ports 1 and 2 are identical; and port 3 and port 4 are completely isolated and independent of frequency.



▲ **Figure 2. Broadband transmission line with single shunt inductance and (a) balanced differential port; (b) all ports unbalanced. Two dots indicate uni-polarity ends of lines.**

Based on these symmetry properties, this hybrid can be analyzed using equal amplitude in-phase and out-of-phase excitations at ports 1 and 2. Consider for simplicity the circuit shown in Figure 2a and assume that there are equal amplitude in-phase sources at ports 1 and 2. In this case, equi-potential terminals 4' and 4" can be connected. Therefore, the signal from port 1 propagates on the chain connecting coaxial cables I-1 and II-2 to the load at port 3, and the signal from port 2 propagates on the chain connecting coaxial cables II-1 and I-2 to the load at port 3. If the characteristic impedance of each line is equal to R, and port 3 has a load impedance of $R/2$, all lines are matched, and the input impedance at port 1 and port 2 equals R.

For out-of-phase signals at ports 1 and 2, the potential at port 3, with respect to ground, equals zero; consequently, this port may be short-circuited. This means that two short-circuited coaxial cables, I-2 and II-2 at port 3, are connected at their other ends in a series between terminals 4' and 4", as it follows from circuit Figure 2a.

Both two-ports (for in-phase and out-of-phase excitation at ports 1 and 2) may be combined into a common

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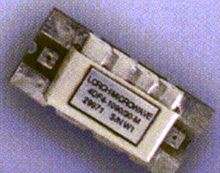

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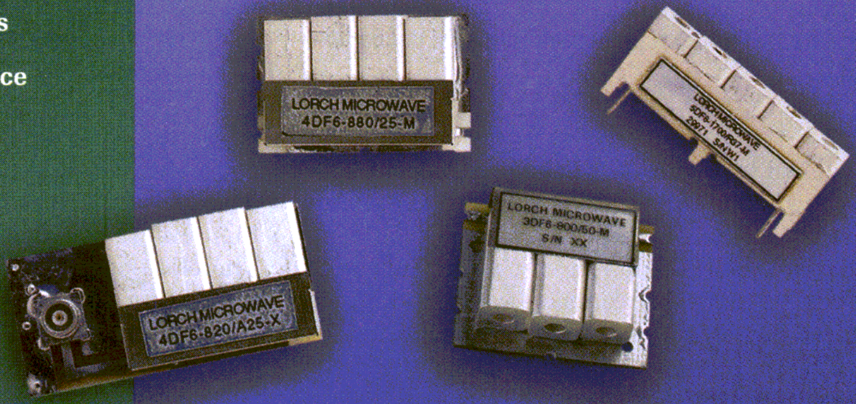

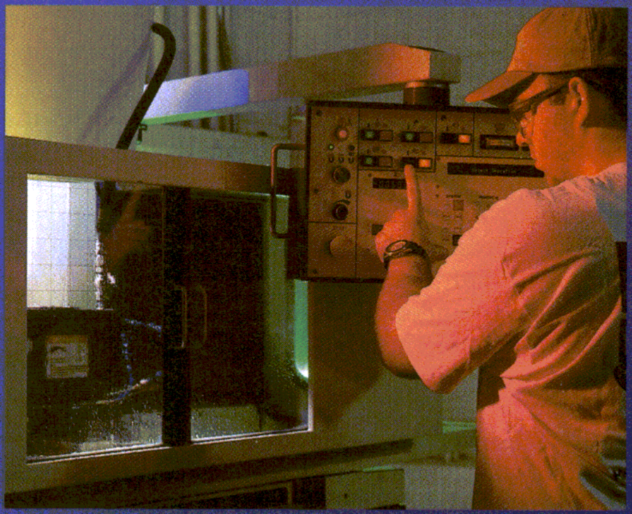

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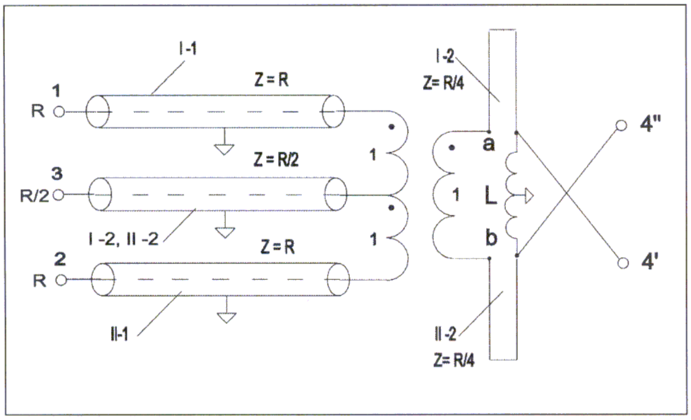
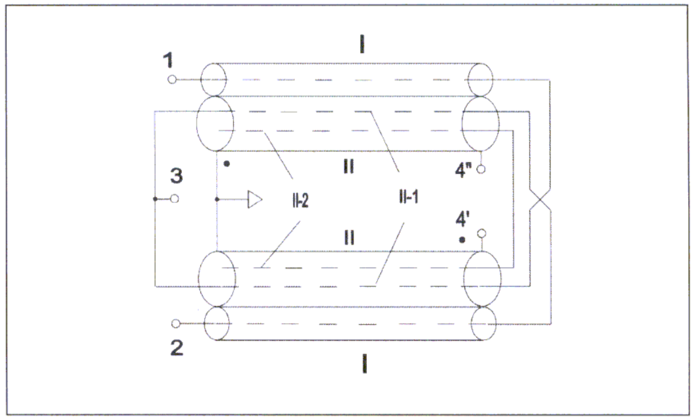


▲ **Figure 3. Circuit Fig. 2a represented in modal decomposition form.**



▲ **Figure 4. Schematic diagram of hybrid with maximum bandwidth.**

circuit, as shown in Figure 3. This circuit is equivalent to the one shown in Figure 2a, only with respect to ports 1 through 4.

In this circuit, the line connected to port 3 represents the two lines I-2 and II-2 connected in parallel. The short-circuited lines at the secondary winding of the ideal hybrid represents lines I-2 and II-2 for out-of-phase excitations. They have characteristic impedances equal to $R/4$ due to the 2:1 transformation coefficient of the ideal hybrid.

If we insert in this circuit (as shown in Figure 3) two identical open-circuited lines between nodes a-4" and between nodes b-4" correspondingly, the constant-R circuit will be created. This circuit provides matching for out-of phase sources at port 1 and port 2. Unfortunately, the nodes a and b are absent in the real scheme because equivalent modal representation (Figure 3) is true only with respect to external ports 1, 2, 3 and 4. However, this circuit can help to understand the idea that can be implemented by modifying the circuit shown in Figure 2 via an additional conductor in each line II, as shown on Figure 4.

At low frequencies, when the electrical length of each line compared to a wavelength is very small, this hybrid operates exactly as a classical one with a single shunt inductance as its frequency limitation element. The extra conductors II-2 in identical three-conductor lines operate as additional unloaded winding and, therefore, play no role.

Due to the role of the transmission line parameters, it at high frequencies the two interconnected three-conductor lines (each having conductors II-1, II-2, and a common outer conductor) form a constant-R impedance transforming the two-port for certain values of the line's characteristic parameters. In other words, this three-conductor line operates as matched 2:1 internal impedance transformer for out-of-phase excitations at ports 1 and 2.

Moreover, matching conditions for in-phase and out-of-phase excitations at ports 1 and 2 are satisfied simultaneously. As a result, all four ports of the hybrid shown in Figure 4 are matched and, consequently, isolated in pairs. Therefore, it is described by matrix (1) if we neglect the influence of stray elements and shunt inductance.

Optimum three-conductor line parameter determination

The wave parameters of each three-conductor line II in Figure 4 can be described as presented for the characteristic admittance matrix [G] because conditions for its physical realization are simple.

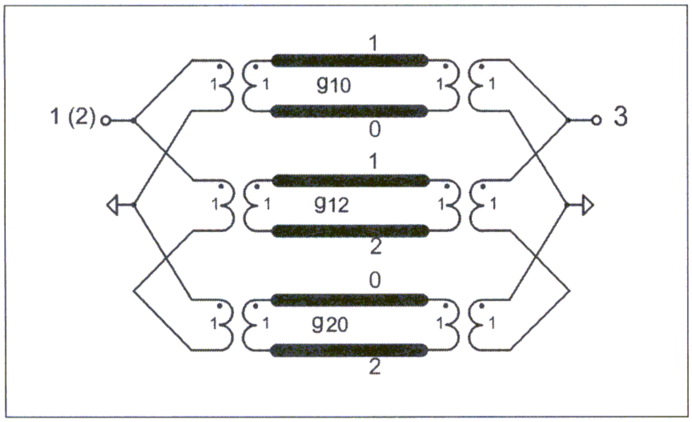
Elements of this matrix can be obtained by applying in-phase and out-of phase excitations at ports 1 and 2 of the hybrid (Figure 4) having the same symmetry properties as the initial circuit (Figure 2a). For an in-phase excitation, the output signal will be at port 3, while for an out-of phase excitation it will be at port 4. The design remains, if an additional balancing coaxial cable is used, as in Figure 2b.

Consider first the in-phase excitation at ports 1 and 2 in Figure 4. Both lines may be assumed to have zero-length if matching is satisfied. Equi-potential terminals 4' and 4" may be connected and grounded (because voltage on each outer conductor is equal to zero). Under these conditions, each three-conductor line II in accordance with its characteristic admittance parameters forms the circuit given in Figure 5.

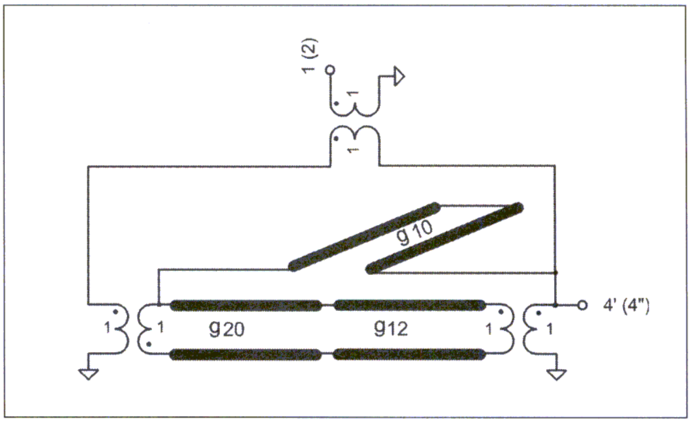
From this circuit, it follows that the condition for matching, assuming the admittance at ports 1 and 2 is normalized to $g=1$, is

$$(P-1)^2+\left(Q-\frac{1}{B}\right)^2=\left(\frac{1}{B}\right)^2 \qquad (2)$$

The equivalent circuit model for out-of-phase excitation at ports 1 and 2 is shown in Figure 6. It will be a constant-R circuit if the following condition is satisfied for normalized ($R=1$) impedance at ports 1 and 2:



▲ **Figure 5. Circuit model of three-conductor transmission line with in-phase excitation at ports 1 and 2 of the hybrid shown in Figure 4.**



▲ **Figure 6. The circuit model of three-conductor line for out-of-phase excitations at ports 1 and 2.**

for normalized ($R=1$) impedance at ports 1 and 2:

$$(Z_{1(sc)} \cdot Z_{1(oc)})^{1/2} = 1$$

where $Z_{1(sc)}$ and $Z_{1(oc)}$ are normalized impedances at port 1(2) when port 4'(4") is short-circuited and open-circuited respectively.

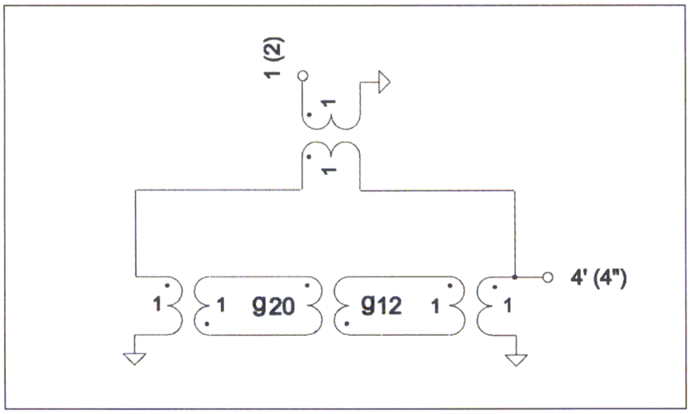
An analysis of the circuit shown in Figure 6, using standard transmission line equations, shows that Equation 3 is satisfied only if:

$$g_{20} = 3_{g12} \quad (4)$$

and

$$g_{10} = \frac{4 - 3g_{12}{}^2}{4g_{12}} \quad (5)$$

Equation (4), for example, may be easily verified in the particular cases when the electrical length of each line in the circuit is equal to 90 degrees In this case, the line with characteristic admittance g_{10} may be excluded and the two other chain-connected lines operate as an ideal phase-reversed transformer, with a voltage ratio g_{20}/g_{12}, as shown in Figure 7.



▲ **Figure 7. Simplified circuit Figure 6 when length of each line is 90 degrees.**

According to Figure 6, since the ratio of nominal impedances at ports 1(2) and 4(4'- 4") equals 2, the ratio of nominal impedances at port 1(2) and half of the impedance at port 4 (4'- 0), equals 4. The corresponding voltage ratio is 2. Under these conditions, it follows from the circuit in Figure 6 that (4) is valid.

Conditions (2), (4) and (5) are satisfied simultaneously only if $g_{10}=1/4$, $g_1=1$ and $g_{20}=3$. This means that the normalized characteristic admittance matrix of the three-conductor line should be:

$$[G] = \begin{bmatrix} g_{10} & -g_{12} \\ -g_{12} & g_{20}+g_{12} \end{bmatrix} = \begin{bmatrix} 5/4 & -1 \\ -1 & 4 \end{bmatrix} \quad (6)$$

Some particular cases and experimental results

There are two options in the implementation of Equation 6: a direct realization in a three-conductor line, as shown in Figure 8a, which is suitable for high and very high power; and use of non-coupled lines (triaxial coaxial line, for example) and an additional line that realizes this coupling, as shown in Figure 8b.

In this case, Figure 8b for 50-ohm nominal impedance at ports 1 and 2, the characteristic impedances of lines are: $Z_{12}=50$ ohms, $Z_{20}=50/3$ ohms and $Z_{10}=200$ ohms, as follows directly from Equation 7. The 200-ohm line is not easy to realize, in spite of the relatively low power transferred through it. The lines with characteristic impedances Z_{12} and Z_{10} are connected in parallel at their ends.

In both cases it is inconvenient to implement parameter g_{10}, i.e., the coupling between line conductors 1 and 0. If we put $g_{10}=0$, only the triaxial line can be used (Figure 8c).

There are two extremely simplified cases that may be chosen when $g_{10}=0$: Matched sum port 3 ($s_{33}=0$, i.e.,

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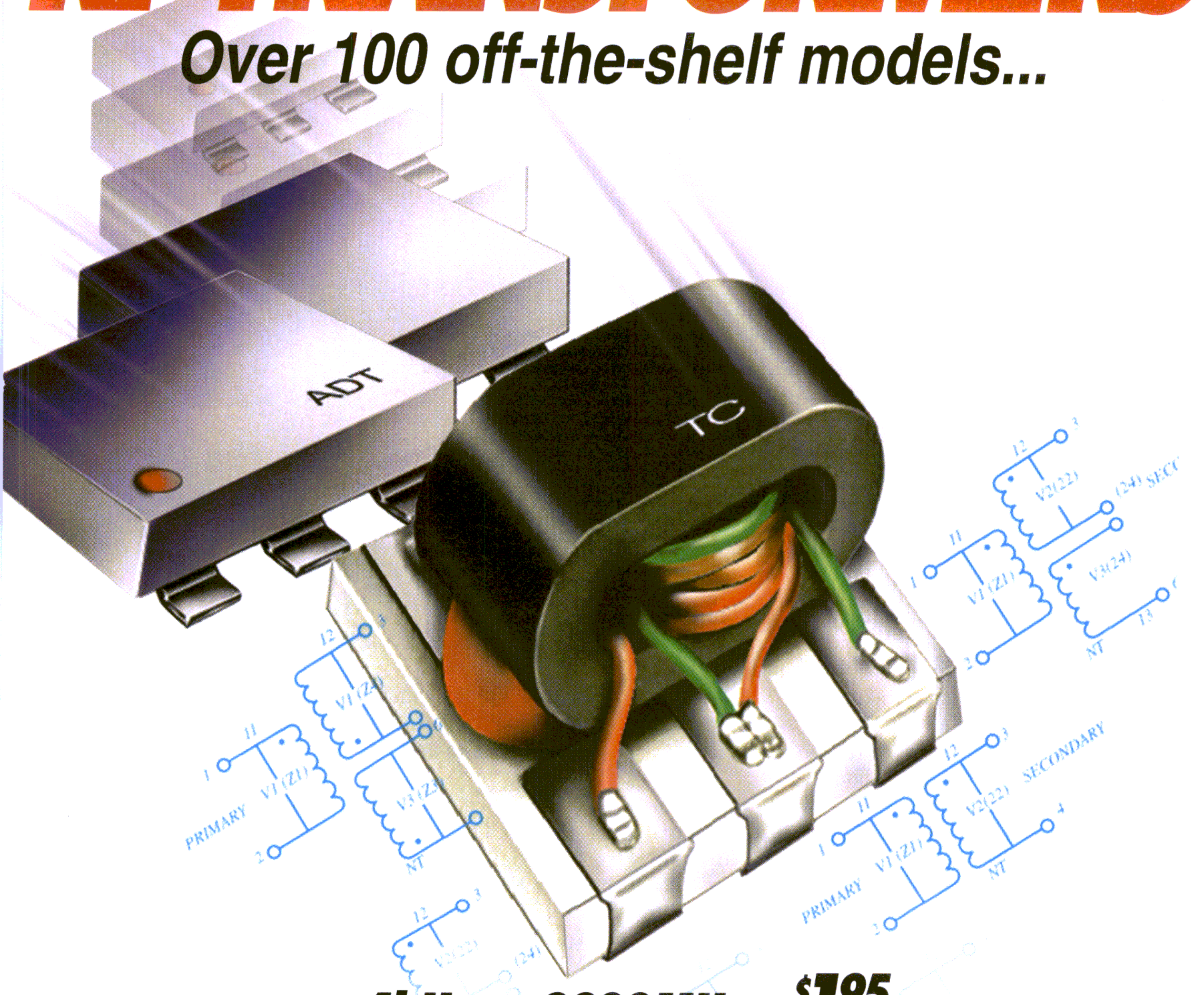

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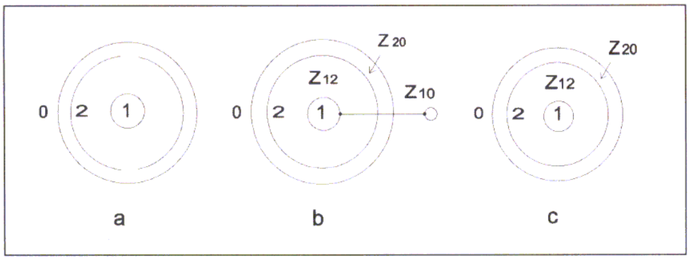


▲ **Figure 8. Possible realizations of line II in circuit Fig.4: (a) with minimum conductors; (b) with extra line that realizes coupling between lines; (c) simplified solution that introduces small mismatch.**

port 1 and port 2 are matched at in-phase excitation); and matched difference port 4 (s_{44}=0, i.e. port 1 and port 2 are matched at out-of-phase excitation).

In the case of s_{33}=0 from Equation 4 and g_{10}=0 from Equation 2, it follows that g_{20}=4 and g_{12}=4/3. Therefore, for a 50-ohm nominal impedance at ports 1 and 2, we have characteristic impedances Z_{20}=12.5 ohms, and Z_{12}=37.5 ohms. In the case where s_{44}=0 from Equations 4 and 5, we obtain:

$$g_{20} = 2\sqrt{3} \text{ and } g_{12} = 2/\sqrt{3} \tag{7}$$

For example, Z_{20}=14.43 ohms, and Z_{12}=43.3 ohms. In both simplified cases, there are the same maximum values $|s_{11}|=|s_{22}|$ × 0.07 and the same minimum isolation between ports 1 and 2 that equals –20 log $|s_{21}|$ × 23 dB.

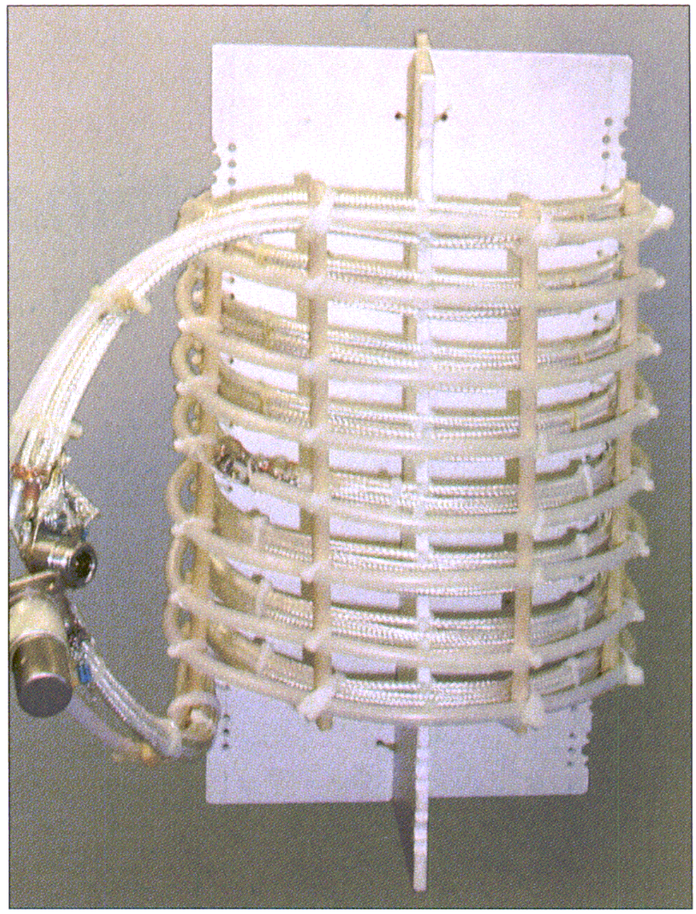
The maximum reflection coefficient s_{44} at port 4 when s_{33}=0, and the maximum reflection coefficient s_{33} at port 3 when s_{44}=0 both equal about 0.14.

There is also an intermediate case when the maximum values of the reflection coefficients are: $|s_{33}|=|s_{44}|$ × 0.07, $|s_{11}|=|s_{22}|$ × 0.037. Minimum isolation between ports 1 and 2 equals –20 log $|s_{21}|$ × 24 dB. Corresponding values of Z_{20} and Z_{12} are: Z_{20}=13.43 ohms and Z_{12}=40.3 ohms.

For all of these cases, we keep the same condition (4) because at the frequency when the electrical length of each line equals 90 degrees, there is maximum sensitivity of hybrid characteristics line parameters variations.

A more critical frequency arises when the electrical length of each line is very close to 180 degrees. In the vicinity of this frequency, a very small difference in electrical length implies resonance increasing reflection and decreasing isolation. Losses in lines make this effect smaller and for lower losses the admissible tolerance is less than 1.

To verify the idea of the described hybrid, an experimental prototype was fabricated without ferrite and with long lines. Only a very limited set of standard components, coaxial cables RG 142 B/U, RG 188 A/U and teflon tubing TFT-200-4, were used to implement lines, according to Figure 8b as the basic. The line with a characteristic impedance near 200-ohms was formed by cable RG 188 A/U without an outer conductor and spaced from coaxial cables. For the "internal" balun that is shown in Figure 2b, two RG 188 A/U cables were used in parallel. All cables were coiled as shown in Figure 9. The electrical length of each coaxial cable was 180 degrees at 46 MHz. Measured data in comparison to calculated data, for the initial hybrid (Figure 2b), having the same line lengths, are shown in Figure 10 and illustrate the principal effect. To provide a better agreement with calculated parameters, non-standard lines with lower parameter tolerances should be used.

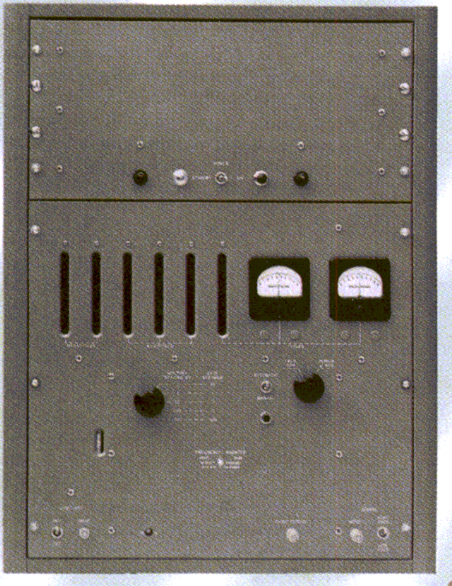


▲ **Figure 9. For the "internal" balun shown in Figure 2b, two RG 188 A/U cables are used in parallel. All cables are coiled as shown here.**

Conclusions

To summarize the result, there are maximum broadband hybrids that have a single shunt inductance as a fundamental limitation that permit theoretically unlimited line lengths. This effect is achieved by using three-conductor transmission lines.

There are simplified solutions with good performance that admit triaxial lines. In all cases, the nonstandard line's characteristic impedances with relatively small tolerances should be used. This will most adequately



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achieve significantly increased bandwidth and power capabilities of hybrids.

The preferable domain of application is a combination of broadband and high power applications when the electrical line lengths should be relatively high, especially if the usage of ferrites is impossible or they introduce additional problems with cooling, nonlinear distortions, and so on.

There is a critical frequency — a 180 degree line length (twice that of known hybrids) that has high sensitivity of the electrical characteristics to small variations of line parameters and stray elements.

Acknowledgements

The author thanks Dr. Leon Susman and Dave McEnany for their encouragement and many useful suggestions.

References

1. N. Dye and H. Granberg, *Radio Frequency Transistors,* Chapter 11, Butter-worth-Heinemann, 1984.

2. S. London and S. Tomashevich, *Reference Book of High Frequency Transformer Units*, Radio and Svaz Press, Moscow, 1984.

3. E. Red, *Arbeitsbuch Fuer Den Hf-techniker*, Franzis Verlag, 1986.

4. R. Bell, *Multimode Antenna System Having Plural Radiators Coupled Via Hybrid Circuit Modules*, Pat. USA Int. Ci.Ho1Q-25/04, No. 5,189,434, 1993.

5. S. London et al., "Promising Radio Transmitters with Power Summation," *Telecommunications and Radio Engineering*, Vol. 45, No. 1, January 1980.

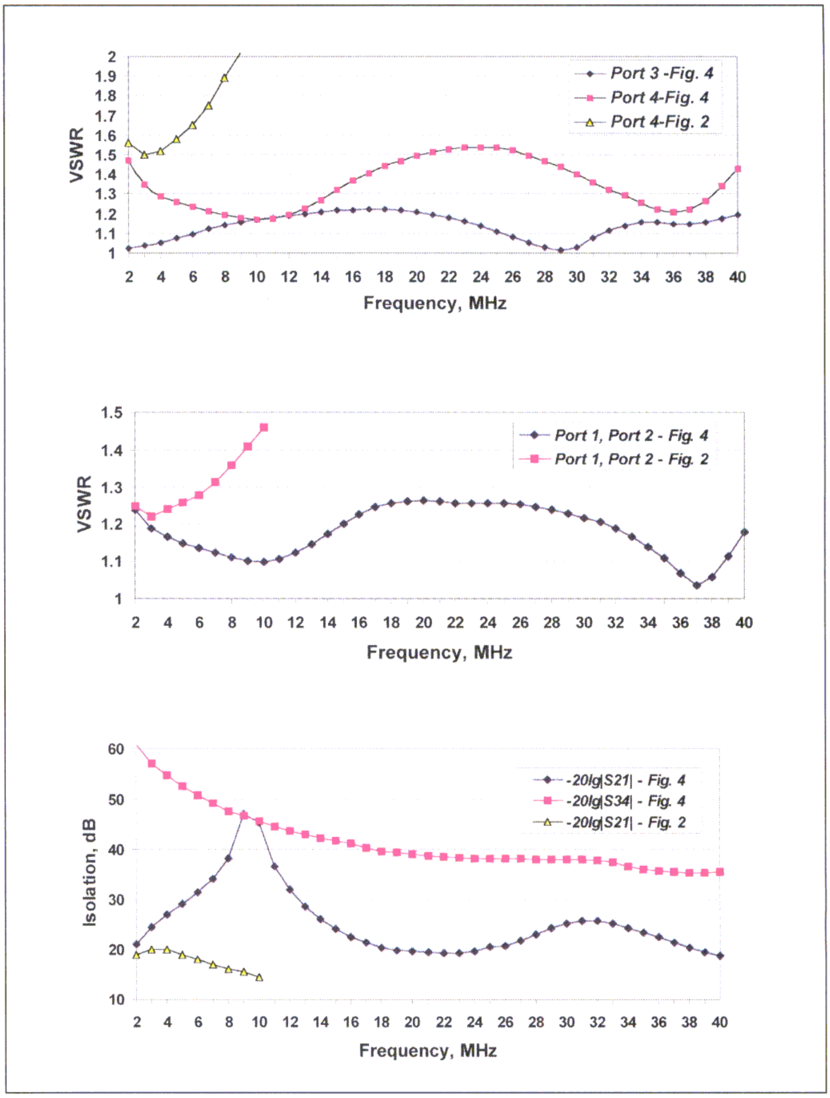

Figure 10. Experimental characteristics of described hybrid in comparison to calculated data for initial hybrid (Figure 2a).

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Choosing the Right Diode for your AGC Detector

Here are the performance characteristics you should know for detector design

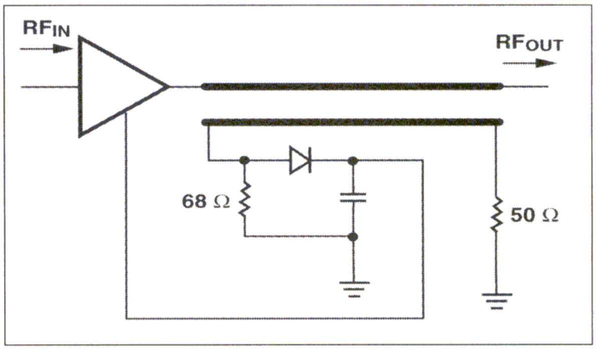
By Raymond W. Waugh
Hewlett-Packard Company

Automatic Gain Control (AGC) loops are used to control the gain or output power of amplifiers in a wide variety of applications. A typical circuit is shown in Figure 1.

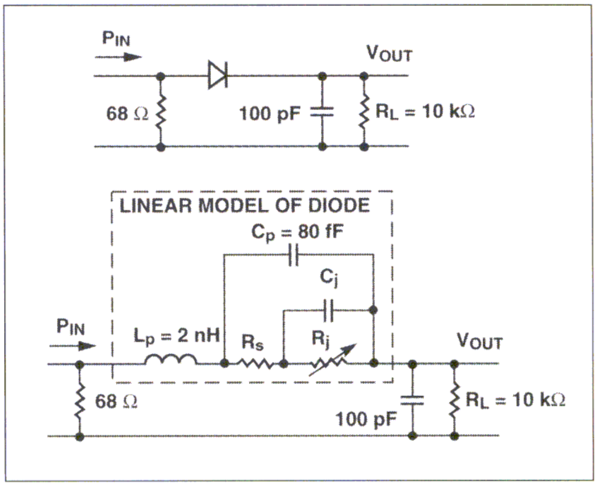
In this circuit, a coupler (distributed transmission line as shown, or lumped element) couples off a small amount of power from the amplifier and feeds it to a Schottky diode detector.. The detector produces a DC voltage proportional to the output power, which is then fed back to the amplifier's gain control circuit. Diode detectors of this type can be externally biased or self biased [1]. Let us first examine the self-biased detector.

The typical self-biased detector (sometimes referred to as "zero-biased") is shown in Figure 2. A diode is combined with a capacitor of sufficient size on the DC side to present a low impedance (compared to that of the diode), and a shunt 68 ohm resistor is placed on the RF side. This resistor serves two functions — it provides a good impedance match at the input to the detector circuit and furnishes a return path for the DC current generated in the diode. The circuit is completed with a DC load resistor of 1 kohm to 10 kohms.

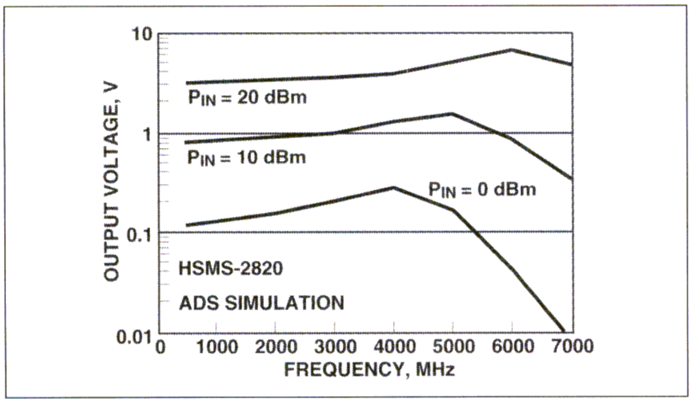
In the lower half of Figure 2, the diode is replaced with its linear equivalent circuit, which can provide insight into the performance of the detector diode. L_p and C_p are package parasitics — little can be done to change their values. The diode chip itself can be represented by a three-element equivalent circuit, including R_s (parasitic series resistance), C_j (parasitic junction capacitance) and R_j (the junction resistance of the diode, where RF energy is converted to DC voltage). As frequency or junction capacitance increases, the junction resistance of the diode will be shorted out and RF energy will be diverted to R_s where it is converted into heat. When this occurs, output voltage will fail.



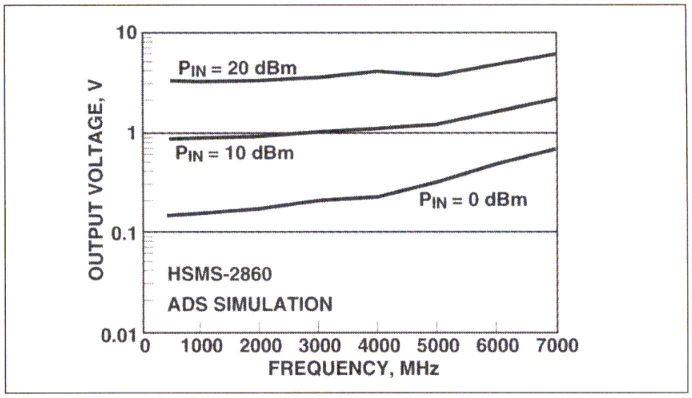
▲ **Figure 1. A typical AGC circuit using a Schottky diode detector.**



▲ **Figure 2. A typical self-biased or "zero biased" detector. Below the schematic is the linear equivalent circuit.**



▲ **Figure 3. Simulation of the HSMS-282x diode family showing the effect of the relatively large junction capacitance in high-frequency rolloff.**



▲ **Figure 4. Simulation of the HSMS-286x diode family showing improved performance above 4 GHz.**

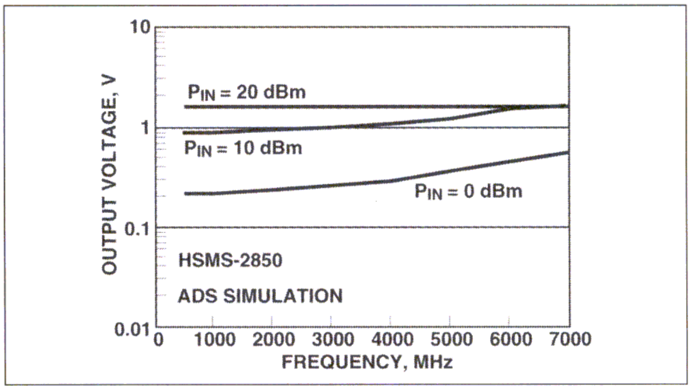
This analysis becomes more complex because junction resistance in a self-biased detector is a variable. As input P_{in} increases, V_{out} will increase, and thus the magnitude of the current circulating through R_L will increase. As this current rises, the value of R_j will fall, diminishing the effect of junction capacitance. The best way in which to conduct the analysis is with a harmonic balance CAD program such as ADS [2].

Schottky diodes are available with a variety of characteristics, based upon the way in which they are fabricated. Diodes based upon p-type silicon feature very low barrier height, making excellent self-biased signal detectors (P_{in}<–20dBm). However, such devices have very low breakdown voltage, severely limiting the maximum value of P_{in}, and very high values of R_s. Diodes based upon n-type silicon offer lower values of series resistance, but their higher barrier height requires a higher value of P_{in} before they begin self-bias. Junction capacitance of the diode can be lowered by reducing the diameter of the Schottky junction, but this comes at the expense of lower yields, lower lot-to-lot consistency and higher cost.

A typical selection of Schottky detector diodes is shown in Table 1. This table provides the key SPICE parameters for the diodes. In addition to C_j and R_s (already defined), they are I_s (saturation current, an indicator of diode barrier height), V_{br} (breakdown voltage) and n (ideality factor). Also shown are ratings of diode cost and lot-to-lot consistency.

Simulations of AGC detectors of the type illustrated in Figure 2 were conducted on ADS, for values of input power (P_{in}) of 0, 10 and 20 dBm and frequencies from 500 MHz to 7 GHz. The results of these analyses are shown in Figures 3, 4 and 5.

In Figure 3, the effect of the relatively large junction capacitance of the HSMS-282x family of diodes is seen in the rolloff of output voltage at high frequencies, particularly at lower values of input power where junction resistance is higher. This low cost and consistent diode



▲ **Figure 5. Simulation of the HSMS-285x diode family of small-signal zero-bias detectors. Such p-type low-barrier diodes are characterized by series resistance and low breakdown voltage, causing the diode to saturate.**

makes an excellent AGC detector at frequencies below 4 GHz, but ought not to be used at higher frequencies.

The HSMS-286x family of microwave detector diodes offers superior performance at frequencies over 4 GHz, as can be seen in Figure 4. However, the higher cost and lot-to-lot variation of this part makes it a poor choice for frequencies below 4 GHz.

Figure 5 presents the results of the simulation for the HSMS-285x family of small signal zero-bias detectors. At first glance, it appears that its performance in an AGC circuit matches that of the n-type HSMS-286x family. However, p-type low-barrier diodes are characterized by high series resistance and low breakdown voltage. While these characteristics cause no problems in the performance of a small signal detector, they lead to severe performance limitations in large-signal AGC detectors. As shown in Figure 5, low breakdown voltage causes the diode output to saturate, especially at frequencies above 4 GHz. P-type diodes such as the HSMS-285x family should never be used for AGC detector applications (see Table 2).

Device	HSMS-282x	HSMS-286x	HSMS-285x
material	n-type	n-type	p-type
Cj, pF	0.65	0.12	0.13
Rs, Ω	7.8	9.0	35.0
Is, A	1.5E-8	5E-8	3E-6
Vbr, V	26.7	7.0	4.8
n	1.067	1.080	1.100
cost	low	moderate	moderate
consistancy	very high	high	low

▲ **Table 1. Key diode SPICE parameters and indication of relative cost and degree of lot-to-lot consistency.**

In summary, low-cost diodes such as the HSMS-282x family make excellent self-biased AGC detectors at frequencies below 4 GHz, while the HSMS-286x family of microwave detector diodes would be a better choice at frequencies above that limit. P-type low-barrier diodes are never used in applications where the input power is higher than –20 dBm. ■

References

1. Raymond W. Waugh, "Designing Large-Signal Detectors for Handsets and Base Stations," *Wireless Systems Design,* Volume 2, Number 7, July 1997.

2. *Advanced Design System*, Hewlett-Packard Company.

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An Analytic Method for Impedance Matching Using MATLAB

A popular mathematics program can be useful for RF/microwave calculations

By Néstor E. Arias
Universidad Nacional de Tucuman

The analytical solution to a problem in transmission lines or waveguides is usually shown adequately using a Smith diagram. Through this process, it is possible to picture what may happen in different places on the transmission line, thus anticipating results and choosing alternative solutions. A simple analytical solution sometimes lacks these qualities.

This paper proposes a calculus method that allows us to solve transmission line or waveguide problems through a different approach. This method is based on both the Smith diagram's graphical criterion and circumference equations, which define the diagram as "a single analytical procedure for all solutions." Thus, it combines the well-known advantages of the graphic method (which follows a step-by-step solution procedure) with the powerful potential of calculus and graphs from mathematical programs such as Matlab.

The graphical procedure consists of determining points that result from the intersection of constant conductance circumferences, with constant susceptance or conductance, straight lines and concentric circumference (such as the displacement on a lossless line) and other similar intersections that lead to a adequate solution.

A analytical method is obtained by means of the graphic criterion and by applying the circumference equations. Such a method allows us to solve different impedance matching problems on transmission lines and waveguides. In other words, this method's analytical contribution to solving some electromagnetism problems consists of creating and then grouping a set of subroutines that solve circumference intersection.

The method is very simple in itself, as the solution to a relatively complex problem is a matter of analytical geometry. Moreover, the equations to be plotted by a mathematical program such as Matlab will be stated will be stated further in this article.

The Smith diagram is obtained by transformation of the complex plane Y (admittances) with respect to an auxiliary plane $P + jQ$. Every point of the diagram that defines a G conductance and a B susceptance implicitly defines a point (P, Q) as a result of the intersection of G with B, as shown in Figure 1.

The constant conductance circumferences are as follows:

$$\left(P - \frac{1}{1+G}\right)^2 + Q^2 = \left(\frac{1}{1+G}\right)^2 \tag{1}$$

With the center in:

$$\alpha_g = \frac{G}{1+G};\ \beta_g = \frac{1}{B};\ \text{and radius } R_g = \frac{1}{1+G}$$

The circumferences of constant susceptance are as follows:

$$(P-1)^2 + \left(Q - \frac{1}{B}\right)^2 = \left(\frac{1}{B}\right)^2 \tag{2}$$

With the center in:

$$\alpha_b = 1;\ \beta_b = \frac{1}{B};\ \text{and radius } R_b = \frac{1}{B}$$

For a given value of G and B and by solving equations (1) and (2), a (P, Q) value is obtained that intersects the point of the G circumference

with the B circumference, as in Figure 1.

The displacement on the transmission line is pictured on the periphery of the diagram with standardized values of x/λ, which correspond to the slope of the straight line passing through the (P, Q) point and the center of the diagram. The slope is:

$$\frac{Q}{P} = -\tan\left(4\pi \frac{x}{\lambda}\right) \tag{3}$$

Once the (P, Q) point coordinates are obtained, the value of x/λ can be estimated (3), and it is:

$$\frac{x}{\lambda} = \frac{\arctan\left(\frac{Q}{P}\right)}{4\pi} \tag{4}$$

The circumferences of constant attenuation have the center in the origin and are as follows:

$$P^2 + Q^2 = R^2 \tag{5}$$

Many problems with impedance matching in transmission lines and waveguides can be solved using a computing program for equations (1) up to (5).

Two systems of matching are shown in Figure 2. In (a), matching occurs by means of a single stub, with the solution procedures designated as (I), (II), and (III). In (b), matching occurs through two stubs, as (1), (2), (3), (4) and (5) are the main solution procedures.

As shown in the diagram, in both cases there are displacements through concentric circumferences with several intersections, such as conductance, susceptances, straight lines, and so on.

Thus, knowing the general procedure that creates a solution to a matching problem or to a problem in the transmission lines, a set of subroutines can be programmed in order to give a partial solution to each procedure. With these solutions, it is possible to work out a program to obtain the final solution through analytical geometry.

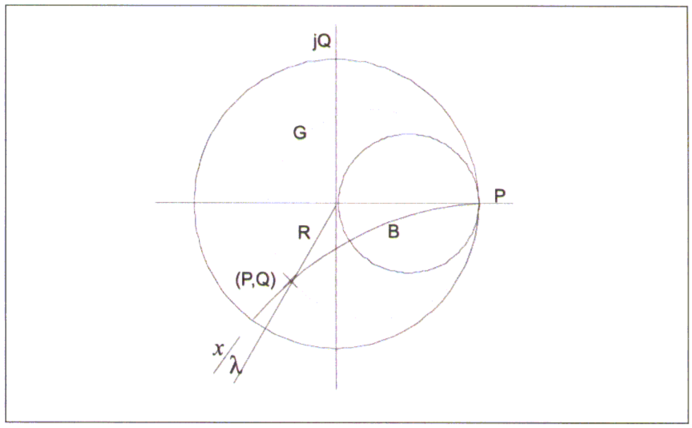
Subroutines

Subroutine circumferences M-file "doscirc"

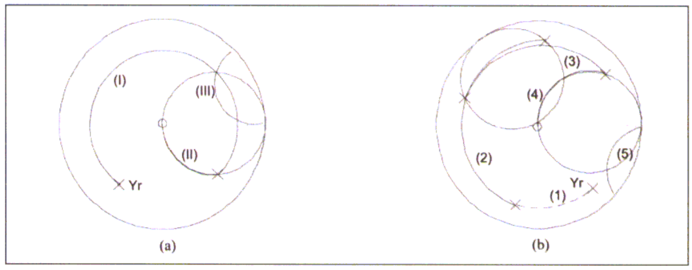
This subroutine determines the intersection among conductance circumferences, susceptances and auxiliary circles. The following parameter circles should be previously defined:

(h_1, h_2) center of circumference 1,
(k_1, k_2) center of circumference 2,
r_1= radius of circumference 1,
r_2= radius of circumference 2.

This gives points (P, Q) that correspond to the intersection.



▲ **Figure 1. A point value is obtained that intersects the point *G* circumference with the *B* circumference.**



▲ **Figure 2. Two available matching systems.**

```
% doscirc
D1=-2*h1;D2=-2*h2;D=D1-D2;E1=-2*k1;E2=-2*k2;
E=E1-E2;F1=h1^2+k1^2-r1^2;
F2=h2^2+k2^2-r2^2;F=F1-F2;
aa=1+(D/E)^2;bb=(2*F*D/E^2)+D1-E1*D/E;
cc=((F/E)^2)-(E1*F/E)+F1;Dis=(bb^2)-4*aa*cc;
p2=((-bb+sqrt(Dis))/(2*aa));p1=((-bb-
sqrt(Dis))/(2*aa));
q1=(-F-D*p1)/E;q2=(-F-D*p2)/E;
```

Subroutine straight line M-file "srecta"

Given a point (P, Q), the angle expressed in x/λ (physical longitude, normalized to the wave longitude) is obtained. One applies a point (P, Q) and the subroutine produces a value of "xlamb."

```
% srecta
if p==0 & q>0,xlamb=.125;end;
if p==0 & q<0,xlamb=.375;end;
if p>0 &q>0, xlamb=.25-xlamb;end;
if p<0 & q<0,xlamb=.5-xlamb;end;
if p>0 & q<0, xlamb=.25+xlamb;end;
```

Subroutine angle M-file "sa"

For this subroutine, we enter a normal value of line longitude (x/λ) "xlamb," and it gives the sign of the coordinates of

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Circle 50

the point (P, Q).

```
% subroutina "sa"
if xlamb ==.125; p=0;q=1;end;if xlamb ==.375;
p=0;
q=-1;end;if xlamb ==0;p=-1;q=0;end;
if xlamb ==.25;p=1;q=0;end;if xlamb >.5;
xlamb=xlamb-.5;end;if xlamb <.125;p=-p;q=q;end;
if xlamb >.125;if xlamb <.25;p=p;q=q;end;end;
if xlamb >.25;if xlamb <.375;p=p;q=-q;end;end;
if xlamb >.375;if xlamb <.5;p=-p;q=-q;end;end;
```

Subroutine circle G M-file "subg"

This subroutine solves the conductance associated with a specific point (P, Q). We enter a value (P, Q) and it gives the value of the conductance G that goes by that point and also produces the graph that corresponds.

```
% subroutine "subg"
m=p^2+q^2;aa=m-(2*p)+1;bb=2*(m-p);cc=m-1;
Di=(bb^2)-4*aa*cc;
Di=sqrt(Di);G=(Di-bb)/(2*aa);
n=0:100;teta=2*pi*n./100;r=1/(1+G);Q=r*sin(teta);
P=r*cos(teta)+(1-r);plot(P,Q,'r');
hold on; axis('square');axis([-1.2 1.2 -1.2 1.2]);
```

Subroutine circle B M-file "subb"

This subroutine solves the susceptance associated with a point (P, Q). We enter a point value and receive the value of the susceptance B that goes by that point and also carries out the corresponding graph.

```
% "subb"
b=2*q/(((p-1)^2)+(q^2));
if b>0;if b<1;
s=(pi+asin((((-2*b)/(b^2+1))+1/b)*b)):pi/300:3*pi/2;
p=(1/b)*cos(s)+1;q=(1/b)*sin(s)+1/b;
axis([-1.2 1.2 -1.2 1.2]);plot(p,q,'b');
hold on;end;end;
if b>=1;
s=acos(((((b^2)-1)/((b^2)+1))-1)*b):pi/300:3*pi/2;
p=(1/b)*cos(s)+1;
q=(1/b)*sin(s)+1/b;plot(p,q,'b');axis([-1.2 1.2 -1.2 1.2]);
hold on;end;
if b<0;if abs(b)<1;
s=pi/2:pi/600:(pi-asin((((-2*b)/(b^2+1))+1/b)*b));
p=(-1/b)*cos(s)+1;q=(-1/b)*sin(s)+1/b;
axis([-1.2 1.2 -1.2 1.2]);plot(p,q,'b');
hold on;end;end;
if b<0;if abs(b)>=1;
s=-pi/2:pi/300:acos(((((b^2)-1)/((b^2)+1))-1)*b);
p=(1/b)*cos(s)+1;q=(1/b)*sin(s)+1/b;
axis([-1.2 1.2 -1.2 1.2]);plot(p,q,'b'); hold on;end;end;
```

Subroutine marks M-file "sm"

With the entry data of a point, this subroutine uses a small circle to indicate the position of a particular point.

```
"sm"
teta=0:.01:2*pi;rmarca=.03;pmarca=p+rmarca.*co
s(teta);qmarca=q+rmarca.*sin(teta);
hold on;plot(pmarca,qmarca);
```

Subroutine M-file "stcp"

This subroutine solves and it draws a segment that unites the center of coordinates with the point.

```
% "stcp"
if (p>0 & q>0),n=0:.001:p;end;
if (p<0 &q>0), n=p:.001:0;end;
if (p<0 & q<0),n=p:.001:0;end;
if (p>0 & q<0),n=0:.001:p;end;
if p>0 & q==0,n=0:.001:p;end;
if p<0 & q==0, n=p:.001:0;end;
if p==0 & q>0,n=0:.001:q;end;
if p==0 & q<0,n=0:.001:q;end;
```

Subroutine M-file "ste"

It solves and it draws a segment in the periphery of the circle (G=0) that is the angular position of (P, Q). It is also helpful to place the outlying indications of x/λ.

```
% "ste"
if (p>0 & q>0) ,n=p:.001:p+.08;end;
if (p<0 &q>0), n=p-.08:.001:p;end;
if (p<0 & q<0),n=p-.08:.001:p;end;
if (p>0 & q<0),n=p:.001:p+.08;end;
if p>0 & q==0,n=p:.001:p+.08;end;
if p<0 & q==0, n=p-.08:.001:p;end;
if p==0 & q>0,n=q+.08:.001:q;end;
if p==0 & q<0,n=q:.001:q-.08;end;
if p<0 &q==0,n=p-.08:.001:p;end;
if p==0 &q>0,n=q+.08:.001:q;end;
if p==0 &q<0,n=q:.001:q-.08;end;
```

Subroutine M-file "sstcc"

This subroutine solves the longitude in xlamb for a stub in short circuits. One enters a xlamb equal to abs(atan(q/p))/(4*pi)), and it solves the position of the stub in one of the four quadrants.

```
% "sstcc"
if p==0 & q>0,xlamb=.375;end;
if p==0 & q<0,xlamb=.125;end;
if p>0 & q>0,xlamb=.5-xlamb;end;
if (p<0 & q<0),xlamb=abs(.25-xlamb);end;
if p>0 & q<0,xlamb=xlamb;end;
if p<0 & q>0,xlamb=.25+xlamb;end;
```

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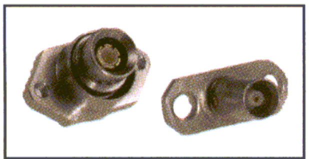

Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 18 Ghz	50 Ohms	Semi-Rigid Flexible	Blindmate/ Slide-on	Stainless Steel Beryllium Copper	Pass/Gold Gold

Also available: Panel mount receptacles, PC board receptacles, hermetic seal jacks, in and between series adapters.

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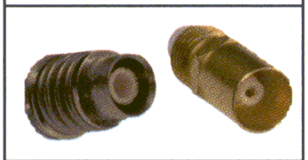
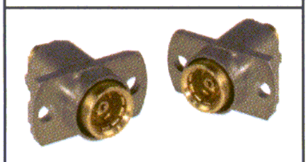


Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 12.4 Ghz	50 Ohms	Semi-Rigid Flexible	Blindmate/ Slide-on	Stainless Steel Beryllium Copper	Pass/Gold Gold

Also available: Panel mount receptacles, PC board receptacles, in and between series adapters.

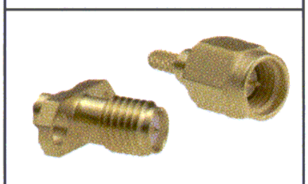
BMA Miniature Blindmate RF Coaxial Connectors



Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 18 Ghz	50 Ohms	Semi-Rigid Flexible	Blindmate/ Slide-on	Stainless Steel Beryllium Copper	Pass/Gold Gold

Also available: In series jack to plug adapters

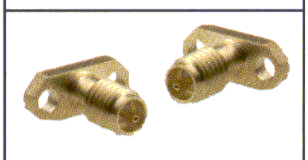
SSMA Screw-on Subminiature RF Coaxial Connectors



Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 26 Ghz	50 Ohms	Semi-Rigid Flexible	Blindmate/ Slide-on	Stainless Steel Beryllium	Pass/Gold Gold

Also available: Panel mount jacks and plugs (hermetic), bulkhead mount jacks (hermetic), surface launch plugs and jacks, in and between series adapters.

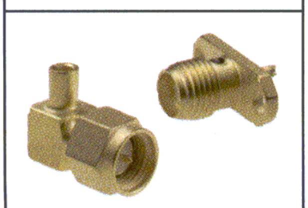
HFSSMA Screw-on Subminiature RF Coaxial Connectors



Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 40 Ghz	50 Ohms	Semi-Rigid	Screw-on	Stainless Steel Beryllium	Pass/Gold Gold

Also available: Panel mount plugs and jacks, in and between series adapters.

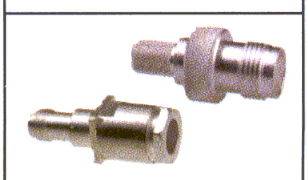
SMA Screw-on Miniature RF Coaxial Connectors



Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 18 Ghz	50 Ohms	Semi-Rigid Flexible	Screw-on	Stainless Steel Beryllium Copper	Pass/Gold Gold

Also available: Panel mount jacks and plugs (hermetic and field replaceable), M.I.C. launcher jacks and plugs, bulkhead jacks (hermetic), surface launcher jacks and plugs, end launcher jacks, in and between series adapters, dust caps, flange mount cable receptacles, glass seals, 27 GHz versions.

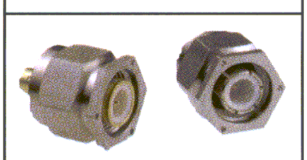
TNC Small-size Screw-on RF Coaxial Connectors



Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 11 Ghz	50 Ohms	Flexible	Screw-on	Brass Beryllium Copper	Silver or Nickel Gold

Also available: Panel mount jacks and plugs (hermetically sealed), bulkhead jacks and plugs (hermetically sealed), surface launcher jacks and plugs, end launcher jacks and plugs, in and between series adapters, dust caps.

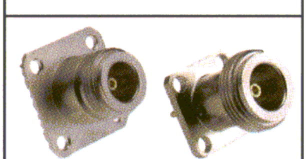
PTNC Precision Small-size Screw-on RF Coaxial Connectors



Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 15 Ghz	50 Ohms	Flexible Semi-Rigid	Screw-on	Stainless Steel Beryllium Copper	Pass/Gold Gold

Also available: Panel mount jacks, bulkhead mount jacks, in and between series adapters, dust caps, hermetics.

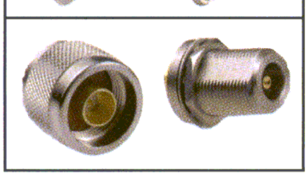
TYPE N Large-size RF Coaxial Connectors



Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 11 Ghz	50 Ohms	Flexible	Screw-on	Brass Beryllium Copper	Silver or Nickel Gold

Also available: Panel mount jacks, surface end launch jacks and plugs, dust caps.

PN Precision Large-size RF Coaxial Connectors



Frequency	Impedance	Cable Type	Coupling	Body & Contact Material	Finish
DC to 12.4 Ghz	50 Ohms	Flexible Semi-Rigid	Screw-on	Stainless Steel Beryllium Copper	Pass/Gold Gold

Also available: In and between series adapters and 18 Ghz versions.

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Matching with two stubs

As an example, the input impedance matching of a 2N3563 transistor in the 1 GHz frequency band is calculated, as shown in Figure. 3. With a two-stub system:

Data:

G_r=0.327 B_r=j 0.089 (Normalized amounts)
H=0.05 x/λ A=0.06 x/λ
λ_0=0.329 wavelength in vacuum
λ_1= 0.6 λ_0 wavelength on the line

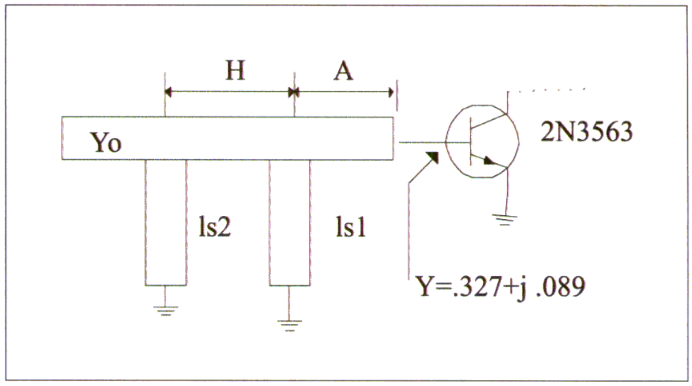
Once executed, the program produces:

ls1=0.3387 [x/λ] ls2=0.0756 [x/λ]
ls1=0.067 [m] ls2=0.015 [m]

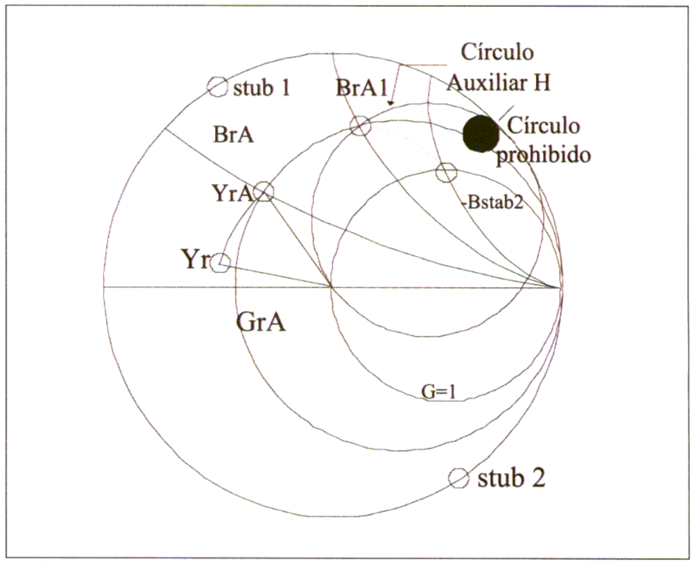
The graph that the program produces when using Matlab is shown in Figure 4. The values of H and A given above have been chosen to withdraw the forbidden circle from the load admittance zone. A system with two stubs presents four solutions to a open circuit stub, and four more to a short circuit stub. One of the eight solutions was adopted in the example above.

With respect to the concepts of "Forbidden Circle" and "Auxiliary circle H," we suggest the reader refer to the references listed at the end of the article. However, to summarize, the forbidden circle is the geometric place that represents the admittance's group and shows that it does not have adaptation, to A and given H.

When designing a system with two stubs, the admittance's group that they can be adapted to should move away from the forbidden circle. This is achieved, when choosing the longitudes A and H appropriately.



▲ **Figure 3. The input impedance matching of a 2N3563 transistor in the 1 GHz frequency band.**



▲ **Figure 4. The graph corresponding to the impedance matching shown in Figure 3.**

Procedures

The set of subroutines can be found in Matlab in the file C:\Matlab\Bin, each one named as mentioned above as: srecta; sm; doscirc;stbi, etc. To initiate the program, Matlab has written stbi on the main screen.

Conclusions

The described method and its program aid in matching and produce corresponding graphs in a step-by-step manner, thus helping to understand the process and how to choose the alternative solution. The tests carried out using Matlab 5 have been highly successful.

By arranging the same subroutines with another flowchart (as mentioned above), it is possible to achieve different kinds of matching on transmission lines and waveguides. The author owns calculus subroutines for transmission lines and matching with a single stub, which are also available. are also available. ■

References

1. N. Arias, "Determinación del Entorno de las Admitancias de Carga que no tienen adaptación en un sistema con dos Stubs," *Revista Telegráfica Electrónica Nº 883. Editorial Arbó*, 1987, Buenos Aires, Argentina.
2. J. Kraus, *Electromagnetics*, Mc Graw-Hill, 1960.
3. D. Roddy, *Microwave Technology*, Prentice-Hall, 1986.
4. R. King, *Transmission Line Theory*, McGraw-Hill, 1955.

Author information

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Circle 42

Programs for Adaption and Calculation with Two Stubs

M-file "stbi"

```
%Calculation with two stubs
%Ing. Néstor E Arias  IIE UNT.
Tucumán,Argentina
%narias@herrera.unt.edu.ar
%arias@tucbbs.com.ar;
        % Input data
g=input('input GR=');b=input('input Br=');
A=input('input A=');H=input('input H=');
h1=g/(1+g);h2=1;k1=0;k2=1/b; Gr=g;Br=b;r1=1/(1+g);
r2=1/b;
doscirc;

pr=p1;qr=q1;%Data represent the point Yr;

xlambH=.25-H;X=abs(xlambH);Rh=.5;if H>.25;X=.5-X;
end;
Angh=X*4*pi;T=abs(tan(Angh));ph=Rh/sqrt(1+T^2);
qh=ph*T;p=ph;q=qh;xlamb=X;
% xlamb=X;
xlambA=X;                %DATA
%sub angle
sa;

 alfa=p;beta=q;  %DATA coordinated of the center of the
circle H

%Drawing of the circumference H

teta=0:.01:2*pi;;ph=p+Rh.*cos(teta);qh=q+Rh.*sin(teta)
;
axis([-1.2 1.2 -1.2 1.2]);axis(['square']);hold on;
plot(ph,qh);
text(p-.1,q+.1,'circle ','FontName','Times new
Roman','FontSize',[9],'color','b');text(p-
.1,q,'auxiliary','FontName','Time New
Roman','FontSize',[9],'color','b');
text(p,q-.13,'H');

%decides if Yr is adaptive, data: Yr,H,A;G,yB

R2=(-((alfa^2)+(beta^2))+2*alfa+...
(Rh^2)-1)/(2*alfa-2*(Rh+1));
R=1-R2;
xlambA=.25-A;X=abs(xlambA);if A>.25;X=.5-X;end;
AngA=X*4*pi;T=abs(tan(AngA));
p=(1-R2)/sqrt(1+T^2);q=p*T;
afa=p;bfa=q;   % afa y befa they are the coordinates of the
center
          % of the forbidden circle
xlambA=X;                %DATA
```

```
xlamb=X;
%sub angle  It takes out the quadrant of xlambA
sa;
 afa=p;bfa=q;%DATA
%Drawing of the forbidden circle
teta=0:.01:2*pi;pp=p+R2.*cos(teta);qp=q+R2.*sin(teta);
axis([-1.2 1.2 -1.2 1.2]);axis(['square']);hold on;
plot(pp,qp);text(p-.1,q+.1,'circle ');
text(p-.1,q,'forbidden');
Z=sqrt(((p1-afa)^2)+((q1-bfa)^2));
if Z < R2;
disp('There is not adaption for "A" and given "H"');
break;end;

%sm  p1 q1)

p=p1;q=q1;
sm;             % It marks Yr

p=p1;q=q1;
%stcp
stcp;   % It traces a zero straight line to the point Yr
if p==0;p=1*10^-7;end;
t=(q/p).*n;hold on;axis([-1.2 1.2 -1.2 1.2]);plot(n,t);
text(p1+.03,q1+.03,'Yr');

if pr==0;pr=1*10^-7;end;
r=1;P=abs(pr);Q=abs(qr);X=(abs(atan(Q/P)))/(4*pi);
xlamb=X;

srecta;  %It takes out the xlamb sign

xlambyr=xlamb;           %DATA
%It determines and it traces the external mark in Yr
pen=abs(tan(xlamb*4*pi));p1e=r/sqrt(1+pen^2);
q1e=p1e*pen; p=abs(p1e);
q=abs(q1e);
sa;
ste;
t=(q/p).*n;hold on;axis([-1.2 1.2 -1.2 1.2]);plot(n,t);

%rotate from Yr to Yra
R=sqrt(pr^2+qr^2); xlambA=xlamb+A;
AnguA=xlambA*4*pi;
Rra=R;            %DATA
T=abs(tan(AnguA));
p11=R/sqrt(1+T^2);q11=p11*T;p=p11;q=q11;
xlamb=xlambA;
sa;
ra=p;qra=q;        %DATA       %Point in Yra
   xlambyrA=xlambA;if xlambyrA >.5;
   xlambyrA=xlambyrA-.5;end; %xlambyrA =>DATA
   sm;
```

```
stcp; t=(q/p)*n;hold on;axis([-1.2 1.2 -1.2 1.2]);plot(n,t);
p11e=r/sqrt(1+T^2);q11e=p11e*T;p=p11e;q=q11e;
sa;
ste;
t=(q/p)*n;hold on;axis([-1.2 1.2 -1.2 1.2]);plot(n,t);

% Function arch, drawn angles between two

a=xlambyr*4*pi;z=xlambA*4*pi;fi=a:.001:z;
P=-Rra*cos(fi);Q=Rra*sin(fi); axis([-1.2 1.2 -1.2 1.2]);
plot(P,Q);hold on;

% it determines the G and the B of the point pra qra

%sub G;
p=pra;q=qra;

subg; Gra=G;
% Sub B
subb; Bra=b;
D=[pr qr xlambyr pra qra xlambyrA Gra Bra alfa beta ...
afa bfa];

%Gra intercepts with circle H
pG=Gra/(1+Gra);qG=0;h1=pG;k1=0;h2=alfa;k2=beta;
r1=1/(1+Gra);r2=.5;
doscirc;
R1=sqrt(p1^2+q1^2);R2=sqrt(p2^2+q2^2);Rih1=R1;
Rih2=R2;            %DATA
pih1=p1;qih1=q1;pih2=p2;qih2=q2;
 %DATA
datos=[pih1 qih1 pih2 qih2 Rih1 Rih2];
piv=p1;qiv=q1;
p=pih1;q=qih1;
sm;
xlambpih1=abs(atan(qih1/pih1))/(4*pi);
xlamb=xlambpih1;
srecta;xlambpih1=xlamb;        %DATA =>xlambpih1
subb; Bih1=b;

p=pih2;q=qih2;
sm;
srecta; xlambpih2= abs(atan(qih2/pih2))/(4*pi);
xlamb=xlambpih2;
srecta;xlambpih2=xlamb;
subb; Bih2=b;

r1=Rih1;r2=.5;h2=.5;

pf1=abs((r1^2-r2^2+h2^2)/(2*h2));
qf1=abs(sqrt(r1^2-pf1^2));
p=pf1;q=qf1;
xlambf1=xlambpih1+H;xlamb=xlambf1;sa;pf1=p;qf1=q;
sm; p=0;q=0;subg;r1=Rih2;r2=.5;h2=.5;
pf2=abs((r1^2-r2^2+h2^2)/(2*h2));
```

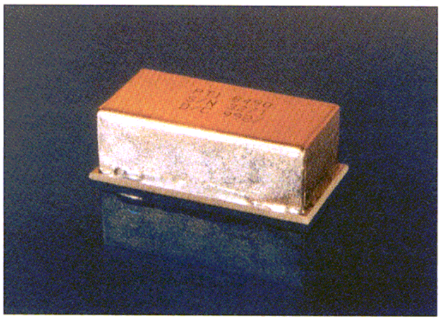
```
qf2=abs(sqrt(r1^2-pf2^2));p=pf2;q=qf2;
xlambf2=xlambpih2+H;xlamb=xlambf2;sa;pf2=p;qf2=q;

sm;
p=-1;q=0;subg;

p=pf1;q=qf1;subb;Bf1=b;%DATA
p=pf2;q=qf2;subb;Bf2=b;%DATA

%Susceptances of the stubs
BsA1=Bih1-Bra;
BsH1=-Bf1;
BsA2=Bih2-Bra;
BsH2=-Bf2;a=-1;o=1.15;
text(a,o, 'narias@herrera.unt.edu.ar');
a=-1;o=1.05;text(a,o, 'arias@tucbbs.com.ar');
a=-1;o=-1.15;
text(a,o, 'ADAPTATION WITH TWO STUBS');
%There are EIGHT SOLUTIONS:
% 4 FOR STUBS IN short circ. AND 4 FOR open cir.
%SOLVE FOR open circ. sA1 and sA2
r1=1;h1=0;k1=0;r2=1/BsA1;h2=1;k2=1/BsA1;doscirc;
p=p1;q=q1;sm;psA1=p;qsA1=q;
r1=1;h1=0;k1=0;r2=1/BsA2;h2=1;k2=1/BsA2;doscirc;
p=p1;q=q1; psA2=p;qsA2=q;
xlamb=abs(atan(qsA1/psA1))/(4*pi);p=psA1;q=qsA1;
srecta; xlambsA1ca=xlamb;%open circ. sA1
xlamb=abs(atan(qsA2/psA2))/(4*pi);p=psA2;q=qsA2;
srecta; xlambsA2ca=xlamb;%open circ. sA2

%Solve for short circ. sA1 y sA2
xlamb=abs(atan(qsA1/psA1))/(4*pi);p=psA1;q=qsA1;
sstcc; xlambsA1cc=xlamb;% short circ. sA1
xlamb=abs(atan(qsA2/psA2))/(4*pi);p=psA2;q=qsA2;
sstcc; xlambsA2cc=xlamb;% short circ. sA2

%Solve for short circ. sH1 y sH2
r1=1;h1=0;k1=0;r2=1/BsH1;h2=1;k2=1/BsH1;doscirc;
p=p1;q=q1;sm;psH1=p;qsH1=q;
r1=1;h1=0;k1=0;r2=1/BsH2;h2=1;k2=1/BsH2;doscirc;
p=p1;q=q1; psH2=p;qsH2=q;
xlamb=abs(atan(qsH1/psH1))/(4*pi);p=psH1;q=qsH1;
sstcc; xlambsH1cc=xlamb;% short circ. sH1
xlamb=abs(atan(qsH2/psH2))/(4*pi);p=psH2;q=qsH2;
sstcc; xlambsH2cc=xlamb;% short circ. sH2
%Solve for open circ. sH1 y sH2
xlamb=abs(atan(qsH1/psH1))/(4*pi);p=psH1;q=qsH1;
srecta; xlambsH1ca=xlamb;% CC sH1
xlamb=abs(atan(qsH2/psH2))/(4*pi);p=psH2;q=qsH2;
srecta; xlambsH2ca=xlamb;% CC sH2
text(psA1+.03,qsA1,'stub1');text(psH1+.03,qsH1,'stub2');
disp('longitude stub1=');disp([xlambsA1cc]);
disp('longitude stub2=');disp([xlambsH1cc]);pause;
z=input('continue ?');if z==1,figure;stb;end;
if z==0;break;end
```

Products

SIGNAL PROCESSING

70 MHz IF filter

Piezo Technology, Inc. (PTI) offers a 70 MHz filter for wireless applications. PTI model 8490 features a surface mount package



capable of meeting high temperature reflow requirements and aqueous cleaning. This model offers exceptional flatness with a 1.5 dB bandwidth of $\pm$18 MHz and a 40 dB stopband $\pm$38 MHz wide. The 8490 is housed in a 1.0 $\times$ 0.5 $\times$ 0.35 inch hermetic package with 50 ohm input and output impedances.
Piezo Technology, Inc.
Circle #162

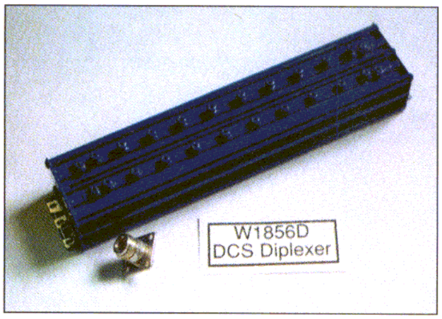
Premium performance mixers for wireless

Stellex Electronics introduces a new line of "CSM" mixers covering cellular, PCS and WLL bands. These mixers are derivatives of the

company's Hi-Rel and Space mixer products with proven field reliability. The result is a low cost mixer family with high performance. The CSM line is provided in a 0.370 $\times$ 0.490 $\times$ 0.187 inch package with a ceramic substrate that has metallization compatible with standard solder reflow processes. The mixers are available in standard double-balances and load insensitive designs with LO power levels from +10 to +23 dBm.
Stellex Electronics, Inc.
Circle #163

IMD-free diplexer

The Model W1856D diplexer from Wireless Technologies Corporation was designed to be IMD-free. The standard two +40 dBm signals



produce less than –130 dBm IMD products, meeting GSM standards. Additional features include full band coverage, <1.2 dB in-band insertion loss, >95 dB RX/TX isolation and better than –16 dB return loss. Power capability is 50 watts minimum. The diplexer is small in size (2 $\times$ 2 $\times$ 10 in.) and uses SMA or type N connectors. Pricing is less than $160 in small quantities.
Wireless Technologies Corp.
Circle #164

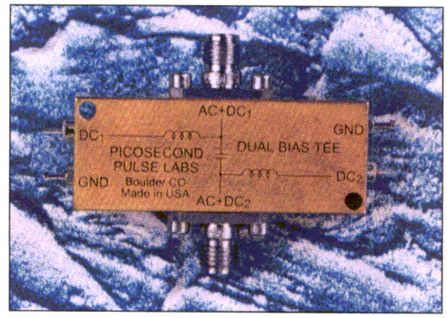
Video signal splitters

A passive splitter from Faraday Technology Ltd. solves the problem of providing two SDI video or AES feeds from one source. For short

runs of cable, it can replace digital distribution amplifiers. From a good SDI signal source, the unit will support approximately 40 meters of Belden 8281 cable. Typical applications include small studios, editing suites and multiple displays in office environments.
Faraday Technology Ltd.
Circle #165

40 GHz bias tee

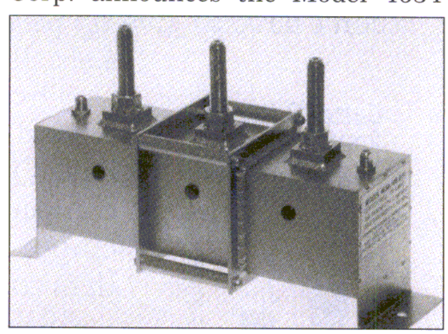
Picosecond Pulse Labs has added a 40 GHz dual inductor bias tee to



its line of wideband products. Model 5542-LL has a rise time specification of 7 ps and a –3 dB bandwidth of 12 kHz to 40 GHz. Insertion loss is 0.2 dB midband, with guaranteed limits of <0.8 dB from 100 kHz to 8 GHz. The bias tee uses 2.92 mm 40 GHz connectors, which are mechanically and electrically compatible with K, SMA and 3.5 mm connectors. Two DC inputs provide independent bias to the two ports. The US list price is $1,550.
Picosecond Pulse Labs
Circle #166

FM channel bandpass filter

Communications and Energy Corp. announces the Model 4634

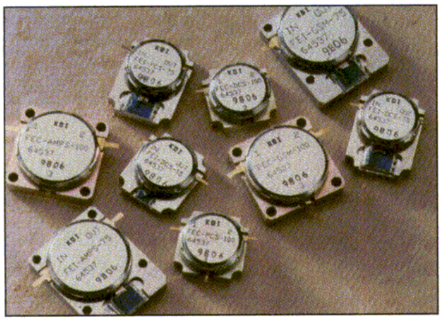


bandpass filter, available for any FM radio channel between 88 and 108 MHz. The 3 dB bandwidth is 40 kHz with an insertion loss of 5 dB. Rejection at $\pm$750 kHz is 30 dB. Connectors are 50 or 75 ohm BNC female, with other connectors available. The filter measures 3 $\times$ 3 $\times$

12 inches and weighs one pound. Power handling rating is one watt. The filter is priced at $575.
Communications and Energy Corp.
Circle #167

Drop-in terminated circulators for PCS and cellular

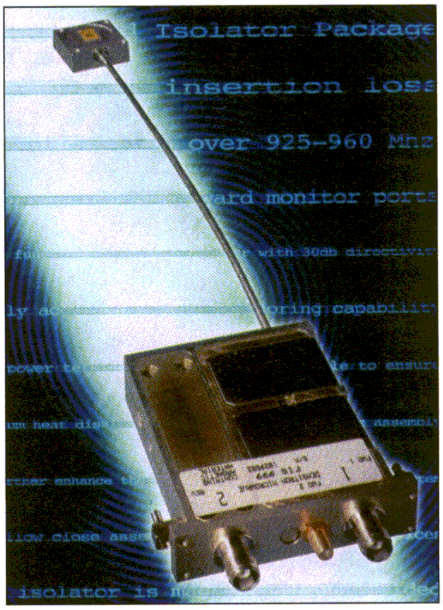
KDI/triangle Corp. has designed its FAN series of terminated ferrite



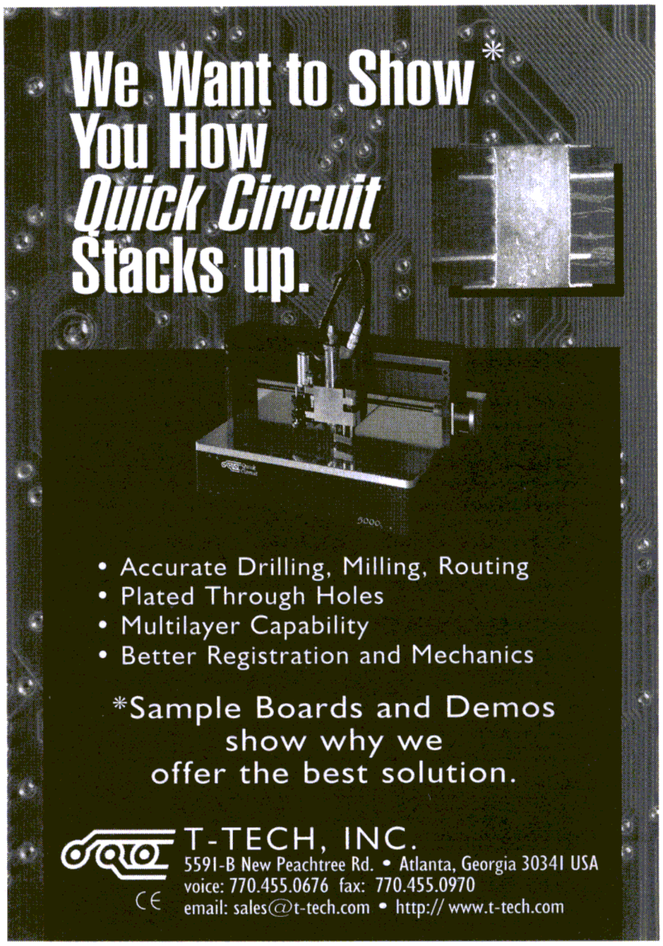
circulators with aluminum nitride terminations instead of beryllium oxide (BeO). The FAN series operate from 869 to 1990 MHz at power levels up to 60 watts. Power levels to 100 watts will be offered in the future. Typical insertion loss is 0.3 dB maximum and isolation is 22 dB minimum. The FAN series also features 1.20:1 VSWR and 50 ohm impedance.
KDI/triangle Corp.
Circle #168

Integrated cellular isolator and coupler

A new integrated isolator package from Densitron Microwave does the work of both isolator and coupler, providing 0.4 dB insertion loss and 50 dB isolation over 925-960 MHz. It also incorporates two forward power monitor ports and a reverse coupler with 30 dB directivity for accurate system monitoring. The high power termination is supplied with a cable to place the maximum heat dissipation away from



the isolator assembly. To allow multiple isolators to be installed in a close assembly, the isolator is magnetically shielded.
Densitron Microwave
Circle #169

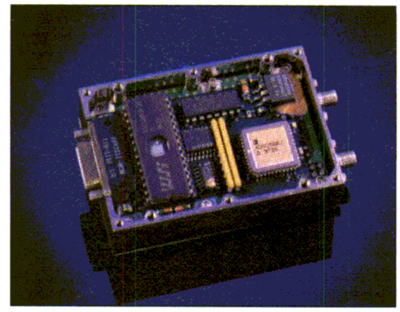


Circle 45

Products

Dual channel phase detection subsystem

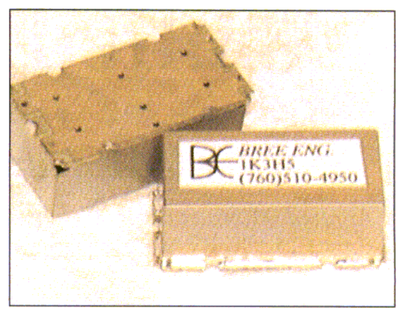
Model IFS-9830-7086 from Signal Technology Corporation's Olektron Operation is a 2-channel phase detection subsystem with a center frequency of 160 MHz and an operating bandwidth of 10 MHz. The unit operates with a phase range of 0 to 360 degrees with a pulse width capture of 75 ns minimum. Input dynamic range is 60 dB and differential dynamic range is 15 dB. Other features include a fast video rise time of 25 ns and a phase resolution of 8 bits. The unit operates from –40° to +85° C and requires ±5 and +10 to 15 VDC. It is designed for many EW applications and passes military screening for vibration and shock. The price is $8,500 each in quantities of 5 to 9.



Signal Technology Corporation, Olektron Operation
Circle #170

Surface mount GPS diplexer

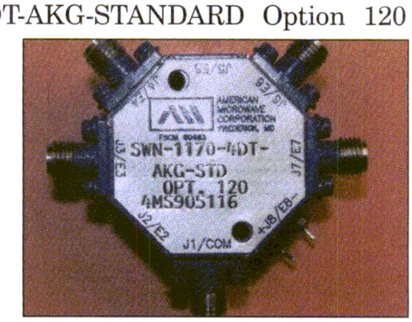
A new series of filters from Bree Engineering includes a GPS diplexer. This unit has a loss of 0.7 dB at the L1 and L2 passbands with channel-to-channel isolation of 30 dB. The location of input and output pads can be specified at the time of purchase to accommodate many board configurations. The diplexer is 1.0 × 0.5 × 0.4 inches in size and will survive an Sn62 reflow soldering environment.



Bree Engineering
Circle #171

100 dB isolation SP4T switch

The SWN-1170-4DT-AKG-STANDARD Option 120 from American Microwave is an SP4T switch capable of 100 dB isolation from 0.1 to 20 GHz. Turn on time is less that 65 ns and turn off time is less than 45 dB. Insertion loss is less than 4.5 dB. Operating voltages are +5 and –12 VDC.

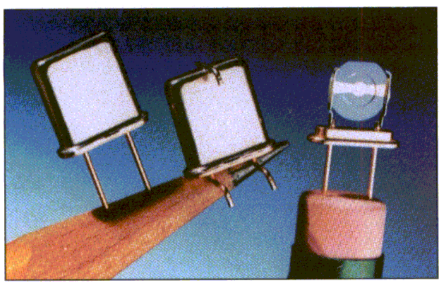


American Microwave Corporation
Circle #172

FREQUENCY CONTROL

High frequency crystals

Champion Technologies announces a new series of inverted mesa high frequency fundamental crystals. The CIM-32 series is available immediately in frequencies from 51.84 to 155.52 MHz. These crys-

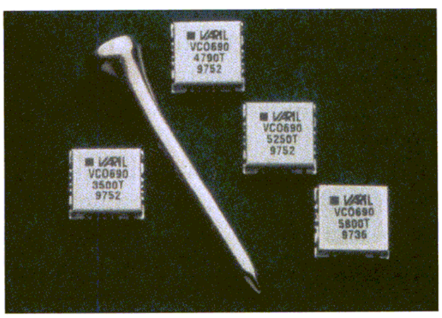


tals offer low series resistance, high pullability and unit-to-unit repeatability. Pricing depends on frequency, but will typically range from $12 in hundreds to $10 in thousands.

Champion Technologies
Circle #173

5.4-5.6 GHz VCO

Vari-L Model VCO690-5500T generates frequencies from 5400 to 5600 MHz with control voltages from 0.5 to 4.5 volts. The unit typically requires 7.14 mA of current from a +5 volt supply. Typical phase noise at 100 kHz offset is –100 dBc/Hz. Typical power output



is –1 dBm, second harmonic suppression is –15 dBc and third harmonic suppression is –20 dB.

Vari-L Company
Circle #174

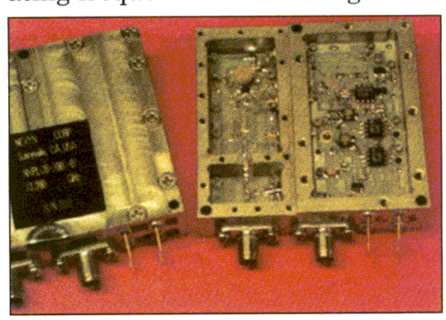
Miniature SMD crystal

Valpey Fisher has added a miniature crystal to its product line. The VFC232 has a low profile of just 1.0 mm, suitable for use in PCMCIA cards and many portable devices. Stability is specified at ±50 ppm, frequency tolerance is ±10 ppm at 25° C and aging is +5.0 ppm per year. Available frequencies cover 11 to 150 MHz. Pricing is $1.88 each in quantities of 1,000.

Valpey Fisher Corporation
Circle #175

Phase locked DROs

NEXYN Corporation offers rugged phase locked DROs, generating frequencies in the range of 12

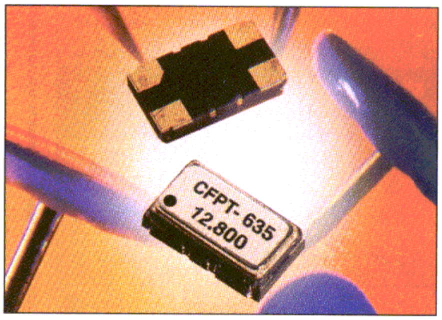


to 16 GHz. Performance features include low microphonics, +13 dBm output power, –80 dBc spurious levels and –20 dBc harmonics. Phase noise at 13.2 GHz is –105 dBc/Hz at 1 kHz offset. The unit requires a 100 to 200 MHz external reference signal.

NEXYN Corporation
Circle #176

Small, light TXCOs

C-MAC Frequency Products has introduced an ultracompact temperature compensated crystal oscillator offering stability to within ±2.5 ppm over a temperature range from –30 to +80° C. The

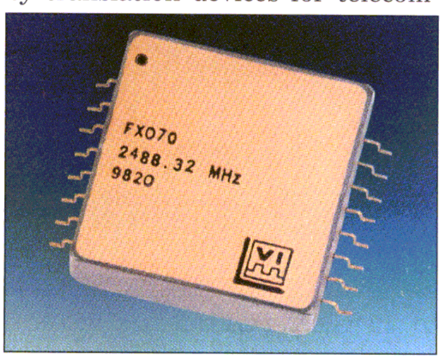


CFPT-635 is provided in a surface mount package measuring just 6.0 × 3.5 × 1.7 mm and weighing 115 mg. Current consumption from a +3 volt supply is 2 mA. The CFPT-635 is available in frequencies of 12.8 MHz, 13.0 MHz, 14.4 MHz and 16.8 MHz. Aging is specified to within 1 ppm per year and devices can be trimmed via an automatic frequency control (AFC) pin. Pricing ranges from $4 to $6 in quantities of 1,000 to 10,000.

C-MAC Frequency Products
Circle #177

Frequency translation unit

Vectron International has introduced a series of low jitter frequency translation devices for telecom-



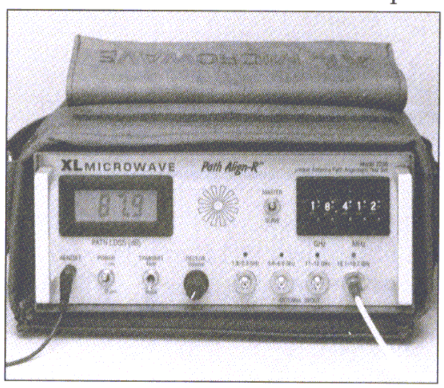
munication applications. The model FX070 is a low noise, narrowband PLL that generates a 2488.32 MHz output from an external 12.96 MHz reference clock. The units have an output level of 0 dBm minimum into 50 ohms and are available in a 16-pin surface-mountable flatpack measuring 1 × 1 × 0.28 inches. Typical output jitter is <5 ps at the output frequency. The FX070 is designed for clock frequency translation and clock distribution in SONET/SDH, ATM and other applications.

Vectron International
Circle #178

TEST EQUIPMENT

Antenna alignment test set

XL Microwave offers a battery powered alignment test set weighing 7 lbs. for on-tower operation by a technician. The unit consists of a synthesized signal source tunable to operating frequencies of 1.8 to 19.7 GHz and includes a full duplex

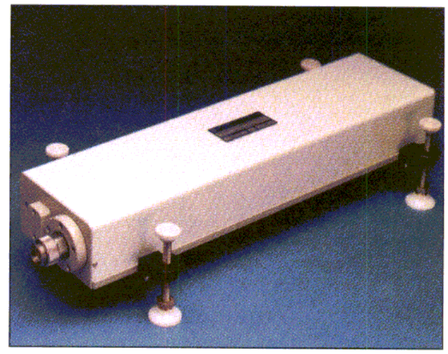


voice channel so technicians at each end of the path can communicate during alignment. An LCD readout provides direct readout of path loss with a 0.1 dB resolution. The test allows installation and alignment of a microwave antenna system prior to installation of the equipment, which typically requires a signal generator and microwave spectrum analyzer. The Model 2200 is priced at $17,500 (includes two units).

XL Microwave
Circle #179

Automated harmonic tuner

Maury Microwave now offers the model MT999 precision automated harmonic tuner. The tuner is capable of presenting a high mismatch over a broad frequency range of 0.8 to 7.5 GHz. Designed to work with the MT980 series of ATS (Automated Tuner System), the MT999 is designed for load pull

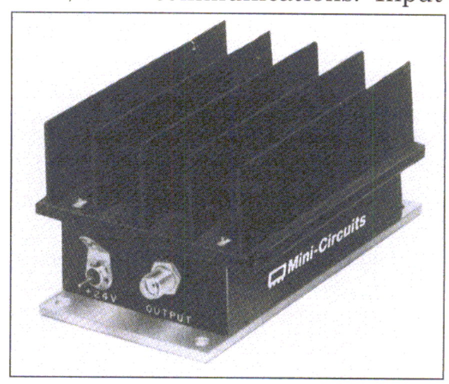


measurements requiring very high mismatch values. With the appropriate multiplexer, harmonic frequencies are isolated from the fundamental for accurate device characterization measurements.

Maury Microwave
Circle #180

Broadband amplifier for lab or communications

Mini-Circuits' ZHL-1010 coaxial amplifier covers 50 to 1000 MHz with 10.5 ±0.3 dB gain and maximum power output of 29 dBm (P_{1dB}). Applications include development and implementation of high traffic cellular and other VHF/UHF communications. Input



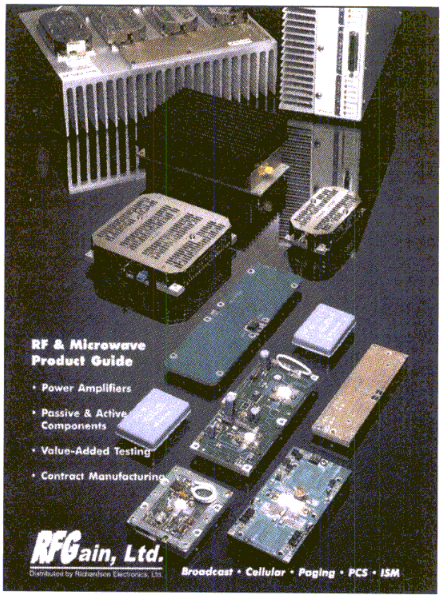
and output VSWR are specified as 1.5:1 maximum. The third order intercept point is +46 to +48 dBm, while second order intercept is +68 to +83 dBm. The ZHL-1010 is equipped with SMA connectors and heat sink for operation in the –20 to +65° C temperature range. The unit is priced at $149.95 each in 1 to 9 unit quantities.

Mini-Circuits
Circle #181

LITERATURE

Microwave product guide

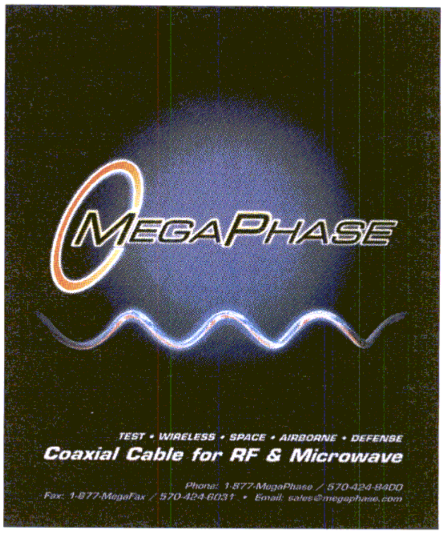
The RF Gain Division of Richardson Electronics has published a new RF and Microwave Product Guide featuring the company's custom RF and microwave power transistors, MMICs and power amplifiers. The 15-page guide details key product specifications for general-purpose amplifiers, FM broadcast amplifiers, HF and VHF amplifier pallets and low noise amplifiers. Specifications are also provided for special-function modules for broadcast transmitters, demo boards for special-function broadcast modules, RF high-power hybrid modules and splitters/combiners. Package outline drawings for RF hybrid modules are included, as are schematics of a variety of RF lineups.



Richardson Electronics, RF Gain Division
Circle #182

Coaxial cable assembly catalog

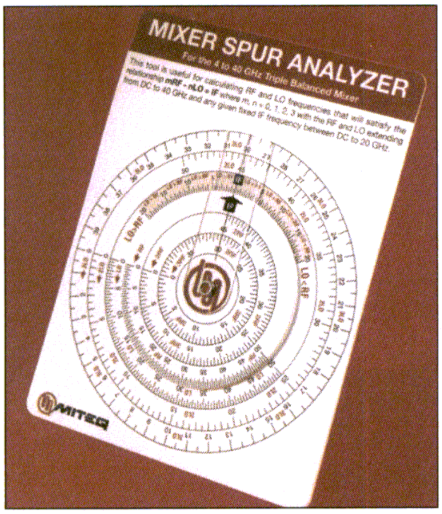
MegaPhase has published its 1999 catalog, highlighting the company's line of coaxial cable assemblies for RF and microwave applications through 40 GHz. The catalog includes color product photos, product data and graphs, as well as the company's Test & Measurement Series cables, designed for phase and amplitude stable measurements through 40 GHz.



MegaPhase
Circle #183

Mixer chart

The Special Mixer Department of MITEQ has designed a special circular chart that allows mixer users to check for the existence of

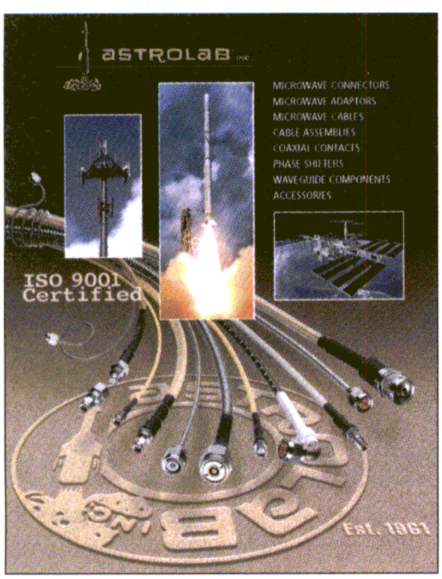


the highest-level spur products (first three harmonics of the LO and RF) in the block downconverter mode. The chart speeds the choice of operating parameters that are then more closely analyzed for higher order products by a numerical program.

MITEQ
Circle #184

Microwave component catalog

Astrolab, Inc. announces its new 1999-2000 product catalog, featuring the company's line of passive

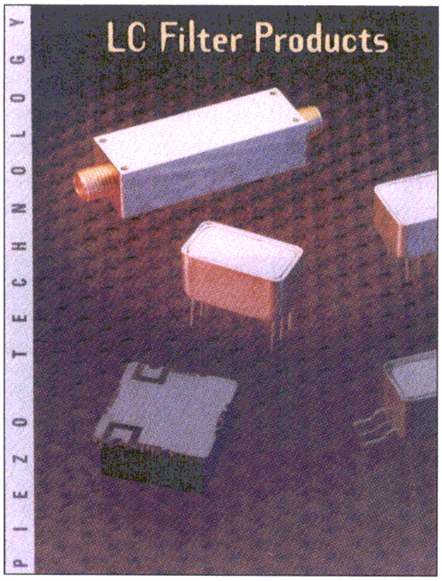


microwave components for test, commercial, space and military applications to 50 GHz. Included are microwave adapters and connectors, flexible and semi-rigid microwave cable from .041" to .500" in diameter, precision phase shifters, terminations, attenuators and flexible and semi-rigid cable assemblies. The catalog also highlights the patented minibend cable assemblies for use to up 40 GHz.

Astrolab
Circle #185

Filter brochure

PTI has released a new LC Filter brochure, featuring the company's line of LC filters available for low-pass, bandpass, and the band reject applications. LC filters manufactured by PTI are designed for use in a variety of commercial and military applications. Commercial applications include wireless communications infrastructure, point-to-point

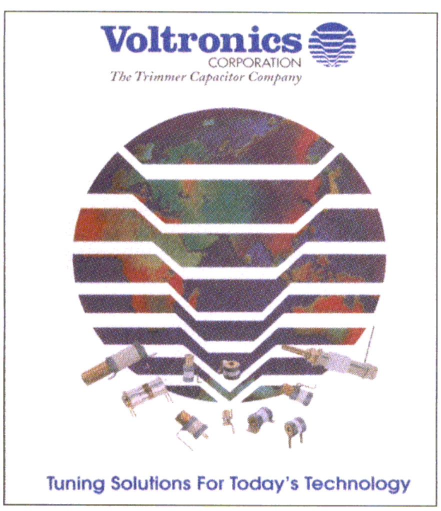


and multipoint microwave radios, commercial satellite communications, navigating systems, instrument and medical applications. Military uses include aircraft communication and navigation systems, missile systems, air-to-land communications and air-to-air communications.

Piezo Technology, Inc.
Circle #186

Capacitor catalog

Voltronics Corporation announces its new 40-page catalog, describ-



ing the company's complete line of PTFE, glass, quartz, sapphire and air variable capacitors. Information is included about Voltronics' latest solid dielectric trimmer line, which is designed for GHz frequencies, and features high Q, small size, low cost and high reliability. The company also has catalogs presenting half-turn ceramic chip trimmers and will soon be introducing a new catalog of non-magnetic MRI and NMR trimmers.

Voltronics Corporation
Circle #187

Waveguide component catalog

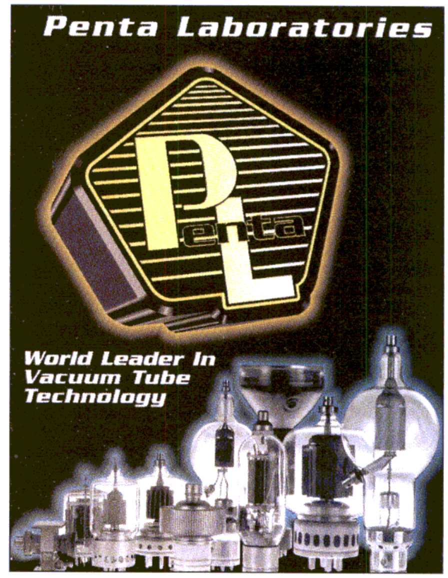
Mega Industries has released a new illustrated catalog highlighting the company's line of fabricated waveguide components from DC to 18 GHz. The catalog features wave-

guide components, flexible waveguide components and coaxial transmission line and components. Mega inventories copper, bronze, aluminum and invar waveguide tubing from WR 10 to WR 2300.

Mega Industries
Circle #188

Electron tube catalog

Penta Laboratories introduces a new catalog describing its line of electron tubes. The company's product line covers broadcast, industrial, research, military, medical and high end audio applications. Penta's inventory ranges from small 250-watt drivers to large 100,000-watt vapor cooled tubes. Specialties include the manufacture of ceramic/metal tubes, triodes and tetrodes. The company

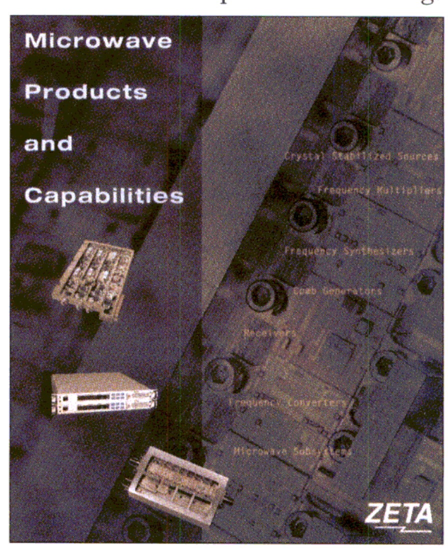


offers a full range of receiving tube types as well as an inventory of many tube types that are no longer being manufactured.

Penta Laboratory
Circle #189

Microwave products and capabilities catalog

Zeta, a microwave product provider, has announced the publication of its new Microwave Products and Capabilities Catalog.

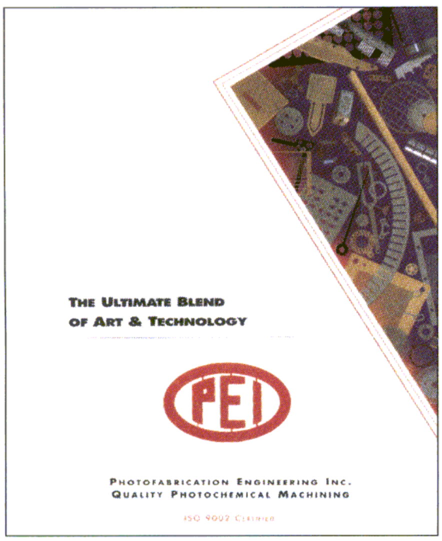


Zeta provides solutions that include a full range of microwave products: crystal stabilized sources, frequency multipliers, frequency synthesizers, comb generators, receivers, frequency converters and microwave subsystems. These products and subsystems are specifically designed for use in missile guidance, ground support equipment, radar, satellite communications, data links and other applications.

Zeta
Circle #190

Photo-etching brochure

Photofabrication Engineering, Inc. (PEI) has issued a revised 12-page brochure describing the company's capabilities for photo-etching a broad variety of metals, including such metals as pure titanium, zircaloid/zirconium alloy and beryllium copper. PEI's warehouse allows the company to stock more



than 2000 part numbers of material, in thicknesses from 0.0003 in. (0.0076 mm) to 0.90 in.(22.86 mm). PEI's products can be used for applications such as heat sinks, lead frames and oxygen generators, as well as in the aerospace, telecommunications, automotive and medical industries.

Photofabrication Engineering
Circle #191

SMP series catalog

Dynawave, Inc. has issued a brochure featuring its RF/ microwave sub-miniature push-on connectors, the SMP series for DC

to 40 GHz. SMP connectors provide efficient packaging for RF and microwave systems, with easy interface and an insertion force that can be varied to suit each application. The brochure contains electrical, mechanical and environmental specifications, along with materials and finish information for hermetic and non-hermetic shrouds, contacts and insulators.

Dynawave, Inc.
Circle # 192

Mechanical Design Tips for EMI Shielding

By Fred Broekhuizen
Holland Shielding

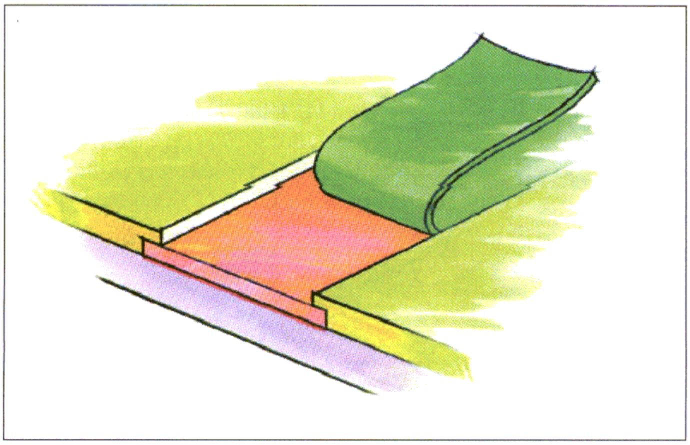
Every company today seems to be involved with CE/EMI demands. The use of electronics increases, and so do the frequencies. Therefore, these demands have to be taken into account at an early stage during the development of new products. In many cases, it is impossible to solve EMI problems at a PCB level, and is it necessary to shield the enclosures and cables.

Applications

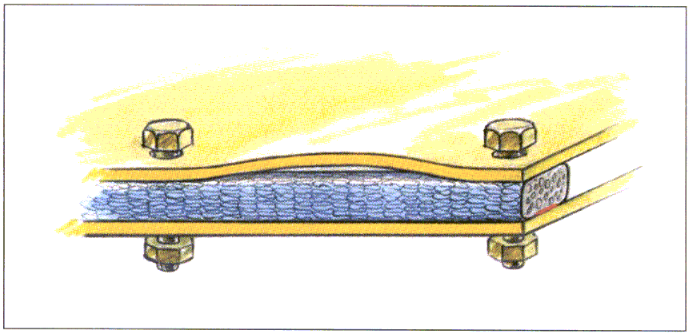
Shielding is a fast way to comply with legal demands or to prevent electromagnetic interference. Because no long-lasting development is required, it is a cost-effective method. Therefore shielding is used for smaller series or if a quick market introduction is needed. Besides that, it is also used for appliances with high radiation or sensitivity levels or for products of which little is known in advance, such as modular enclosures.

Radiation and conduction

Electromagnetic interference can be transferred by radiation and conduction. Conduction plays an important role for frequencies below 10 MHz. To prevent the interference transfer, cables and enclosures have to be shielded well with magnetically conductive materials. The lower the frequency, the thicker the shielding needs to be. For high frequencies (HF shielding, >40 MHz), only a very thin layer of highly conductive material is needed.



▲ **Figure 2. Metal tape with conductive self-adhesive to increase corrosion resistance.**



▲ **Figure 1. Deflection of parts because of too high stiffness of the gasket.**

Avoid gaps

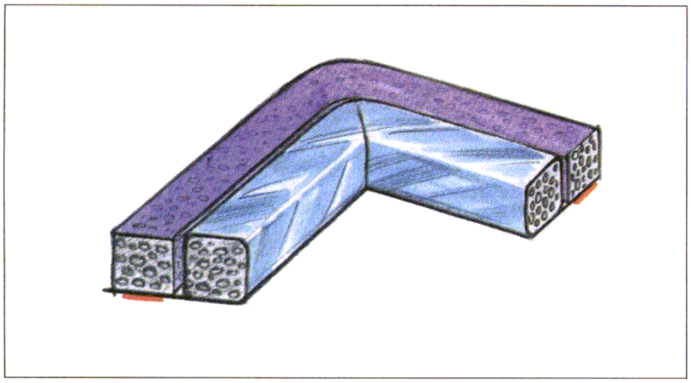
The higher the frequency, the shorter the wavelength. This means that with increasing frequency, the tolerable gap dimensions decrease. In other words, doors, panels and other parts need to be connected electrically on all sides. The easiest way to do this is with highly conductive EMI shielding gaskets. Most of them are self-adhesive for easy mounting.

To select the appropriate gasket, several aspects have to be taken into account, such as the rigidity of the construction, the distance between the fixings and the distance between the fixings and the construction materials used.

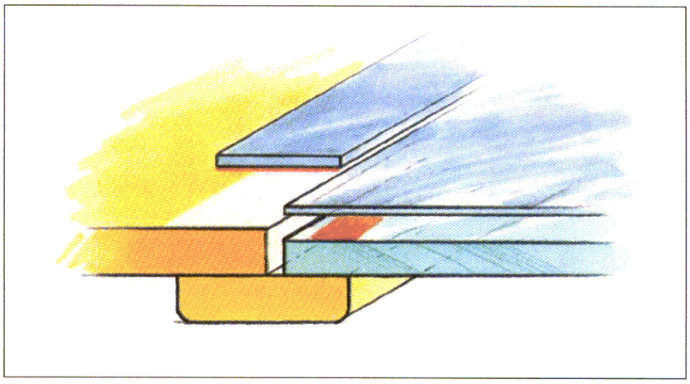
The allowed stiffness of the gasket depends on the rigidity of the construction and the distance between the fixings. If the gasket is too stiff, the door, lid or panel will deflect, causing gaps (Figure 1). Several kinds of gaskets have been developed especially for doors, combining a very large compression range, low closure force and high conductivity. Many of them can be used in existing products without changing the construction of the product.

Galvanic corrosion

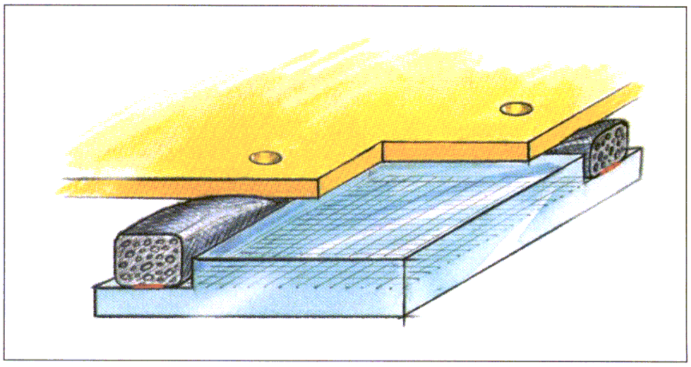
The conductive layer on the outside of the gasket needs to be in the same galvanic range as the construction materials. Otherwise, galvanic corrosion will occur and the electrical conduction between the parts will be reduced, thus decreasing the shielding performance. Commonly used criteria include: no more than 0.3 volts for harsh environments (salt spray/weathering) and no



▲ Figure 3. Combined EMI/water seal.



▲ Figure 4a. Shielded display with transparent conductive foil.



▲ Figure 4b. Shielded display with laminated metal wire mesh.

more than 0.5 volts for benign environments (indoors, salt-free condensation only).

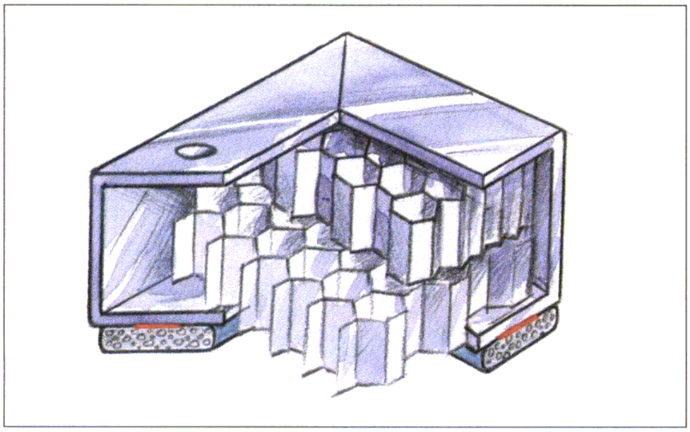
To obtain a contact surface within the same range as the conductive covering of the gaskets, a metal tape with conductive self-adhesive can be applied, such as masking tape with a smaller width. The paint should overlap the tape to increase bonding and corrosion resistance (Figure 2).

Another way to avoid galvanic corrosion is to make sure that the environmental influences do not reach the EMI shielding gasket by using, for example, a combined EMI/water seal. (Figure 3).

Some manufacturers of EMI shielding gaskets use carbon-containing layers on the outside to prevent corrosion of the gasket. But be aware that these are not galvanically compatible with many commonly used construction materials and that corrosion of the construction contact materials may be inevitable. EMI shielding gaskets with a conductive layer of reinforced Amucor® foil are much more compatible with materials like zinc-plated steel and aluminum and will prevent this kind of corrosion.

Displays and vent panels

Aside from connection between construction parts, displays and vent panels also need proper shielding. Displays can be provided with a sputtered, transparent conductive coating for HF shielding (>30 Mhz, Figure 4a) or a fine metal wire mesh for lower frequency/high performance shielding (Figure 4b). The conductive sputter layer can be coated directly on the display or on thin films to form smaller demands.



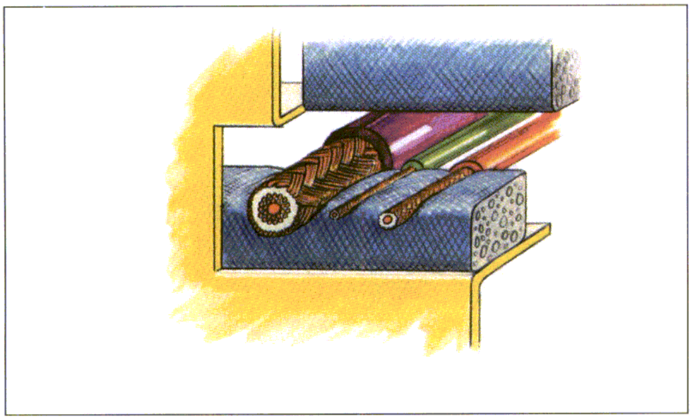
▲ Figure 5. Cross-cell honeycomb vents.

The shielding of the displays needs to be connected with the shielding of the enclosure to guarantee optimal damping. This can be done with a gasket or metal tape with conductive self-adhesive.

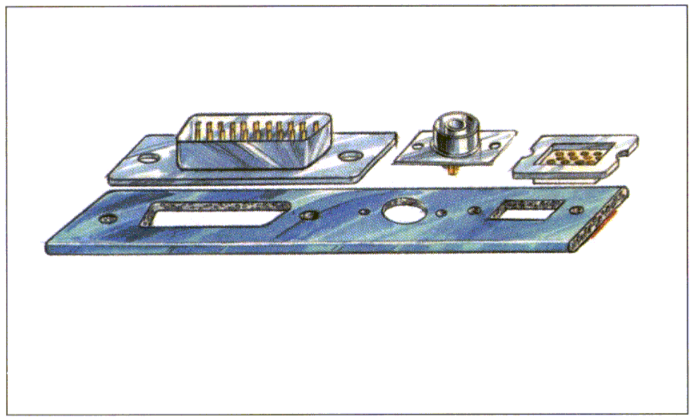
Vent panels are normally shielded with aluminum honeycomb vents, which provide excellent shielding performance with minimal loss of airflow. For superb shielding performance so-called cross-cell honeycombs vents are used. These vents consist of two or more layers of aluminum honeycomb, which are rotated 90 degrees (Figure 5). Honeycombs are normally applied with a rigid aluminum frame and a gasket of 2 to 5 mm for optimal connection with the construction

Cables

To avoid radiation emission, power and signal cables need to be shielded or filtered. Shielding can be achieved with ready-made shielded cables, shielding tube and cable wrapping. Shielding tube consists of hollow braided metal wire, through which the cable or bundle of



▲ **Figure 6. Entry-shield.**

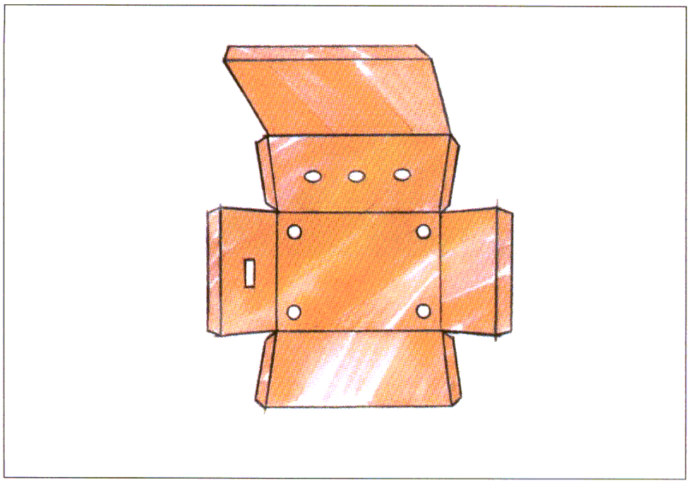


▲ **Figure 7. Connector gaskets.**

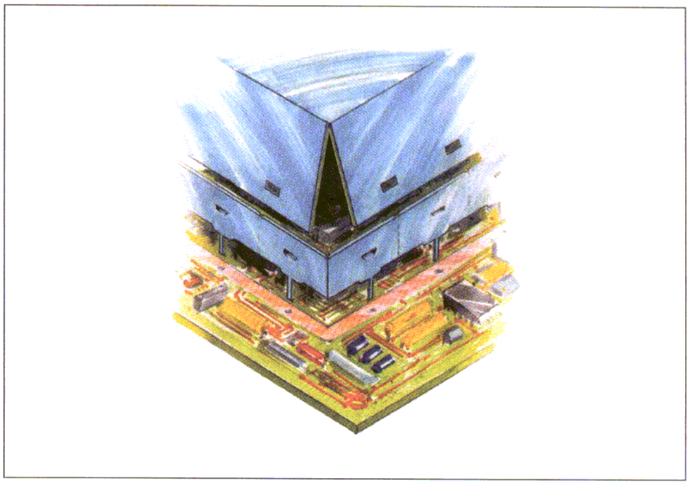
cables can be pulled. Cable wrapping is a knitted metal wire tape, which is wrapped around a cable or bundle of cables. Using this wrapping, branches can be made very easily.

Cable shielding always needs to be connected properly with the shielding of the enclosure, otherwise the cable will act as an antenna and shielding will be useless. For heavy-duty and military applications, shielded cable glands and special cable entry systems with compressed conductive rubber seals are commonly used.

For commercial applications and appliances that do not need a water seal, entry-shield is used in most cases. Entry-shield consists of two precompressed flexible strips of EMI shielding gasket, between which the cables are entered. This way, many cables can be entered simultaneously with minimal mounting, and it is very easy to add cables later (Figure 6).



▲ Figure 8. Shielded box of die-cut foil.



▲ Figure 9. Shielding of parts of a PCB.

Connectors

Connectors also need to be shielded or filtered and connected with a gasket. These gaskets can consist of 1 mm-thick die-cut material, which can be manufactured easily according to customer specifications, with little tooling costs (Figure 7).

Shielding at the source

If the source of the radiation or sensitivity is known, shielding should begin at this level. The interfering parts can be packed in a folded box or envelope of die-cut shielding foil with an insulating layer on the inside to avoid short-circuiting (Figure 8). It can also be done by soldering vertical metal strips on the PCB to create compartments. These compartments are closed by placing a lid of flexible die-cut shielding foil (Figure 9) or by pressing a soft foam sheet with a conductive surface against the strips (Figure 10). This final option allows many compartments to be shielded with just one single cover. ■

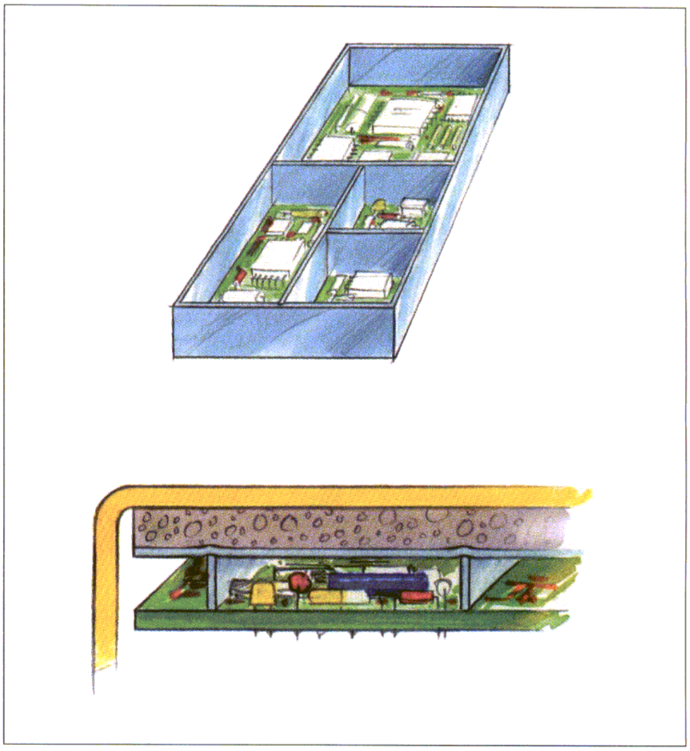
Author information

Fred Broekhuizen has been product manager at Holland Shielding Systems BV for three years. He is responsible for the development of new EMI shielding materials, which combine better shielding performances, lower closure forces and easier mounting.

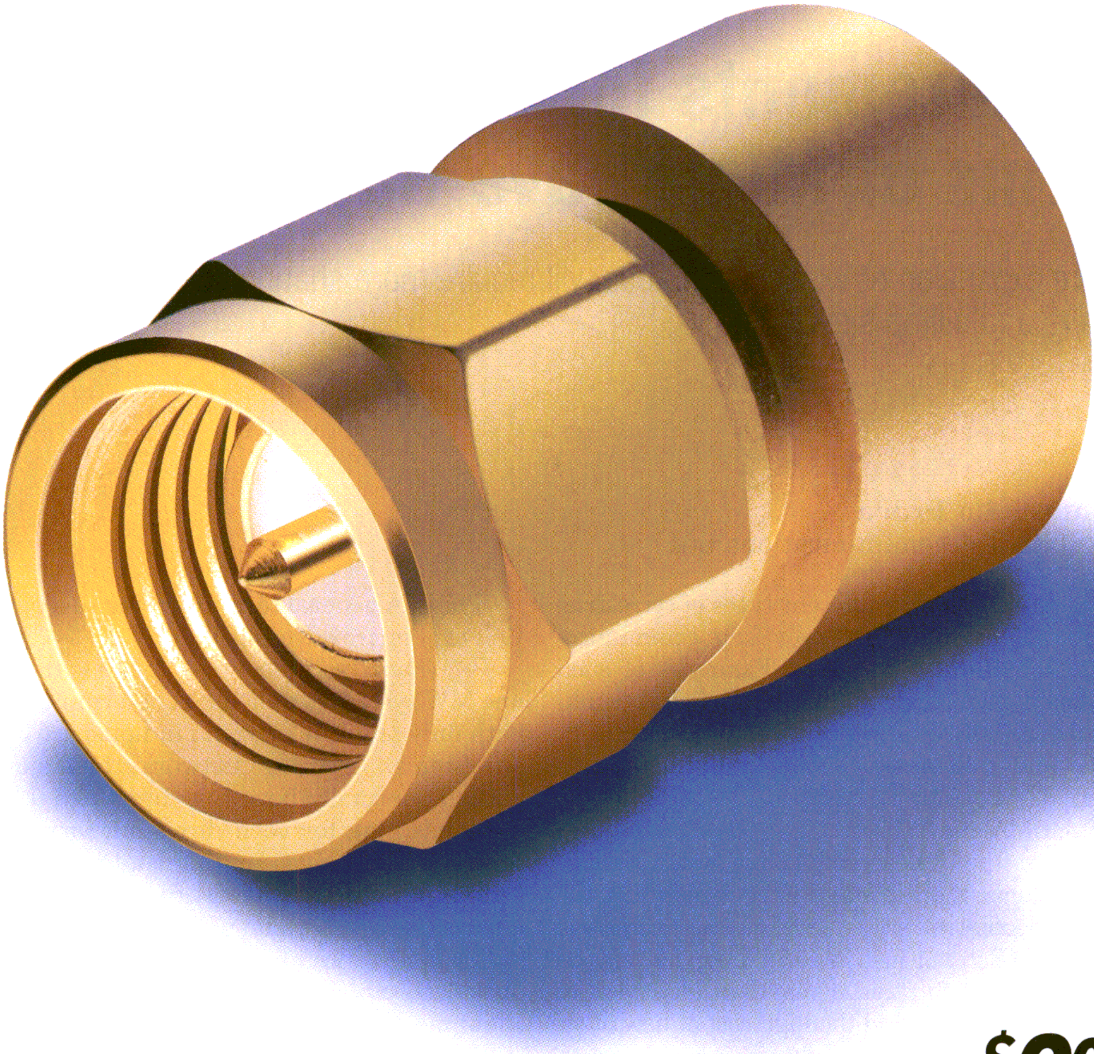
Holland Shielding Systems BV has been developing and manufacturing EMI shielding materials for 18 years. These materials vary from EMI shielding gaskets to shielding of military buildings, hospitals and air traffic control towers. The company focuses on cost-effective shielding methods with short delivery times, and manufactures according to customer specifications.

Holland Shielding's latest documentation about EMI shielding in Adobe Acrobat Reader can be downloaded from www.hollandshielding.com/doc.pdf.

For more information contact Holland Shielding Systems BV, P.O. Box 730, NL-3300 AS Dordrecht, The Netherlands; Tel: +31 78 6131366; Fax: +31 78 6149585; Internet: www.hollandshielding.com; E-mail: info@hollandshielding.com



▲ Figure 10. Compartments of a PCB.



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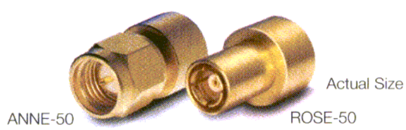

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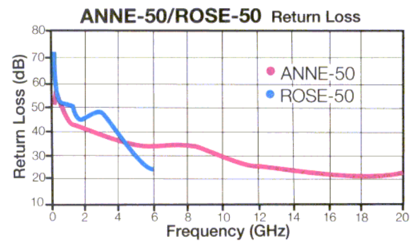

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Requirements for Sharing Sites in Terms of Microwave Radiolinks

Future expansion of wireless services will require more sharing of towers and hilltop sites

By Marcello Praca
NEXTEL Telecommunications Ltd.

Presently, many different types of terrestrial radio systems are providing communications directly to users. Examples of such systems include paging, analog and digital trunking such as iDEN™, two-way mobile radios, PCS, WLL, and cellular telephone systems such as NMT, TACS, AMPS, EAMPS, NAMPS, GSM, PHS, CDMA and TDMA.

Despite the widespread deployment of fiber optic systems, there is still a huge demand for the interconnection of sites using digital microwave radios (DMRs), not just in rural areas but also in cities. Reasons for this demand include lack of existing cable ducts and the high cost of new ones, the ease of installing radiolinks, their rapid deployment and expansion, high availability and the ease of routing reconfiguration. Considering these factors, interference is an issue becoming more important for microwave system engineers.

The necessity of sharing sites is expanding, mainly because of the high cost of the necessary infrastructure, such as poles or towers, supporting structures like masts, grounding, real estate renting, shelters, air conditioning, power supply and fire protection systems. However, when sharing sites it is essential to avoid harmful interference, not only on radio frequency (RF) systems but also on microwave (MW) radio systems.

This paper discusses some useful guidelines to prevent damaging interference among microwave radiolinks in order to guarantee maximum usage of towers and poles (in terms of the number of microwave parabolic dishes that can be installed in the same physical location at the same time).

Some useful definitions

Within the scope of this article, the following definitions will be useful:

Site — A general term referring to a base station or a microwave repeater.

PoP (Point of Presence) — A site with at least one MW system installed (i.e., a terminal station with only one MW antenna in nonspace diversity systems). In a large network, the majority of stations normally have two directions (i.e., two antennas, one for each direction, forward and reverse). Note that, in this context, the word "site" does not always refer to a PoP, since a PoP always has a MW radio while a site may have or not. For instance, a site can be linked via fiber optics, HDSL (High bit-rate Digital Subscriber Line) modem or even satellite.

Requesting company — the company that requests the microwave sharing of a PoP.

Requested company — the company that receives a request for sharing of a PoP.

Local end — the PoP to be shared

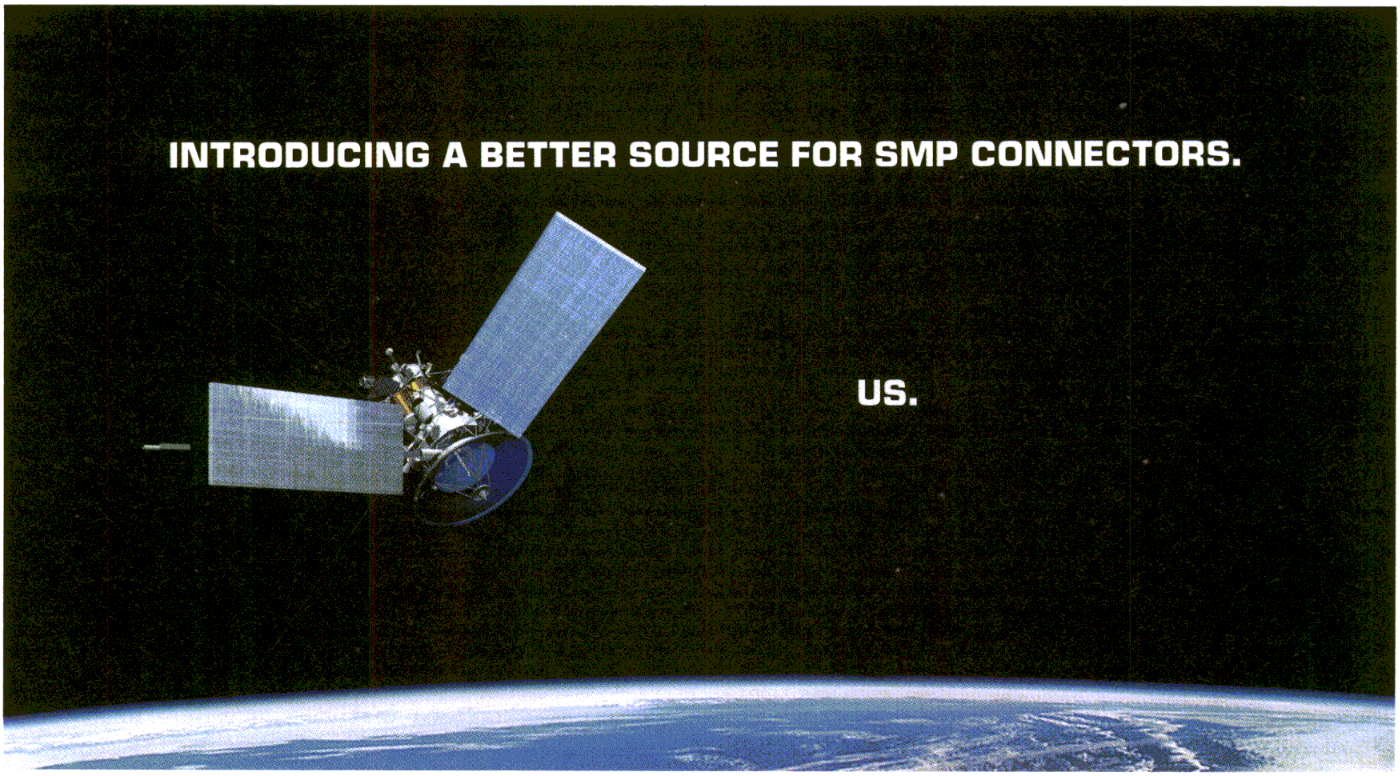
Remote end — the other PoP linked to the local end via one or more MW radio links.

Objectives and presupposition

The main objective of this article is to establish technical criteria for sharing sites from a microwave point of view. The guidelines are primarily oriented for the 15-, 18- and 23-GHz bands, as these are the most frequent bands used by cellular-type TELCOs when they are interconnecting sites by means of digital microwave radios.

However, the same methodology is also valid for other microwave frequency bands, including the 11- (SDH STM-1), 26- or 38-GHz bands. According to IEEE, waves between 30 GHz and 300 GHz are termed millimeter waves instead of microwaves.

As an essential presupposition, we will



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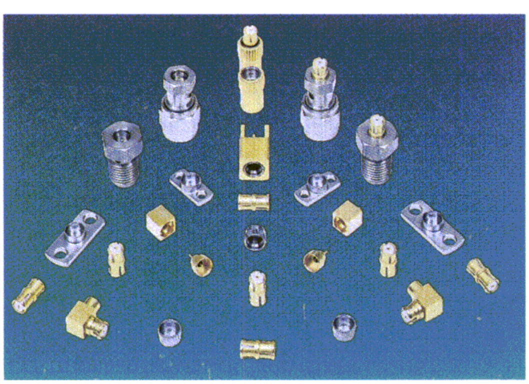

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assume the requested and/or requesting company has a versatile software package, able to perform accurate microwave interference, performance and availability calculations, with a specialized and well-skilled technical team as well as a superb radiolink and equipment database.

The main purpose of the study is to ensure that the installation of the requesting company's radiolink will not substantially degradate the existing radiolinks at the PoP and near it. The second purpose is to ensure that the requested company can authorize new sharings after this.

The allowed degradation casued by the new radiolink must be defined by the requested company according to its interference/availability criteria. Suppose we have an 18-GHz sharing. If the requested company has an objective of .02 percent of unavailability per annum per link (due to propagation only; mainly rain), this objective cannot be exceeded with the sharing addition. From the point of view of the requested company, the degradation caused by the new radiolink must keep all of the individual unavailabilities of all other radiolinks below the desired value (.02 percent per annum per link in this example). This is a sine qua non condition for the approval of the sharing. It is important to note that this condition is fundamental but not sufficient for the approval. Infrastructure and legal questions must always be taken into account.

Technical documentation

For each sharing, the requesting company always has two distinct possibilities. The first is to provide the complete microwave design for the link, proving to the requested company that microwave interference will be under acceptable limits. This is, of course, the preferable option, although it is a complex subject for most companies, due to lack of specialized personnel, design data and software.

The second possibility is that the requesting company sends all the technical information to the requested company, which then completes the frequency coordination. If frequency coordination is acceptable, sharing is feasible. Otherwise, some design modifications must be made in order to approve the sharing.

Notice that, in the second option, only the frequency coordination will be completed by the requested company (and, even so, between its own radiolinks and the shared radiolinks). Performance calculations and frequency coordination with other companies and systems (like satellites and radars) are always the responsibility of the radiolink owner.

For instance, radio-relay systems operating in the 6-GHz band may suffer interference from uplinks of C-band satellites, and radio-relay systems operating in the 4-GHz band may cause interference in downlinks of C-band satellites. Thus, the installation of radiolinks operating at 6 GHz or 4 GHz requires frequency coordination with C-band satellite systems.

In addition, it is the responsibility of the requesting company to suggest the antenna location (based on the determination of antenna heights and reflection points) and to investigate possible interference with existing flying fields and airports. It is possible, for example, that there is no physical space for a new antenna at the correct bearing and height on the tower.

For the second possibility, the requesting company must provide the following technical information and infrastructure data:

The remote end — The remote end must be provided with its name and full address.

The PoP to be shared — The PoP (local end) where the microwave sharing will occur must be provided.

The positioning coordinates of the remote end — The geographical (GEO) coordinates (latitude and longitude) are typically expressed in the sexagesimal form (i.e., degrees, minutes and seconds). Sometimes the requesting company presents its coordinates in UTM (Universal Transverse Mercator) format, or in values expressing north or east, for example. When the positioning coordinates are obtained from topographical charts, they are normally expressed in UTM format. Usually in this case, it is necessary to convert from UTM to GEO before inserting these values in the software package (the software typically works with latitude and longitude only).

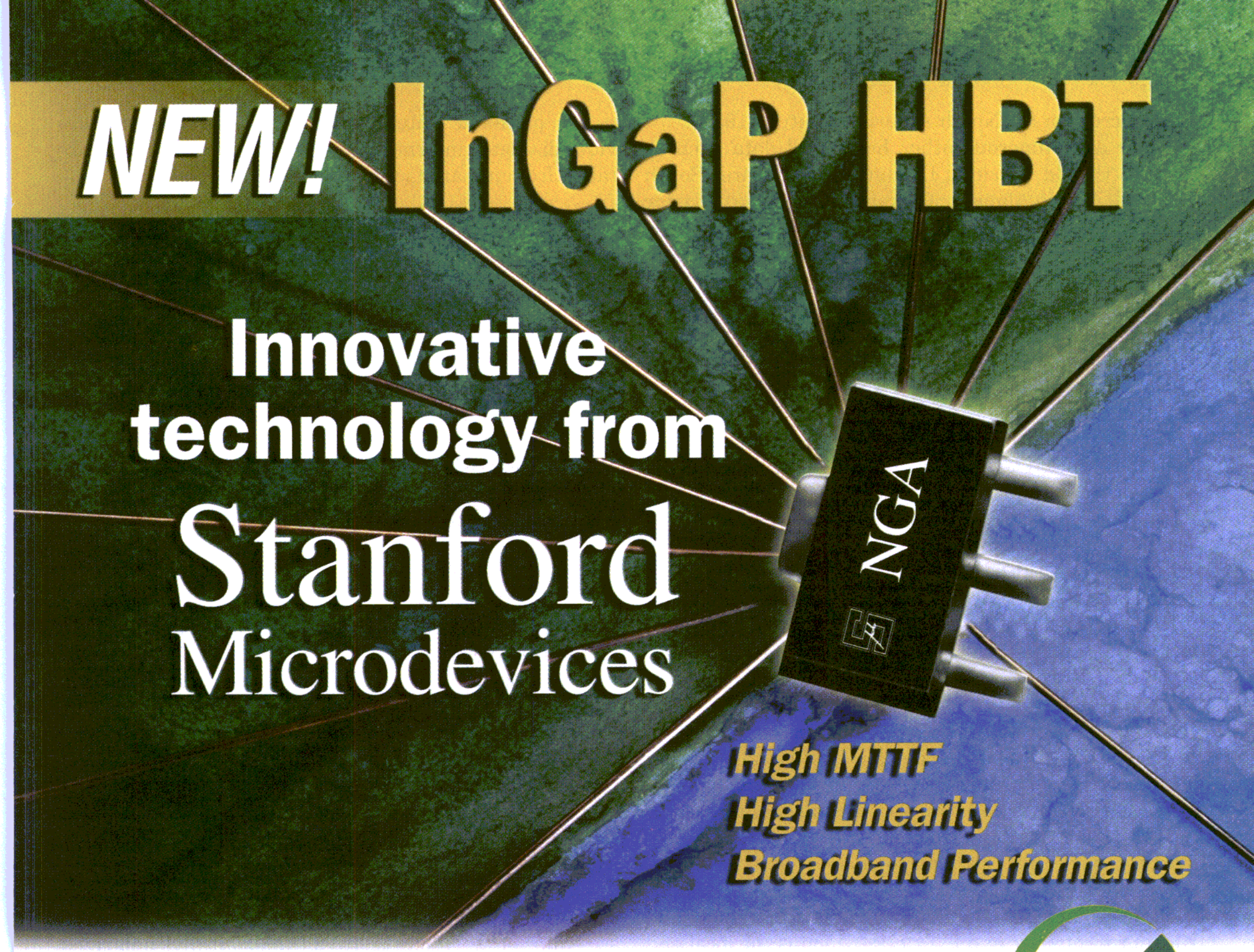
GEO		UTM
Latitude ($=\phi$)	$\Rightarrow$	Northing Value (=N)
Longitude ($=\lambda$)	$\Rightarrow$	Easting Value (=E)

The accuracy of the coordinates must be within 50 meters (±164 ft) of the exact, or ideal, location (with an error circle with a radius of 50 m). This is the minimum acceptable accuracy for positioning coordinates to be used for microwave frequency coordination. It is essential to be aware of the horizontal or planimetric reference datum (or HRD) since the geographical coordinates change when planimetric datum changes.

Geographical coordinates for a PoP may read, for example:

Site: Icarahy
Latitude = 22° 35' 23.6" S
Longitude = 45° 14' 10.2" WGr
HRD = SAD-69

where S stands for south (N for north) and WGr stands for west of Greenwich (EGr for East of Greenwich). SAD-69 is an acronym for South American Datum 1969 and is a widely-used horizontal datum for South America. In North America, we have for example, NAD



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P1dB (dBm)	17.5	19.0
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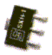

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83 (an acronym for North American Datum 1983).

There are numerous other horizontal data such as WGS-84 (World Geodetic Datum 1984), Yacare (South America), Tokyo (Japan), Djakarta (Indonesia), Easter Island (Pacific Ocean) and WGS-72 (World Geodetic Datum 1972). The right choice of the horizontal datum is crucial for good path calculations. We do not pay particular attention here to the positioning coordinates of the local end because they are obviously known by the requested company (after all, it is its own location).

Altitude and height (expressed in meters or feet) — Altitude is measured with reference to the mean sea level (MSL), and height is measured with reference to the soil or ground level. In this application, altitudes are known as AMSL (above mean sea level) and heights as AGL (above ground level). It is essential to inform the vertical or altimetric reference datum (or VRD) with the altitude since altitudes change when the vertical datum changes.

Height measures the vertical distance from antenna port to the ground. Presently, the official vertical datum adopted in Brazil is the tidal station of "Maregrafo de Imbituba" in Santa Catarina state, south Brazil.

Equipment configuration — Equipment configuration can be either fully non-protected (both transmitters, and receivers) or protected. There are several types of protection schemes and diversity arrangements, including (1+1) hot-standby, frequency diversity, quadruple diversity, space diversity, and so on.

Transmit frequencies (expressed in GHz) — Transmit frequencies include F Tx Rem, which is the remote end transmit frequency, and F Tx Loc, which is the local end transmit frequency.

Link polarization — The radiolink polarization must be of linear type, either horizontal (H-pol) or vertical (V-pol). Since V-pol is superior to H-pol (as a protection against rain effects), it is possible that the requested company will reserve V-pol, at the local end, for its own links. In the case of helical antennas (see next section) circular polarization appears (either left-hand or right-hand).

Antenna data — This includes model and manufacturer (e.g., VHP4-142 ANDREW); diameter (expressed in meters or feet); and mid-band gain (expressed in dBi or dBd).

Terrestrial microwave antenna systems use, in most cases, parabolic antennas (and, for this type of aerial, diameter is very useful). However, other types of antennas may be utilized like horns and, in the beginning of microwave frequencies, Yagis and helicals.

There is a theoretical controversy on the beginning of the microwave frequency band. Some authors claim that this occurs at 900 MHz, others at 500 MHz, 300 MHz (coinciding with the beginning of UHF band) and even at 3 GHz (the end of the UHF band or the beginning of the SHF band).

For parabolic antennas, the model frequently provides diameter information. The following examples are taken from a manufacturer's catalogue.

Model = UHX10-59W	d = 10 ft (or 3,0 m)
Model = KP8-25B	d = 8 ft (or 2,4 m)
Model = VHP1-570	d = 1 ft (or 0,3 m)

Normally, for microwave bands, antenna gains are measured in dBi (decibels over an isotropic radiator) and not in dBd (decibels over a half-wave dipole). The unit dBd occurs more frequently in VHF (Very-High Frequency) and UHF (Ultra-High Frequency) radio systems instead of SHF (Super-High Frequency) and EHF (Extremely-High Frequency). The relationship between the two units, dBi and dBd, is expressed as follows:

$$X\ (\mathrm{dBi}) = Y\ (\mathrm{dBd}) + 2.15$$

Other data such as the front-to-back ratio (FBR), half-power beamwidth angle (HPBW) and cross-polarization discrimination (XPD0) can be extracted directly from the RPEs diagrams (see the next section).

Radiation pattern envelopes (RPE) — Four RPEs are always needed when analyzing the behavior of microwave antennas: two parallel envelopes (named HH and VV) and two crossed envelopes (named HV and VH). RPEs must be sent in tabulated format as well as graphical format for checking. These acronyms mean:

- HH — The response of a horizontally polarized antenna port (H-port) to a horizontally polarized microwave radio signal.
- VV — The response of a vertically polarized antenna port (V-port) to a vertically polarized microwave radio signal.
- HV — The response of a horizontally-polarized antenna port to a vertically-polarized microwave radio signal.
- VH — The response of a vertically polarized antenna port to a horizontally polarized microwave radio signal.

Transmit output power (expressed in dBm) — It is always necessary to define the interface related to the transmit output power value (e.g., antenna port or radio port). Without this information, it is impossible to obtain the real gain/loss block diagram of the radio equipment.

If the radio includes a booster or a high power amplifier (HPA), this issue must be considered in the transmit output value. The same can be said for automatic transmitter power control (ATPC). In addition, if transmit output power can be reduced (e.g., –3 or –6 dB below its nominal value), one must also be aware of it to reduce interference levels to acceptable limits.

Bit rate (expressed in Mbit/s or megabits per second)— The most correct approach for bit rates is the use of the gross bit rate (GBR) or the aggregate bit rate (ABR). GBR is the final result of the bit rate after inserting the forward error correction (FEC), voice frequency channel, data channel and control/monitoring channel via the radio equipment.

Modulation scheme — We have, for example, O-QPSK (offset quadrature phase-shift keying), 16-QAM (16-states quadrature amplitude modulation), 32-QAM, 64-QAM, 128-QAM, 4-FSK (four-level frequency shift keying) or 4D-TCM (Four-Dimensional Trellis Coded Modulation).

Receive noise (expressed in dB) — Receive noise is measured at the receiver input port.

Receive thresholds for a 10E–3 and 10E–6 BER (expressed in dBm) — The receive threshold is the receive power level normally at the antenna interface (equal to antenna port) for a given BER (bit error rate). Receive thresholds depend on the equipment configuration and bit rate capacity. This is 2E1, 4E1, 8E1, 16E1 in CEPT hierarchy (Conférence Européenne des Administrations des Postes et des Télécommunications). Usually, we use the BER 10E–3 and 10E–6. Sometimes the receive threshold for a 10E-10 BER, or for other values somewhat close to this, is also provided.

Transmit spectrum mask (spectrum occupancy) — All filters and devices (circulators, isolators, transitions, elbows) must be right in the beginning of the waveguide (elliptical, circular or rectangular) or coaxial cable in lower frequencies. They must be provided in the form of a decibel versus frequency offset curve. The offset represents the positive or negative frequency offset from the carrier frequency (that is to say, $f_0 + \Delta f$ and $f_0 - \Delta f$), and is generally expressed in MHz. In terms of unwanted emissions (spurious and out-of-band), the equipment must meet the appropriate specifications (like, in the U.S., FCC Part 101 Section 101.111, emission limitations).

Receive frequency response from RF section to BB (baseband) section — The receive chain (RF + IF + BB) filtering is composed by three curves, namely the receive RF filter frequency response curve, the receive IF filter frequency response curve and the receive BB filter frequency response curve. All three curves show the filter response (in dB) versus the frequency offset (in MHz).

Attenuator (expressed in dB) — When a fixed in-line attenuator (pad) is used, it is mandatory to recognize whether the attenuator belongs to the transmit path only, to the receive path only or to both paths (transmit and receive one).

Additional Losses (expressed in dB) — Additional losses are divided into two parts. Both parts include the portion between the antenna interface and the radio interface. The antenna interface is located between the antenna and the transmitting line (waveguide or coaxial cable). The radio interface is located between the radio equipment and the transmitting line.

The antenna interface consists of the transmit path losses and the radio interface consists of the receive path losses. Depending on the situation, it is possible that there are some differences between these two losses. Overall additional losses are equal to the summation of losses in the transmission line, flex-twists (or jumpers for coaxial), hybrid devices, switches, circulators, isolators, straight sections, flange adapters, waveguide to coaxial adapters, taper transitions, 90 degree E-Plane and H-Plane elbows, power dividers and the radome.

Infrastructure data for microwave sharing

Supply of power — Power consumption depends on the equipment configuration. The best choice is the use of guaranteed maximum wattages for each unit and, as a direct consequence, for the radio equipment as a whole. The addition of protection schemes or diversity

arrangements, service channels, HPAs (boosters) and other optional electrical units, such as relay interface modules, increase radio power consumption.

Power supply main specifications include operating currents, DC input voltage range and polarity, when applicable (some equipment uses positive or negative ground). This is typical with the use of 48 VDC systems.

Circuit breakers are the responsibility of the requesting company. The number of breakers is a function of the radio configuration. Generally, one single indoor unit needs one breaker; two indoor units need two breakers. If available, the battery noise level mask must be provided, showing noise level in the vertical axis, in volts RMS (root mean square) versus noise frequency in the horizontal axis (in Hz).

It is a good engineering practice to install surge protectors on data/signal lines, telephone lines, coaxial lines and AC lines. It is mandatory that coaxial lines entering shelters or houses have their own protections (one per coax).

Commonly, we use gas tube surge protectors for microwaves by virtue of their low insertion loss, low VSWR (voltage standing wave ratio), easy installation and wideband behavior. Coaxes carrying signals between outdoor and indoor radio units operate not only in baseband, including DC for powering the outdoor unit, but also in intermediate frequencies like 70 or 140 MHz and even higher values.

This broadband behavior prohibits the use of quarter-wave stub protectors for microwave applications since they can not pass DC signals and their frequency bands are generally incompatible with those bands travelling across the IDU to the ODU coaxial.

Dimensions and weights for units, antennas, coaxes or waveguides — It is essential to have access to information on physical dimensions (height, width and depth) and weight, both for indoor (IDU) and outdoor (ODU) units. Sometimes ODU is known as a radio unit (or a radio frequency unit, RFU), and IDU is known as a signal unit (or a signal processing unit, SPU). Dimensions are generally expressed in millimeters (mm) or inches (in), and weights are expressed in kilograms (kg) or pounds (lb). At this point it is appropriate to say that, strictly speaking in terms of physics, mass and weight are different physical quantities (so, they are measured by different physical units, i.e., kilograms for mass and newtons for weight in the International System of Units — S.I.). In this case, we are speaking about mass, not weight, as mass is often confused with weight and vice-versa.

The two previously-mentioned

units are related by:

1 in = 25.4 mm (exact)

1 kg ≈ 2.2 lbm

where the suffix m (in lbm) stands for "mass," emphasizing its opposition to force (pound-mass instead of pound-force).

The requested company often limits the diameter of the parabolic dish in its own site in order to maximize physical space occupation and to reduce wind loading (in order to achieve this, a moulded radome may be needed). It is very rare but it is possible that there are restrictions on antenna paints, radome colors (gray, aviation orange and white) and radome types (moulded x planar).

Usually the largest acceptable diameter is 4 feet (or 1.2 meters). If an antenna with larger diameter (e.g., 8 ft/2.4 m or 10 ft/3.0 m) is needed, it must be installed in the remote end. The presence or absence of antenna shielding is also important since the overall physical dimensions and weight increase because of cylindrical shielding.

Some mechanical characteristics of the coaxial cable interconnecting IDU and ODU or waveguide are also important. They include dimensions over jacket or outer diameter (in millimeters or inches), distributed weight (in kgf/m or lbf/ft), and minimum bending radius (in millime-

Environmental requirements

1. Ambient Temperature Ranges (in °C or °F)
   1.1 Transportation and Storage
   1.2 Full Operational
   1.3 Operational but Degraded (e.g., presence of signal errors)
2. Percent Relative Humidity
   2.1 Operational
   2.2 Transportation
3. Altitude (above Mean Sea Level)
   3.1 Operational
   3.2 Transportation
4. Wind Effects
   4.1 Axial Force (= F_A)
   4.2 Side Force (= F^S)
   4.3 Twisting Moment (= M_T)
5. Hail and Snow
6. Ice Accumulation on Outdoor Parts
7. Aerial Pollutants and Particles
8. Dust and Sand Storms
9. General EMI (Electromagnetic Interference)
10. Lightning
11. Vibration
    11.1 Indoor (installed units)
    11.2 Transit (packaged units)
12. Shock (drop / bump)
    12.1 Transit
    12.2 Handling
13. Earthquakes

PN / 99-1

PRODUCT NEWS

INNOVATIVE NEW SIGNAL PROCESSING COMPONENTS

TRANSFORMERS • POWER SPLITTERS/COMBINERS • BIAS-TEES • ATTENUATORS

FREQUENCY MIXERS

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Applied MICROWAVE & WIRELESS

Editorial Calendar Update
November 1999 through June 2000

Issue	Ad Closing	Ad Materials	Technical Topics and Product Focus
Nov 1999	Oct 1, 1999	Oct 8, 1999	Regulatory update • Small-signal devices • Antenna technology
Dec 1999	Nov 1, 1999	Nov 8, 1999	System performance • Connectors • Low-cost techniques
Jan 2000	Dec 1, 1999	Dec 8, 1999	Oscillator design • EMC/EMI compliance • 3G technologies
Feb 2000	Jan 3, 2000	Jan 10, 2000	mm-Wave systems • CAD/CAE software • Mixers and modulators
Mar 2000	Feb 1, 2000	Feb 8, 2000	Filter design • miniaturized components • Satellite systems
Apr 2000	Mar 1, 2000	Mar 8, 2000	Frequency synthesis • Test equipment • Front-end RFICs
May 2000	Apr 3, 2000	Apr 10, 2000	Power transistor • Precision components • Digital signal processing
Jun 2000	May 1, 2000	May 8, 2000	Coax and waveguide • Broadcasting • Capacitors and Inductors

Applied Microwave & Wireless is published monthly, with a mailing date that typically provides delivery to U.S. readers within the first 10 days of the issue month.

Submissions of press releases for the New Products, Calendar and News sections must arrive two weeks prior to the ad closing date for the intended issue of publication. Technical articles, Guest Editorials and other feature materials require a longer lead time — please contact the editorial staff at the earliest possible date to propose these types of articles.

Advertising rates and materials specifications, reader profiles and additional information can be found at our web site: **www.amwireless.com** ters or inches).

For waveguides, the last specification is the minimum bending radius (E plane and H plane), with and without rebending. This waveguide is not the flex-twist section used in 15-, 18- or 23-GHz systems, but a waveguide for lower frequencies (e.g., 4, 5, 6, 7, 8 or 11 GHz), making the connection from the indoor branching to the outdoor antenna, generally by dozens of meters.

For coaxial cables interconnecting IDUs and ODUs (operating in intermediate frequency IF or baseband BB) the maximum acceptable length is vital information for the installation. Usually, the maximum length is about 300 meters (or 984 feet) due to electrical limitations of the coaxial cable.

Finally, coaxes or waveguides must be installed inside protection ducts (of iron or some polymeric material like polyvinyl chloride-PVC). When the environment is hazardous, due to presence of chemicals, explosive atmospheres, corrosive environments, risk of shock, or there are a lot of T1/E1 signals travelling across the line (such as STM-0 or STM-1), it is a good approach to seek physical protection. The duct can also act as an obstacle against vandalism, the influence of ultraviolet rays, water penetration and fire, thus preserving the cable(s) inside it.

Supplemental installation requirements — If an additional inside rack is needed, do not forget to inquire about rack size. Is the access necessary to the back and/or to the front of the equipment? This answer will determine, for example, the minimum distance from the wall to the back of the rack. Sometimes the IDU must be installed as a desktop unit instead of using a rack (this can occur when there is no physical space for a new rack unit and the existing ones are fully populated).

Be careful when installing rooftop mounts. There can be serious impermeabilization problems. A concrete base for the rooftop mast largely reduces this risk. Typically the mast is 2 meters high and its outer diameter is a function of the antenna dimensions and type (shielded versus unshielded, parabolic versus Yagi or helical, solid versus grid, radomized versus unradomized), as well as the associated hardware.

Table 1 shows common pipe outer diameters versus parabolic diameters for microwave antennas. The dimensions of the concrete bases are

Pipe Outer Diameter (inches)	Antenna Diameter (inches)
4	1.2 or 1.8
3 or 4	0.6
2, 2.4, 3 or 4	0.3

▲ **Table 1. Common pipe outer diameter versus parabolic diameters for microwave antennas.**

also a function of the antenna diameter and type.

Next to the outdoor unit, a 110/220 VAC shielded socket and an illumination lamp are very useful. Always have them, unless expressly forbidden.

Another issue is the pressurization system for waveguides. It demands physical space and electric power for the pressurization equipment (dehydrators, distribution panels, gas distribution manifolds, line monitors, extra tanks).

For pressurization equipment, there are basically two types of shelves: a wall shelf and a rack shelf. The wall shelf, of course, becomes attached to a wall and the rack shelf to a 19-inch rack. Sometimes, we use a floor stand for the dehydrator and the regulating tank.

It is important to remember to never attach a pressurization equipment directly to a radio-populated rack unless there is some kind of vibration attenuation scheme, since vibration reduces the lifespan of the electronic equipment.

Some additional technical remarks

If the radio uses FEC (forward error correction) and the FEC is enabled, it must be considered when informing receiving thresholds due to FEC coding gain. A controversial issue is the use of typical or guaranteed values when talking about receiving thresholds, noise figures, transmit output powers, wattages, and general losses. The recommended procedure is to provide both values for a full technical analysis.

When the design is completed by the requesting company, it is important to declare what kind of values were used in the calculations. Two calculations (the first one using typical values and the second one using guaranteed values) must be provided to ensure that there will be no problems with the sharing.

It is also important to clearly define the rules of working/accessing the local end in order to perform actions of operation and maintenance. These would include working hours, who is qualified to access, what kinds of jobs may be done without previous authorization, responsibilities of both parts, procedures in emergency situations, contact people and phones. ■

Author information

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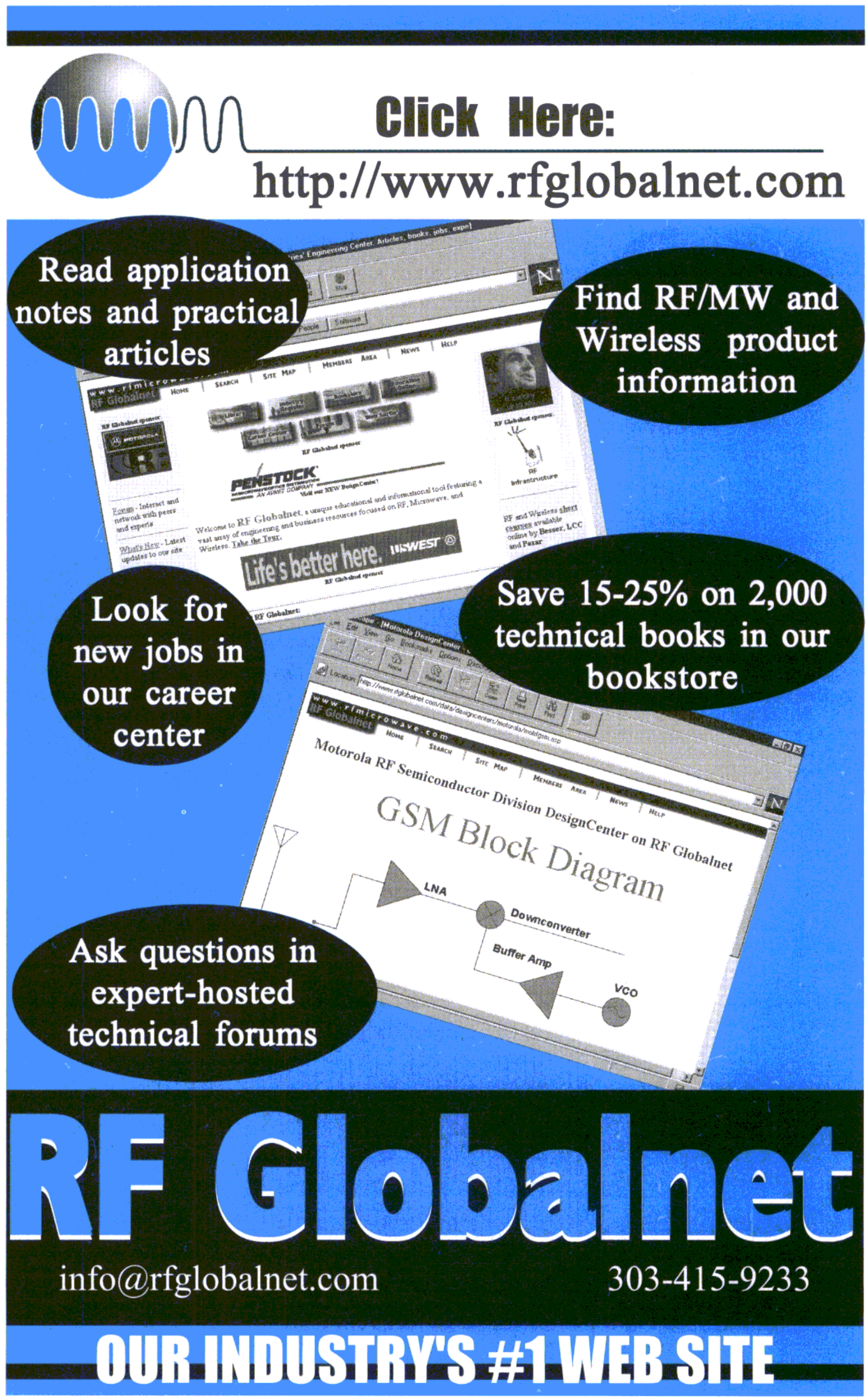
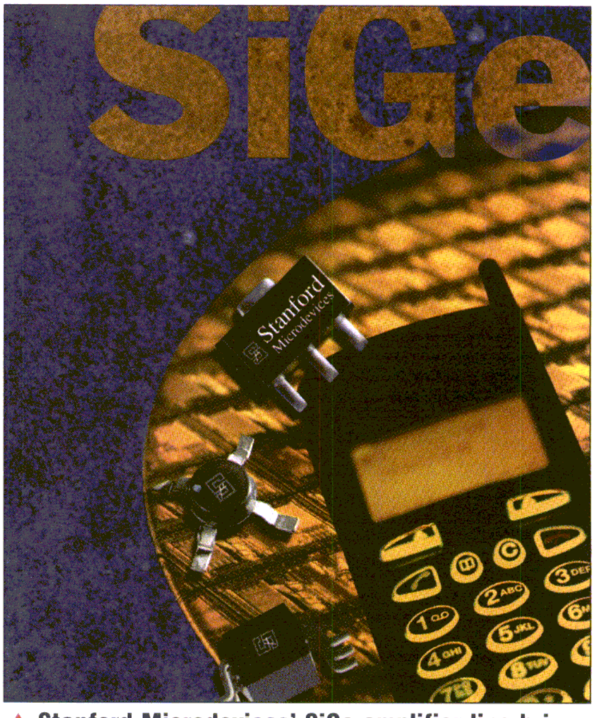


Silicon-Germanium ICs Offer Price and Performance Advantages

SiGe technology reaches mass-production with competitive pricing

Stanford Microdevices, Inc. recently announced the immediate availability of Silicon-Germanium process (SiGe) components for high volume wireless and other high frequency applications. The company's amplifier product line features high gain, high linearity at highly competitive market prices. The devices are packaged in industry-standard SOT363, SOT89, SOT23-5 and 85-mil diameter surface-mount types and are available from Stanford's distributors, including Richardson Electronics and Avnet Electronic Marketing.

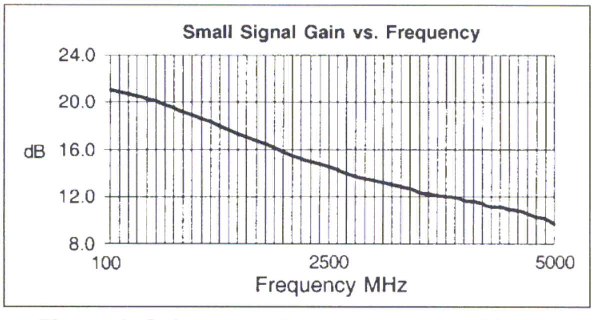
The high-volume, low-cost marketing experience of the company has been as asset in launching a new product line with immediate availability. A selection guide showing the available parts in the new SiGe amplifier line is shown on the following page.



▲ **Stanford Microdevices' SiGe amplifier line brings a new price/performance standard to market.**

Product example — the SGA-6486

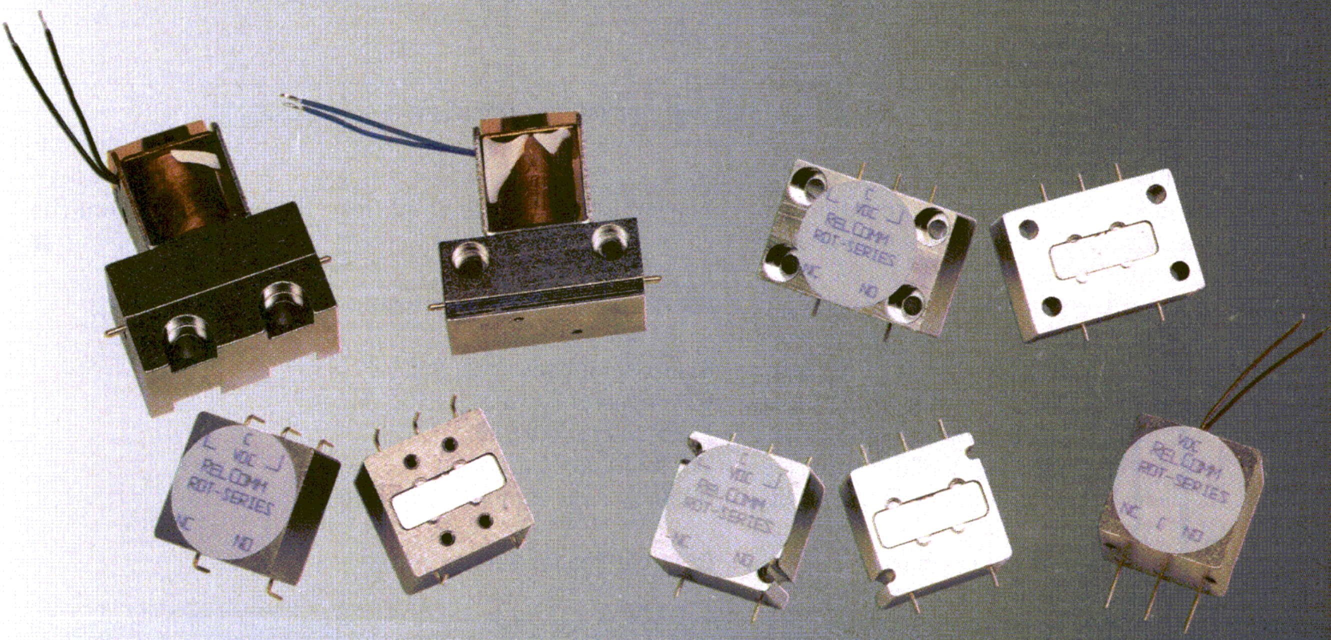
To illustrate the performance offered by the new line, we will examine one of the amplifiers at the upper end of the available power levels. The SGA-6486 is an 85-mil diameter "pill" packaged amplifier rated for +20 dBm power output (P_{1dB}) over DC-2400 MHz with a +5.2 volt supply. The third order output intercept (IP_3) is typically +34.8 dBm, indicating the part's good linearity performance.



▲ **Figure 1. Gain versus frequency for the SGA-6486 over 100 MHz to 5 GHz.**

The device features a SiGe Heterojunction Bipolar Transistor (HBT) process with 1 micron emitters and f_T up to 65 GHz.

Small-signal gain versus frequency is shown in Figure 1. Typical gain is 19.7 dB at 1000 MHz, 16.7 dB at 2000 MHz and, although outside the recommended operating range of the device, gain is 12.3 dB at 5 GHz. Input and output VSWR are 1.5:1 over the entire frequency

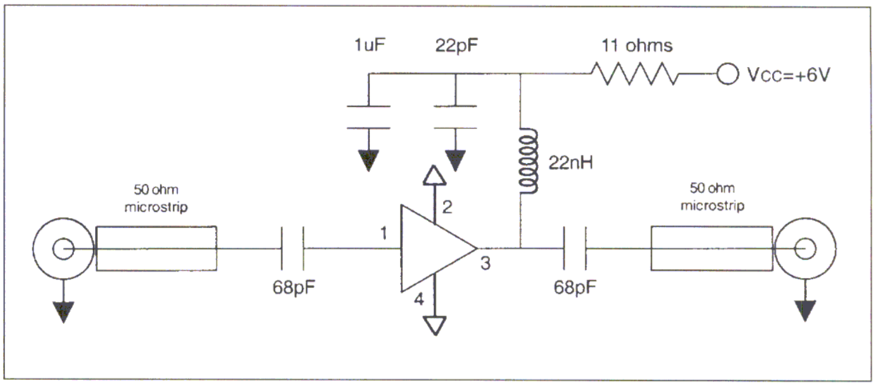


range. The SGA-6486 has a noise figure of 3.0 dB and draws 75 mA in a typical application circuit (Figure 2). Recommended bias resistor values are 11 ohms for the +6 volt supply shown, 31 ohms for a +7.5 volt supply, 51 ohms for +9 volts and 91 ohms for +12 volts.

The SGA-6486 uses a darlington pair topology with resistive feedback for broadband performance and stability over the entire rated temperature range of –40° to +85° C. The device is internally matched to 50 ohms, requiring only DC blocking capacitors and supply bypassing capacitors for operation. Typical applications for the SGA-6486 include buffer amplifiers for oscillators, final power amplifiers in low power applications, IF/RF buffer amplifiers and CATV drivers.

Other devices in the SiGe amplifier line provide output powers from –4.0 to +20.0 dBm, with devices operating from +2.2 volts to +5.2 volts. Third order intercept points are offered from +7.0 to +34.5 dBm. 1 GHz gain specifications range from 10.4 to 21.5 dB with 2 GHz gain from 10.2 to 19.4 dB. Eight of the nineteen models listed in the Selection Guide below feature noise figures below 3.0 dB.

For designers, complete *s*-parameter characterization is available for these amplifiers, downloadable from the company's web site.



▲ **Typical 1900 MHz application circuit for a +6 volt supply.**

For more information, contact:

Stanford Microdevices, Inc.
522 Almanor Avenue
Sunnyvale, CA 94086
Tel: 800-SMI-MMIC
Internet: www.stanfordmicro.com

Or circle Reader Service #200

Part Number	Vd (V)	Id (mA)	3dB BW	P1dB (dBm)	IP3 (dBm)	Gain@ 1 GHz	Gain@ 2 GHz	NF 50 Ohm	SOT-363	86	SOT-89	SOT-25	Features
SGA-11	4.5	12	DC-6.0	-4.0	+7.0	11.6	11.2	3.3	SGA-1163				S12 >45dB
SGA-12	2.6	10	DC-4.0	-5.0	+5.0	13.8	13.0	2.8	SGA-1263				S12 >45dB
SGA-21	2.2	20	DC-5.0	+7.0	+20.0	10.5	10.2	4.1	SGA-2163	SGA-2186			+/-0.3dB response to 3 GHz
SGA-22	2.2	20	DC-3.5	+7.0	+20.0	15.0	14.0	3.2	SGA-2263	SGA-2286			Can operate at 2V
SGA-23	2.7	20	DC-2.8	+7.0	+20.0	17.4	16.4	*2.9*	SGA-2363	SGA-2386			Excellent Noise Figure
SGA-24	2.7	20	DC-2.0	+7.0	+20.0	19.6	18.0	*2.5*	SGA-2463	SGA-2486			Excellent Noise Figure
SGA-32	2.7	35	DC-3.6	+12.0	+26.0	14.8	13.4	3.5	SGA-3263	SGA-3286			Flat response to 3 GHz
SGA-33	2.5	35	DC-3.6	+12.0	+25.0	17.4	16.2	3.0	SGA-3363	SGA-3386			>20% PAE
SGA-34	2.9	35	DC-2.0	+12.0	+25.0	21.5	19.4	*2.6*	SGA-3463	SGA-3486			Excellent Noise Figure
SGA-41	3.2	45	DC-6.0	+15.0	+29.0	10.4	10.2	4.6	SGA-4163	SGA-4186			+/-0.3dB response to 4 GHz
SGA-42	3.2	45	DC-3.5	+15.0	+29.0	13.8	12.6	3.3	SGA-4263	SGA-4286			>20% PAE
SGA-43	3.3	45	DC-2.5	+15.0	+29.0	17.0	15.2	*2.8*	SGA-4363	SGA-4386			Excellent Noise Figure
SGA-44	3.2	45	DC-2.0	+15.0	+29.0	19.0	16.8	*2.5*	SGA-4463	SGA-4486			Excellent Noise Figure
SGA-52	3.5	60	DC-4.0	+17.0	+30.0	13.5	12.7	4.1		SGA-5286	SGA-5289	SGA-5225	Flat response to 3 GHz
SGA-53	3.6	60	DC-3.2	+17.0	+31.0	17.3	16.0	3.5		SGA-5386	SGA-5389	SGA-5325	25% PAE, High TOIP
SGA-54	3.5	60	DC-2.4	+17.0	+31.0	19.7	18.0	2.8		SGA-5486	SGA-5489	SGA-5425	25% PAE, High TOIP
SGA-62	4.2	75	DC-3.5	+20.0	*+34.0*	13.8	12.4	3.9		SGA-6286	SGA-6289	SGA-6225	>30% PAE, High TOIP
SGA-63	5.0	80	DC-3.0	+20.0	*+34.5*	*15.4*	13.8	*3.8*		SGA-6386	SGA-6389	SGA-6325	High TOIP
SGA-64	5.2	75	DC-1.8	+20.0	*+34.0*	*19.7*	16.7	*2.9*		SGA-6486	SGA-6489	SGA-6425	High Gain, Good NF, High TOIP

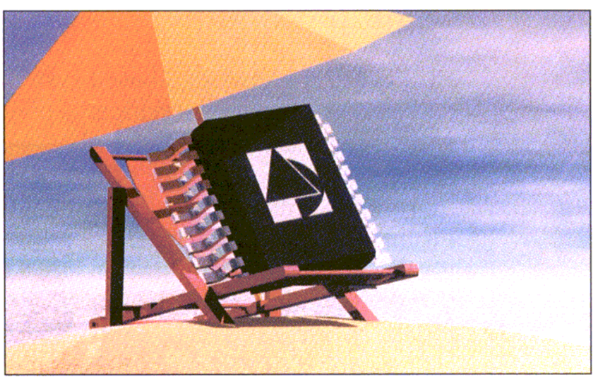
▲ **Selection guide for the SiGe amplifier product line.**

Product Focus — Devices Offered for Specific Modulation Formats

With new systems and upgrades to existing systems, wireless communications uses dozens of different modulation formats. It seems appropriate, then, to highlight a group of new products by their applicability to a specific modulation format or family of similar formats. Here are some of the latest products to be introduced that fit this category.

Synthesizer supports cable modem and set-top box applications

Anadigics' new ACS2301 is a dual-frequency synthesizer, manufactured using a CMOS process to provide maximum cost savings over more complex BiCMOS designs. The ACS2301

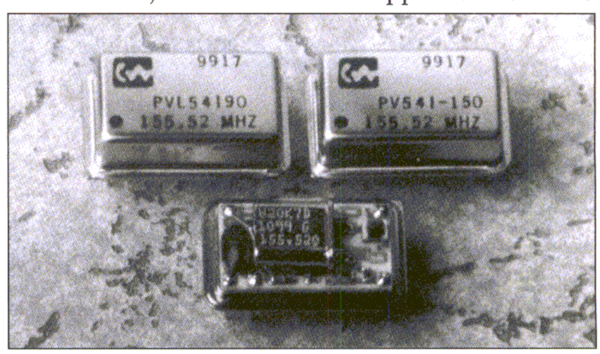


is equipped with two on-board voltage-controlled oscillators (VCOs) to handle two intermediate frequencies (IFs). The device has two fully programmable RF dividers that operate up to 1.1 GHz and 2.0 GHz respectively. The VCO output is divided down to a reference frequency and locked using a DC tuning voltage. The ACS2301 also has two on-chip dual modulus prescalers that divide by 64/65. The frequency of operation covers 400 MHz to 2.0 GHz. Manufactured by Taiwan Semiconductor Manufacturing Company Ltd., the IC is offered in a TSSOP-20 surface mount package. Pricing is less than $2.00 each in quantities of 10,000.

Anadigics
Circle #193

Low jitter VCXO meets SONET transmitter specifications

The new PVL541 series 3.3 volt VCXO from Connor-Winfield is designed to meet the stringent SONET chip manufacturer specifications for SONET, SDH and ATM applications. This



series of oscillators is suitable for the AMCC S3041 and S3043 OC-48 transmitter chips, with a total frequency tolerance of less than 20 ppm and jitter performance guaranteed to be less than 1 ps in the 12 kHz to 20 MHz band. This jitter performance is achieved by using a fundamental frequency source rather than a multiplier to reach the output frequency of 30 MHz to 155.52 MHz. For 5 volt applications, the PV541 series also performs with the same jitter specification. Packaging is a standard hermetically sealed, welded style with pins that match a 14-pin DIP layout.

Connor-Winfield Corporation
Circle #194


Your Choice!
Consider Synergy's full range of
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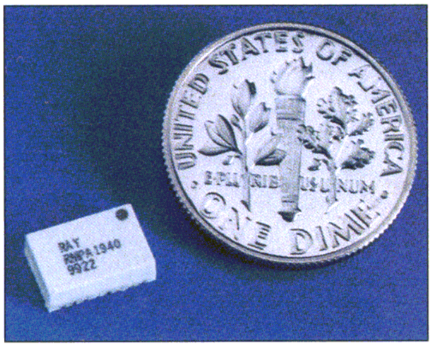
Circle 15

Dual-band power amplifier module supports three transmission modes

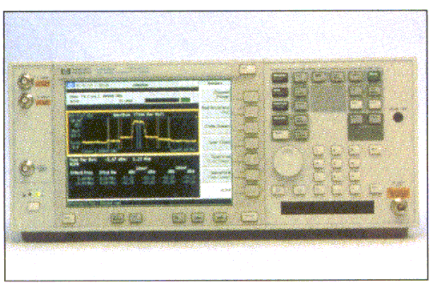
Raytheon's RMPA1940-73 is a 3.5 volt power amplifier containing two monolithic high efficiency power amplifiers for AMPS/CDMA dual-mode operation in the 824 to 849 MHz cellular band, plus PCS CDMA applications in the 1850 to 1910 MHz band. Each amplifier circuit uses a single ended configuration that uses harmonic tuning for increased efficiency and linearity. External output matching is required. In the cellular band, the RMPA1940-73 provides 30 dB small signal gain and 32 dBm power output. At 31.5 dBm output, the device exhibits 55 percent efficiency. At 28.5 dBm output, efficiency is 35 percent, with an ACPR of 46 dBc at ±900 KHz and 65 dBc at ±1.98 MHz. In the PCS band, small signal gain is 28 dB with 29 dBm minimum power output. ACPR at ±1.25 MHz is typically 49 dBc at the rated output power.



Raytheon Microelectronics
Circle #195

Transmitter tester offers third-generation formats

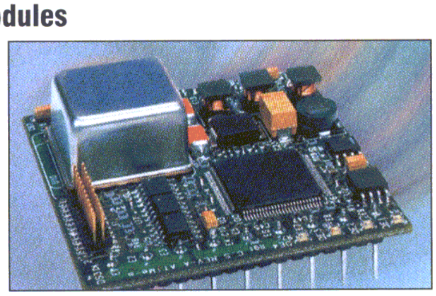
R&D engineers developing third generation (3G) wireless components are the intended users of the Hewlett-Packard HP E4406A VSA-series transmitter tester. The unit now offers standards-compliant, one-button testing for W-CDMA and cdma2000 products, along with previously-available cdmaOne, GSM, PDC and NADC formats. The basic E4406A transmitter tester is priced at $27,800. Option BAF for W-CDMA testing and Option B78 for cdma2000 are each $5,500.



Hewlett-Packard Company
Circle #196

Stratum 3 timing modules

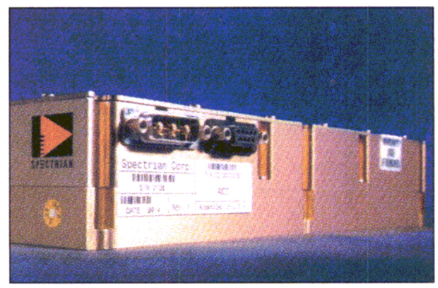
TF-Systems announces its Stratum 3 Timing Modules, offering an integrated clock subsystem and a single module synchronization solution meeting all timing, phase jitter and wander requirements. Applications include many high speed digital communication systems such as ATM, SONET, SDH, voice over IP PBX, giga- and tera-routers, Edge switches and add/drop multiplexers. The modules can be supplied with custom features like phase hit detection and multiple PLL time constants. They meet ETSI, Bellcore GR-1244-5.2 and SONET standards and are available in T1, E1, DS3 16.384 MHz, 19.44 MHz, 38.8 MHz and 77.76 MHz. The 2 × 2 inch module has 18 pins and fits a standard footprint.



TF-Systems
Circle #197

W-CDMA power amplifier for IMT-2000

Spectrian Corporation introduces a new W-CDMA broadband single carrier amplifier for IMT-2000 equipment. The amplifier covers 2.11 to 2.17 GHz with 25 watts power output for this data-intensive 5 MHz bandwidth system. The amplifier can be supplied in standard rack systems with up to four 25 watt amplifiers per shelf.



Spectrian Corporation
Circle #198

Noise and interference emulator extends range for new systems and standards

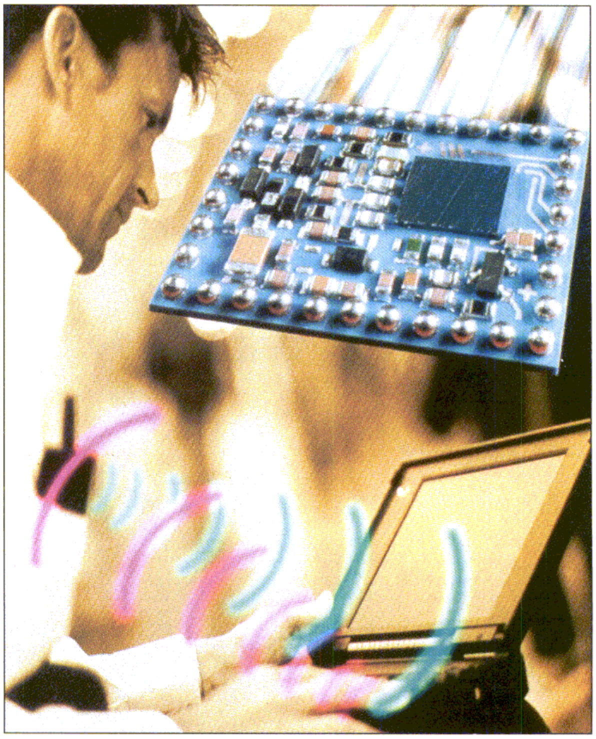
Telecom Analysis Systems (TAS) now offers the 4600AH Noise and Interference Emulator. For this model, TAS has extended the RF carrier frequency range to 2.5 GHz to cover PCS, IMT-2000 and 2.4 GHz ISM applications. The 4600AH is an integrated test instrument for performing accurate carrier-to-noise and carrier-to-interference tests. By extending the frequency range, the 4600AH accommodates precision C/N characterization for wireless devices such as PCS handsets and base stations, mobile satellite handsets, wireless local loop, wireless LAN, smart antenna systems and 2.4 GHz transceivers. The unit accurately measures the power of an incoming signal, then adds the specified amount of noise (AWGN) or interference to obtain a specified C/N or C/I ratio.

Telecom Analysis Systems, Inc.
Circle #199

Bluetooth Radio Transceiver and Development Kit are now Available

Ericsson Microelectronics offers a Bluetooth Development Kit, enabling early adopters of the Bluetooth technology to build applications with reduced development time. The development kit, designed by Ericsson in cooperation with Symbionics, consists of a toolbox of equipment that provides a complete and flexible design environment for engineers to integrate Bluetooth technology into information appliances. It demonstrates the core features of Bluetooth, allowing developers to focus on core competencies rather than learning the new technology from scratch.

Priced at $15,500, the Bluetooth Development Kit contains two boards, each with a complete Bluetooth radio, for effective end-to-end testing of application software. Documentation includes information from a novice's introduction to wireless connectivity to a comprehensive description of the Bluetooth Packet structure, link types and protocols.



▲ **Ericsson announces products for 2.4 GHz Bluetooth wireless systems.**

Modular radio transceiver

Ericsson also announces the availability of the PBA31301/2, a short range radio transceiver operating in the 2.4 to 2.5 GHz ISM band. This radio supports Bluetooth communications applications in portable equipment such as mobile phones and laptop computers. To achieve a complete wireless link, the radio requires the addition of an antenna, a 13 MHz reference and a baseband control circuit (such as the Ericsson Bluetooth Baseband), flash memory, a host computer and application software.

The PBA31301/2 allows digital system designers to create effective wireless data links simply and quickly. The module is a compact 34 Ceramic Ball Grid Array package that requires no external RF shielding. RF power output is 1 mW for communications up to 10 meters. ■

For more information, contact:

Ericsson Microelectronics
Tel: 877-ERICMIC (877-374-2642)
Outside the U.S.: +46 8 757 5000
Internet: www.ericsson.com/microe

Or circle Reader Service #201

"Last Mile" Connections are Provided by mm-Wave Broadband System

Radiant Networks plc has developed a new mesh architecture to provide cost-effective "last mile" connections between trunk networks and subscribers. This broadband fixed wireless access system operates in the 28 to 40 GHz range and can deliver up to 25 Mbps full duplex connections to subscribers with near 100 percent coverage.

Line of sight problems are overcome by routing around obstacles using an Internet-style mesh configuration based on intelligent nodes with small roof-mounted directional antennas. Each node transmits to and receives from other nodes, with multiple paths available for each customer. If one path fails, service is not interrupted. Internode paths are ATM paths, and the nodes act as small ATM switches.

A further benefit of the mesh structure is that it uses spectrum up to 50 times more efficiently than point-to-multipoint. Narrow radio beams provide the links between nodes, allowing increased frequency re-use.

The system is targeted at SME applications where there is increased traffic demand for wide bandwidth applications like videoconferencing and multimedia. Radiant's system is also designed for the residential market, where it is capable for handling video-on-demand and interactive television, as well as Internet access, e-commerce and telephony services.

For the network operator, Radiant calculates that its mesh would incur as little as 15 percent initial infrastructure investment compared to an equivalent point-to-multipoint system. It eliminates the need for costly base stations and towers that may be deemed unsightly. The system is scalable and can grow based on demand.

▲ **Radiant Networks is developing a commercial 28 to 40 GHz system based on an Internet-like mesh architecture.**

Design work aimed at practical implementation has been underway for nearly two years. A demonstration network has been built, which is successfully operating at 40 GHz with full-system data rates. Trials of commercial equipment will begin shortly. Initial applications are expected to be in US 28 GHz local microwave distribution systems, although the technology is also suited for other bands.

For more information, contact:

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2-Way	3000 W	0.1 dB
2-Way	6000 W	0.25 dB
4-Way	1000 W	0.2 dB
4-Way	7000 W	0.3 dB

20 - 500 MHz

Type	Power Level(s)	Insertion Loss
2-Way	100 and 500 W	0.4 dB
2-Way	1500 W	0.5 dB
4-Way	100, 500 and 750 W	0.7 dB

20 - 100 MHz

Type	Power Level(s)	Insertion Loss
2-Way	200, 500, and 1500 W	0.3 dB
4-Way	400 W	0.4 dB
4-Way	3000 and 7000 W	0.3 dB

100 - 1000 MHz

Type	Power Level(s)	Insertion Loss
2-Way	300 W	0.5 dB
4-Way	100 W	0.6 dB
4-Way	250 and 400 W	0.8 dB

Note: All units are isolated and withstand at least one input failure at rated power.

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High Power Combiners
10 kHz - 2.4 GHz

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Circle 41

High Frequency Fundamental Crystals Extend Range to 200 MHz

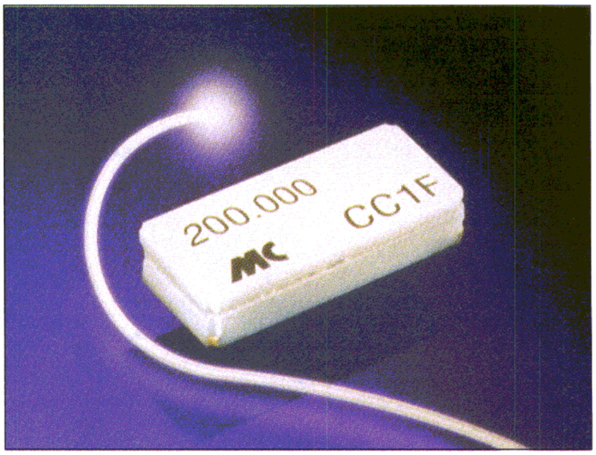
Micro Crystal has extended the frequency range of its high frequency fundamental (HFF) crystals to 200 MHz. The crystals are AT-cut quartz resonators using inverted-mesa construction. The CC1F (ceramic lid package) is suitable for the latest high speed communication systems that require high frequency references, including fiber optic telecommunications, gigabit Ethernet, 10baseT and frame relay applications.

Micro Crystal's inverted mesa processing technologies were improved to extend the frequency range from a previous high of 160 MHz up to 200 MHz. In response to industry demand, the CC1F is available in large quantities at a commercially attractive cost. The crystal fits applications where low jitter and high pullability are required.

The CC1F is offered in a frequency range of 30 MHz to 200 MHz. The crystal resonators are very rugged, due to single ended mounting and encapsulation in a hermetically sealed SMD ceramic package with dimensions of 8.1 × 3.8 × 1.8 mm.

- **Low power dissipation**
- **Stability over temperature range**
- **High shock and vibration resistance**
- **Low spurious modes**
- **Large pulling range**
- **Tight jitter performance**
- **Excellent phase noise**
- **Operating temperature of –40 to +85°C industrial or –55 to +125°C military**

▲ Key features of the CC1F crystals.



▲ Micro Crystal has increased the frequency range of its high frequency fundamental crystal resonators from 160 MHz up to 200 MHz.

The CC1F high frequency crystals are available from stock to eight weeks, depending on frequency and quantity. For 1,000 pieces of a CC1F 100 MHz, ±30 ppm crystal, the cost is $6.30 each. Complete technical data and application notes are available as well as application engineering support.

For more information, contact:

Micro Crystal
601 Campus Drive
Suite B4
Arlington Heights, IL 60004
Tel: 847-818-9825
Fax: 847-818-9915
Internet: www.microcrystal.com

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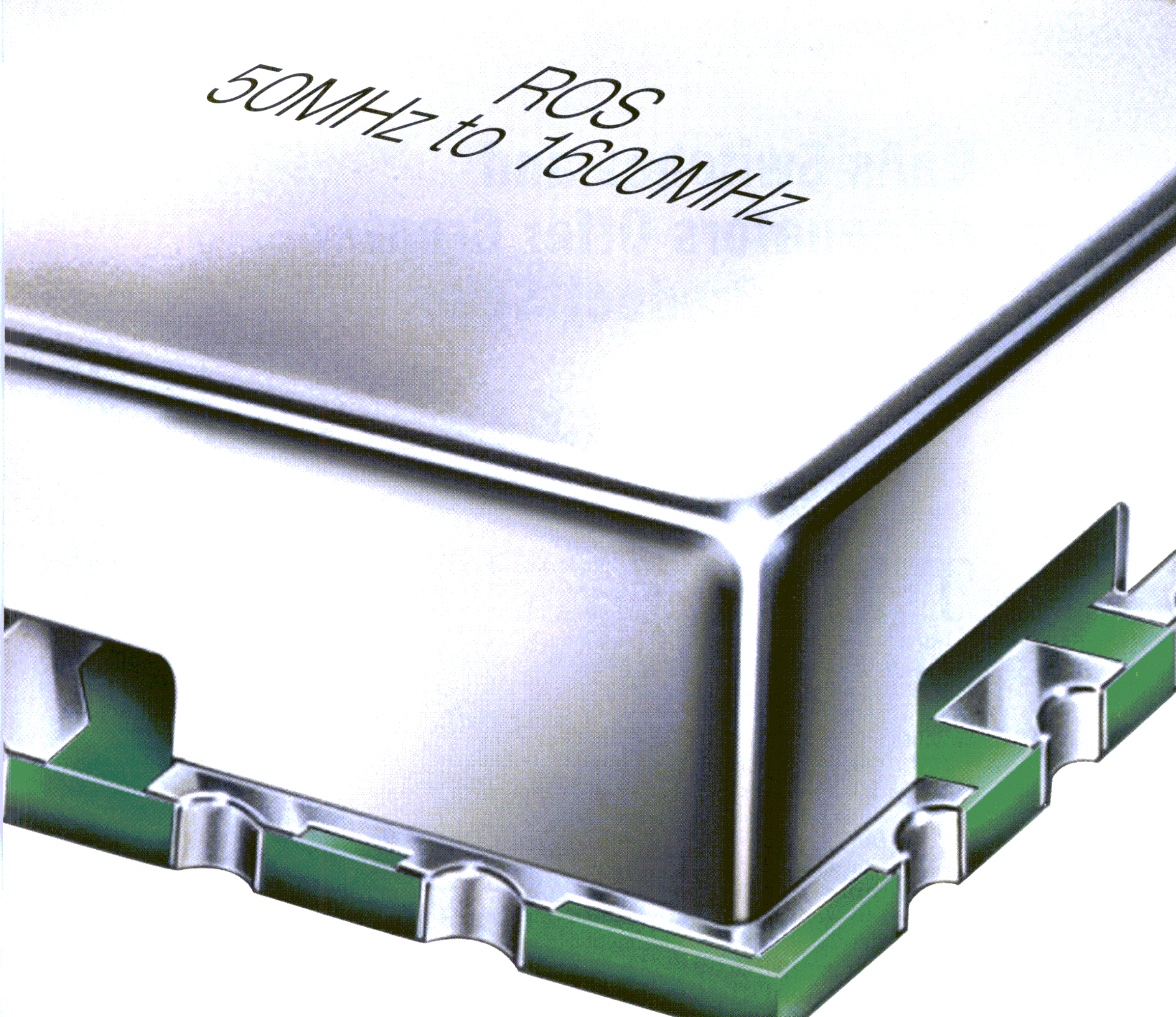
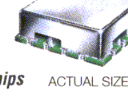


MINIATURE SURFACE MOUNT VCO's from $12.95 (qty. 5-49)

The big news is Mini-Circuits miniature family of ***50 to 1600MHz*** ROS voltage controlled oscillators! Each unit is housed in a shielded 0.5"x0.5"x0.18" non-hermetic industry standard package for highly efficient wash-thru capability, reliability, and cost effectiveness. Models with "PV" suffix typically operate from a 5 volt power supply and require 5V tuning voltage to cover the frequency range. This makes them ideal for integration with monolithic PLL chips and commercial synthesizers working within the 245 to 1600MHz band. The series also features wide band 12V models optimized for 50 to 1410MHz linear tuning, up to one octave band widths, and low phase noise. Support your customers demands for smaller size and better performance, switch to ROS VCO's today!



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ROS-900PV	810-900	5	-102	-25	4.5	12	19.95
ROS-960PV	890-960	5	-102	-27	5	12	19.95
ROS-1000PV	900-1000	5	-104	-33	5	22	19.95
ROS-1600PV	1520-1600	5	-100	-26	5	25	18.95
ROS-100	50-100	17	-105	-30	12	20	12.95
ROS-150	75-150	18	-103	-23	12	20	12.95
ROS-200	100-200	17	-105	-30	12	20	12.95
ROS-300	150-280	16	-102	-28	12	20	14.95
ROS-400	200-380	17	-100	-24	12	20	14.95
ROS-535	300-525	17	-98	-20	12	20	14.95
ROS-765	485-765	16	-95	-27	12	22	15.95
ROS-1410	850-1410	11	-99	-8	12	25	19.95

*Phase Noise: SSB at 10kHz offset, dBc/Hz. **Specified to fourth.

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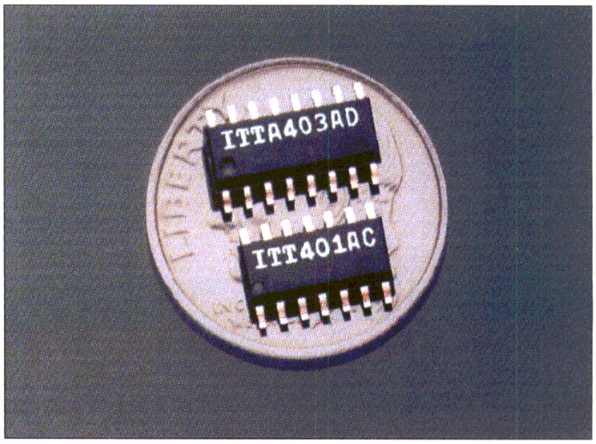
GaAs Switches and Attenuators Offer Greater Control Product Selection

The GaAsTEK Division of ITT Industries has announced a series of new GaAs switches and attenuators, adding to its growing line of control products. These products may be used in wireless handsets, LANs, base stations and other wireless applications.



Switches

ITT501AJ — An SPDT high power T/R switch with 1 dB compression point at +35 dBm and a 5 volt supply, in an MSOP-8 package.

ITT801AN — An SP8T switch with direct 3:8 line TTL control logic and a single +8 volt supply, in a narrow-body SSOP-24 package.

ITT401AC — An SP4T switch with on-chip 2:4 line decoder, low power consumption and non-reflective ports, in an SSOP-24 package.

ITT140AK — An SPDT reflective switch with +3 to +5 volt control, 0.5 dB insertion loss and 1 dB compression at +30 dBm, in an SOT-6.

ITTS107AB — An SPDT reflective switch with +3 to +5 volt control, 0.5 dB loss at 1 GHz and 1 dB compression of +30 dBm, in an SO-8.

ITTS159AB — A –5 volt high isolation SPST reflective switch usable from 0 to 5.0 GHz, with 49 dB isolation at 1 GHz, in an SO-8 package.

ITTS250AB — A –3 to –5 volt high isolation SPDT reflective switch usable from o to 3.5 GHz with 40 dB isolation at 1 GHz and 1 dB compression at +26 dBm, in an SO-8 package.

ITTS402AH — An SP4T 3 volt non-reflective switch with positive control voltage, featuring low power consumption, in a QSOP-28 package.

Attenuators

ITTA402AC — A 4-bit digital attenuator and integral driver with 1, 2, 4 and 8 dB bit sizes for 15 dB attenuation range in 1 dB steps. It can be used from 0 to 2.5 GHz with maximum power handling of +24 dBm. Packaged in an SO-14.

ITTA403AD — A dual control 4-bit digital attenuator with a 15 dB range in 1 dB steps, provided in an SO-16 package.

ITTA503AD — A 5-bit digital attenuator featuring a 15.5 dB attenuation range in 0.5 dB steps. It is usable from 0 to 2.5 GHz and is provided in an SO-16 package.

ITTA504AE — A 5-bit digital attenuator with a 31 dB attenuation range in 1 dB steps. It is usable from 0 to 2.5 GHz and is provided in an SSOP-20 package. ■

For more information, contact:

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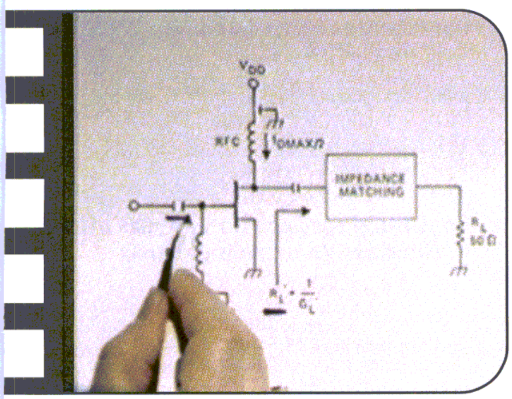
NP-16 . . . . $595.00



RF/Microwave Transistor Amplifier Design
Instructor: Les Besser

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Circle 106

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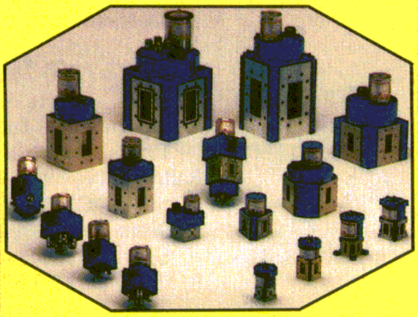

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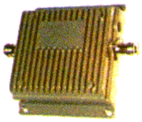

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*30W Power Tx BPF
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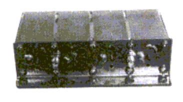

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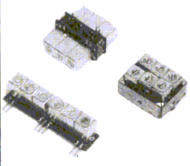

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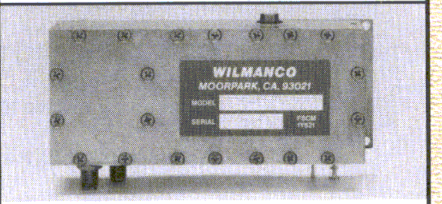
MINIATURE CRYSTAL CONTROLLED BLOCK DOWN CONVERTER



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We have a partnership with the Institute of Semiconductor Physics (IHP), which has 10 years' experience in SiGe processes and is the leader in SiGe:C HBT process development. The HBT process is optimized for low parasitics (deep trench isolation and optimized profiles), and offers an efficient signal isolation scheme. The process in development is CMOS with 0.25 μm L_{eff}.

Motorola has chosen this particular process because it allows simpler processing, using 22 to 27 masks rather than typical 35 mask processes. Its ability to use industry standard epitaxy equipment is an advantage, and it provides a good tradeoff between uniformity and productivity. The SiGe:C process slows down the Boron diffusion and provides better control of the base profile, better reproducibility, a higher early voltage and higher base doping, leading to a lower noise figure. The f_T is tailored for low current operation.

SiGe alone does not enable extra integration of active devices, but it does offer better performance and design flexibility, especially for higher frequency RF front end functions. Signal isolation improvement and the ability to integrate high performance passive devices are believed to be the real enablers for higher levels of integration.

The Motorola RF/IF Division message

With the changing wireless marketplace, and with changes in business organization (such as the separation of the SCG group), Motorola has a renewed focus on RF integrated circuits and transistors. The strength of several different semiconductor processes makes it possible to craft a solution for a wide range of new wireless communications requirements.

Custom solutions for large customers is a key element of our message. That customer may be another Motorola division that manufactures wireless products, or it may be any other company with requirements for low cost, high volume, low power ICs, with the right level of performance. Standard products also will be developed for a wide range of "building block" RF/IF functions. We hope that this review of the capabilties of Motorola's RF/IF Division will plug the "information gap" that has grown over the past few years. ■

Olivier Lauvray is the Technology Manager for the RF/IF Division in Motorola's Semiconductor Products Sector. He received an engineering degree in electronics and microwaves from the Ecole Nationale de l'Avaiation Civile in Toulouse, France, in 1989. He began his career in the French Goverment Agency for Promotion and Research and joined Motorola-France in 1990 as a device engineer for bipolar and SMARTMOSTM products. Since 1995, he has worked in the Motorola R&D and business groups in Phoenix, AZ.

The Guest Editorial column in *Applied Microwave & Wireless* features commentary, industry observations, and informed opinions from industry leaders and other interested parties involved in microwave, RF and wireless technology. We welcome contributions for future columns; suggestions for editorials should be sent to the Publisher, *Applied Microwave & Wireless*, 4772 Stone Dr., Tucker, GA 30084; Tel: 770-908-2320; Fax: 770-939-0157; E-mail: amw@amwireless.com

Restoring the Visibility of Motorola's RF/IF Technology

By Olivier Lauvray
Motorola RF/IF Division

We at the RF/IF Division of Motorola Semiconductor want to do a better job of publicizing our product and technology capabilities to show how we are addressing the widely varied needs of the wireless marketplace. We would like to share some of our plans in these areas with you.

The products provided by the RF/IF Division are used in a wide variety of wireless applications such as cordless phones, cellular phones, pagers, mobile radios, laptop computers, wireless data links, security and positioning systems and even garage door openers. Specific functions of our devices include: RF front end ICs such as upconverters, downconverters and power amplifiers; RF building blocks including amplifiers and mixers; RF/IF subsystems ICs for cordless phones, receivers and transmitters; miscellaneous functions such as ADCs and DACs and encoders; plus frequency synthesis ICs including PLL synthesizers, prescalers, voltage-controlled oscillators and phase-frequency detectors. We also offer low power discrete transistors.

Our sister division, the Wireless Infrastructure Systems Division (WISD), provides RF power discrete transistors for wireless base station applications. The RF/IF Division is expanding its focus on the merchant market, which is why we need to become more open with our strategic technology and product plans.

Products use multiple process technologies

Simply put, we are not selling a technology, we are selling product solutions. We have a broad portfolio of semiconductor technologies (process, test and packaging) to offer our wireless customers. This wide range of processes allows us to apply the best fit in cost/performance tradeoffs for many different solutions.

Currently, we have four core processes: GaAs, Advanced BiCMOS, RF LDMOS and SMARTMOS™. A new SiGe:C (silicon-germanium-carbon) version of RF BiCMOS is being developed in conjunction with the Institute for Semiconductor Physics (IHP) in Frankfurt, Germany. The four current process are all used in products for both Motorola internal designs and for the merchant market. With SiGe:C technology, we expect to increase our design-in wins in the wireless market.

GaAs — This process is primarily used for power amplifiers which require high output power at low voltages with high gain, linearity and efficiency. We now have MESFET and pHEMT (depletion mode, enhancement mode and zero V_{TH}), and the HBT process will be on line in early 2000.

RF BiCMOS — High level integration for transceiver subsystems is the primary application area for BiCMOS. These products demand low power dissipation at low voltages, with integration of mixed signal functions on a single chip. In addition, it allows integration of high performance resistors, inductors and capacitors. Presently, Motorola's RF BiCMOS has a qualified 0.25 μm L_{eff} process, with 0.15 μm to be ready in the third quarter of 2000. The present process has 15-20 GHz and 24-35 GHz f_T and offers 5 percent resistors and capacitors, plus inductors with Qs of 20.

RF LDMOS — The LDMOS process is used by the RF/IF Division mainly for low voltage, high frequency transistors. 3.6 volt 1 GHz devices are available now, with 2 GHz devices coming very soon. The power LDMOS devices from WISD are now available up to 120 watts at 2 GHz, operating at 26 volts. 50 volt devices up to 300 watts at 1 GHz are scheduled in early 2000.

SMARTMOS — This process is a cost-effective medium voltage BiCMOS that is ideal for power management, audio, digital control and power amplifier control functions in handheld equipment. A 65 volt, 1.2 μm process is in use, as well as 10, 18 and 65 volt, 0.8 μm. In the first quarter of 2000, our 7 to 65 volt, 0.35 μm process will be qualified. Products to be introduced soon include power/audio management ICs, which can be provided with a CODEC.

SiGe:C — The silicon-germanium process being developed by Motorola will be most cost-effective for use in RF front end building blocks such as 5.0 to 6.0 GHz ISM and NII band applications. Exploratory work is underway for HBT power amplifiers using this process. The HBT process will be qualified in the second quarter of 2000, offering 50 to 70 GHz f_T. Engineering prototypes will be evaluated before the end of 1999.

More on SiGe:C

Motorola's RF BiCMOS processes focus on passive performance: high Q copper conductors, high linearity capacitors and high density isolated capacitors. Accuracy of these devices is another key area of emphasis.

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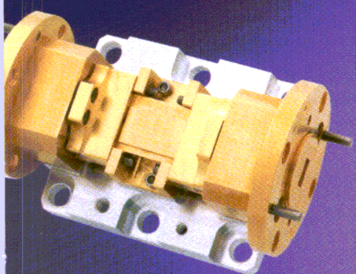
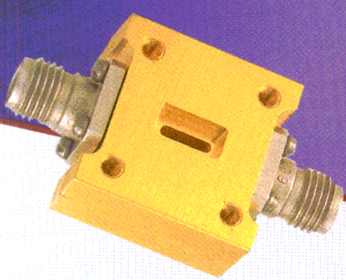
MILLIMETER WAVE COMPONENTS
AMPLIFIERS • MIXERS • MULTIPLIERS



AMPLIFIERS

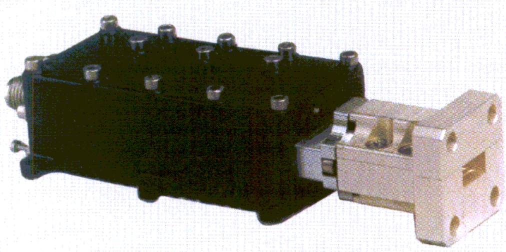
Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	I/O VSWR (Max.)	Output Power at 1dB Comp.* (dBm, Typ.)
JSW4-18002600-18-5A	18-26	28	1.0	1.8	2.0:1/2.0:1	5
JSW4-26004000-25-5A	26-40	25	2.5	2.5	2.0:1/2.0:1	5
JSW4-18004000-32-8A	18-40	21	2.0	3.2	2.0:1/2.5:1	8
JSW4-30005000-45-5A	30-50	21	2.5	4.5	2.5:1/2.5:1	5
JSW4-40006000-65-0A	40-60	16	2.5	6.5	2.5:1/2.5:1	0

* Higher output power options available



MIXER/CONVERTER PRODUCTS

Model Number	Frequency (GHz)			Conversion Gain/Loss (dB, Typ.)	Noise Figure (dB, Typ.)	Image Rejection (dB, Typ.)	LO-RF Isolation (dB, Typ.)
	RF	LO	IF				
LNB-1826-30	18-26	Internal	2-10	42	2.5	20	45
LNB-2640-40	26-40	Internal	2-16	42	3.5	20	45
ARE3436LC1	34-36	15.5-16.5	2.7-3.3	25	4	20	60
SBW3337LG2	33-37	33-37	DC-4	-7.5	8	N/A	25
TB0440LW1	4-40	4-42	.5-20	-10	10.5	N/A	20
DB0440LW1	4-40	4-40	DC-2	-9	9.5	N/A	25
SBE0440LW1	4-40	2-20	DC-1.5	-10	10.5	N/A	20



MULTIPLIERS

Model Number	Frequency (GHz)		Input Level (dBm, min.)	Output Power* (dBm, min.)	Fundamental Feed Through Level (dBc, min.)	DC current @+15VDC (mA, nom.)
	Input	Output				
MAX2M260400	13-20	26-40	10	12	18	160
MAX2M200380	10-19	20-38	6	14	18	200
MAX2M300500	15-25	30-50	10	8	18	160
MAX4M400480	10-12	40-48	10	8	18	250
MAX3M300300	10	30	10	10	60	160
MAX2M360500	18-25	36-50	10	8	18	160
MAX2M200400	10-20	20-40	10	10	18	160
TD0040LA2	2-20	4-40	10	-3	30	N/A

* Higher output power options available

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Mil-Spec RG-213	.405	40	12.0
Mil-Spec RG-393	.390	60	11.0
LMR® 300	**.300**	**90**	**9.2**
LMR® 240	**.240**	**90**	**11.5**
LMR® 200	**.195**	**90**	**15.0**
LMR® 195	**.195**	**90**	**17.0**
Mil-Spec RG-58	.195	40	25.0
Mil-Spec RG-142	.195	60	23.0
LMR® 100A	**.103**	**90**	**35.0**
Mil-Spec RG-174	.100	40	43.0
Mil-Spec RG-316	.103	40	41.0

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