July 2001

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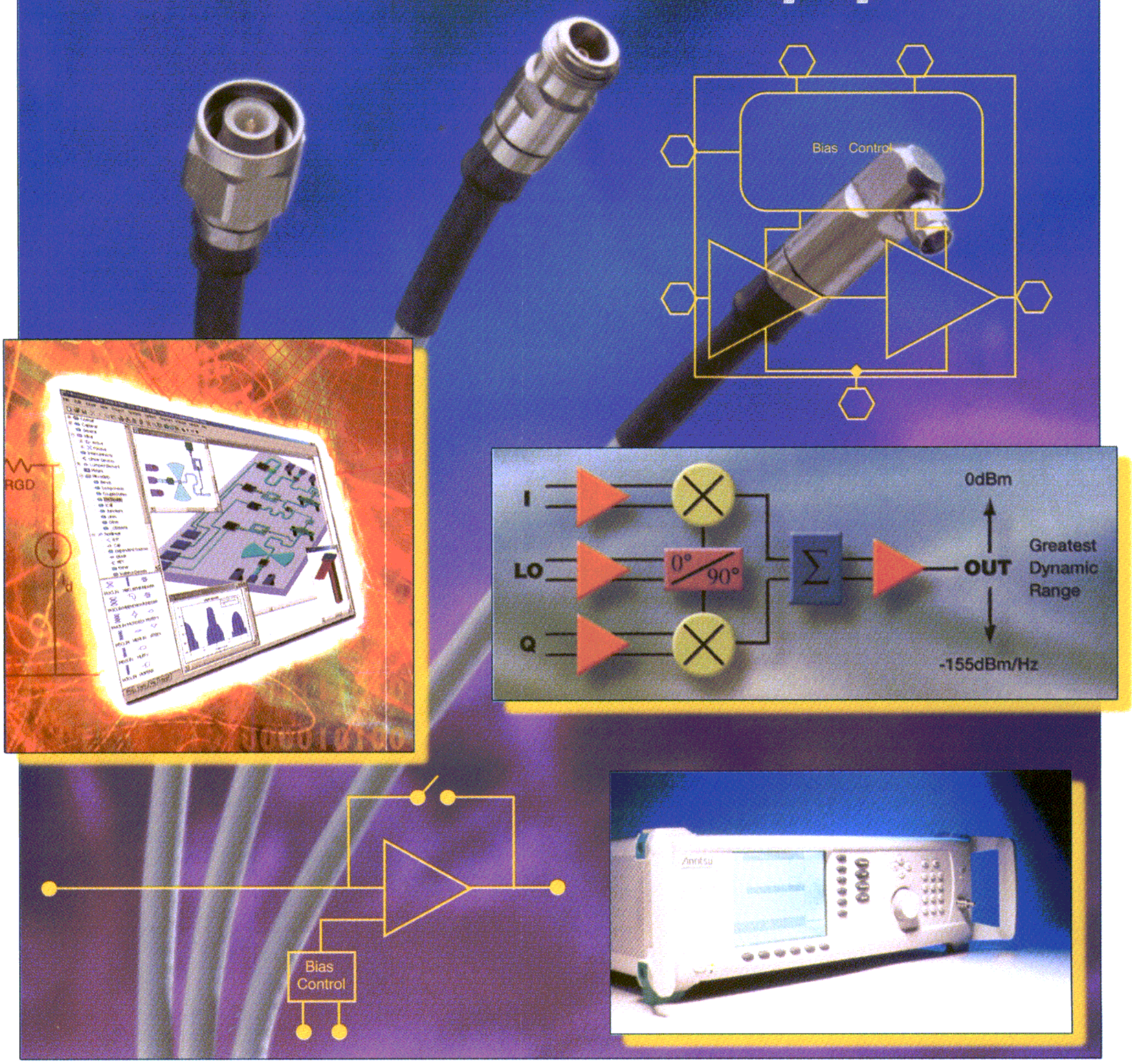

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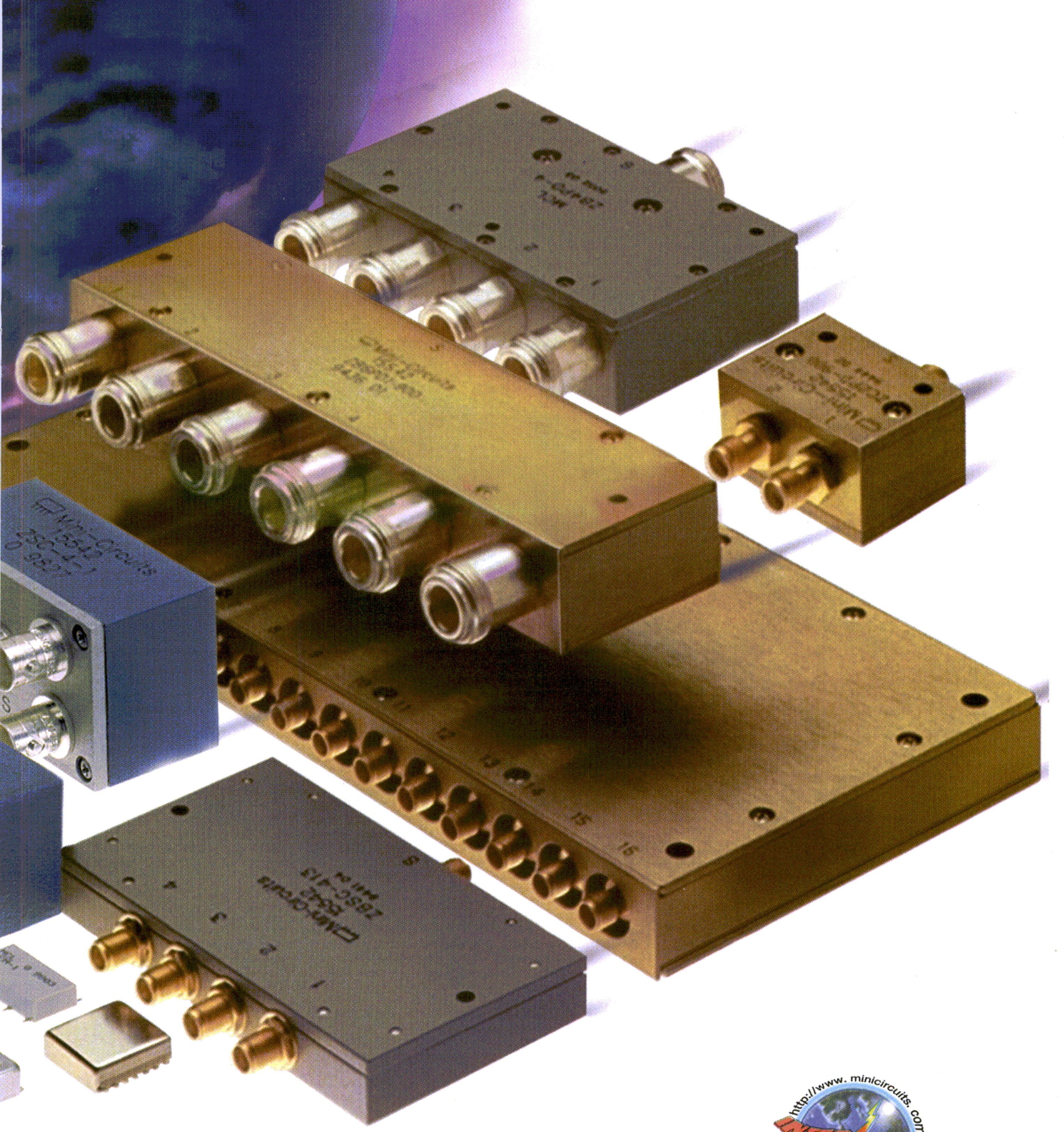

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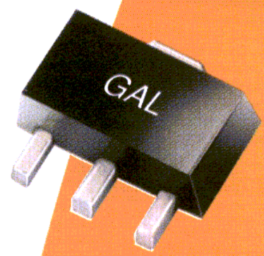

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GAL-1	DC-8000	12.7	11.8	±0.5	12.2	4.5	27	108	40	3.4	.99
GAL-21	DC-8000	14.3	13.1	±0.6	12.6	4.0	27	128	40	3.5	.99
GAL-2	DC-8000	16.2	14.8	±0.7	12.9	4.6	27	101	40	3.5	.99
GAL-33	DC-4000	19.3	17.5	±0.9	13.4	3.9	28	110	40	4.3	.99
GAL-3	DC-3000	22.4	19.1	±1.7	12.5	3.5	25	127	35	3.3	.99
GAL-6	DC-4000	12.2	11.8	±0.3	18.2	4.5	36	93	70	5.2	1.49
GAL-4	DC-4000	14.4	13.5	±0.5	17.5	4.0	34	93	65	4.6	1.49
GAL-51	DC-4000	18.1	16.1	±1.0	18.0	3.5	35	78	65	4.5	1.49
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Applied MICROWAVE & WIRELESS

July 2001
Vol. 13 No. 7

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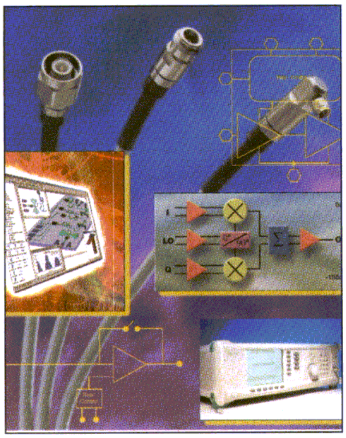

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On Our Cover

Products Unveiled at 2001 International Microwave Symposium

Product introductions at the annual IEEE MTT-S show included design software, test instruments, cable assemblies, amplifiers, modulators and more.

Artwork courtesy Applied Wave Research, Semflex Inc., Anritsu Company, Analog Devices, Motorola Semiconductor Products Sector and Anadigics Inc.

TECHNICAL FEATURES

Applied MICROWAVE & WIRELESS

July 2001
Vol. 13 No. 7

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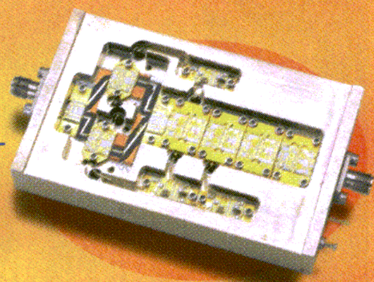
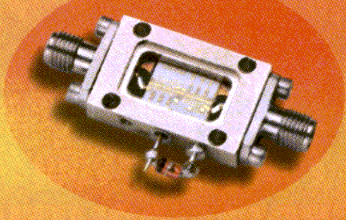
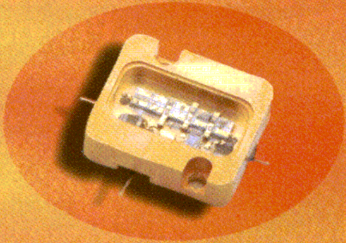
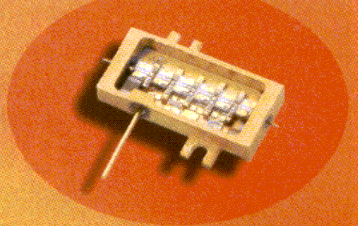
JCA12-P01	1.0-2.0	32	3	1	30	40	2.0:1	800
JCA34-P01	3.7-4.2	30	3	1	30	40	2.0:1	750
JCA56-P01	5.9-6.4	30	3	1	30	40	2.0:1	850
JCA78-P01	7.9-8.4	30	4	1	30	40	2.0:1	900
JCA812-P02	8.3-11.7	40	5	1.5	33	40	2.0:1	1700
JCA910-P01	9.5-10.0	30	4	1	33	40	2.0:1	1300
JCA1011-P01	10.7-11.7	30	4	1	30	40	2.0:1	950
JCA1819-P01	18.1-18.6	30	5	1	27	37	2.0:1	800
RADAR & COMMUNICATION BAND LOW NOISE AMPLIFIERS								
JCA23-302	2.2-2.3	30	0.8	0.5	10	20	2.0:1	80
JCA34-301	3.7-4.2	30	1	0.5	10	20	2.0:1	80
JCA56-502	5.4-5.9	50	1	0.5	10	20	2.0:1	160
JCA78-305	7.25-7.75	27	1.2	0.5	13	23	2.0:1	100
JCA910-305	9.0-9.5	27	1.4	0.5	13	23	1.5:1	150
JCA1112-305	11.7-12.2	27	1.5	0.5	13	23	1.5:1	150
JCA1415-305	14.0-14.5	26	1.6	0.5	13	23	1.5:1	160
JCA1819-305	18.1-18.6	22	2.0	0.5	10	20	1.5:1	160
JCA2021-600	20.2-21.2	30	2.2	1	13	23	1.5:1	240
TRI-BAND AMPLIFIERS (5.85 TO 14.5)								
JCA514-201	5.85-14.5	8	7	1.5	10	20	2.0:1	100
JCA514-300	5.85-14.5	14	6	1.5	10	20	2.0:1	150
JCA514-302	5.85-14.5	22	6	1.5	20	30	2.0:1	350
JCA514-400	5.85-14.5	25	6	1.5	10	20	2.0:1	250
JCA514-403	5.85-14.5	32	6	1.5	23	33	2.0:1	500
JCA514-501	5.85-14.5	35	6	1.5	16	26	2.0:1	375
JCA514-503	5.85-14.5	41	6	1.5	23	33	2.0:1	500
ULTRA-BROAD BAND AMPLIFIERS (2.0 TO 18 GHZ)								
JCA218-200	2.0-18.0	15	5	2.5	10	20	2.0:1	90
JCA218-300	2.0-18.0	23	5	2.5	10	20	2.0:1	110
JCA218-400	2.0-18.0	29	5	2.5	10	20	2.0:1	150
JCA218-500	2.0-18.0	39	5	2.5	10	20	2.0:1	180









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Circle 49

Editorial

Wireless Technology In Daily Life

By Gary A. Breed
Publisher

When interviewing prospective new employees, talking with business associates, or just telling friends what my job is about, I often need to explain what readers of *Applied Microwave & Wirleless* do in their jobs. Recently, one of people subjected to my rambling explanation expressed surprise at how many ways wireless technology was used in daily life. So I decided to analyze my own use of wireless in a typical day.

My first wireless uses are opening the garage door with a 318 MHz remote control, starting my pickup truck and hearing Morning Edition on the local National Public Radio FM station, which gets its programming via satellite link. Most people are two steps ahead of me, because I use a simple alarm clock instead of a clock radio, and I don't watch TV in the morning.

As I drive to work, I may see the Gwinnett County Police monitoring traffic with radar. The radio station's traffic report relies on wireless links from helicopter reporters and wireless phone reports from drivers. Many busy highway segments are monitored by cameras that use wireless links to transmit the images to the traffic control center.

At the office, there's a mix of wireless activity. The UPS and Fedex morning deliveries and afternoon pickups send reports back to their main offices through their wireless terminals. Other office visitors have a wide assortment of wireless phones, two-way radios and pagers. Some have found our office using GPS-based navigation systems. During the day, at least a few of our long distance telephone calls and faxes are relayed by satellite link.

Out of the office, I might make a couple calls on my wireless phone at lunch time. The drive-through at a nearby fast food place gives the employees a chance to use their 900 MHz wireless headsets on my behalf. My FM radio is now tuned to the local classic rock music station.

On the way home after work, a quick stop for a few items at a convenience store finds a microwave motion sensor on the automatic door and a clerk taking inventory using a handheld wireless terminal. Later, I'll make calls using a 2.4 GHz cordless phone and may watch something on TV.

These are just a few daily uses of wireless technology. If my day involved cross-country travel or some other activity out of the routine, I'd have an even longer list of wireless experiences! ■

Comments in support of wireless data standards

Editor,

As one actively designing 802.11 radios, I just had to comment on Gary Breed's editorial, "Are Standards Really Needed for Wireless Data Applications?" (*Applied Microwave & Wireless*, April 2001).

We all know in the engineering field that real world designs, more often than not, involve complex parameter tradeoffs. As such, there is usually "more than one way to skin a cat." It is therefore natural and, in fact, healthy that the IEEE 802.11 group has such discussions! This process may outwardly seem slow (and perhaps "contentious," per the opinion expressed in your editorial); however, it ensures that the adopted protocol meets its goal of flawless transfer of data over real (make that imperfect) radio channels. We have also put in place a world class certification authority guaranteeing the complete interoperability of all IEEE 802.11 products.

Since IEEE 802.11 has been around substantially longer the Bluetooth, I'd also like to point out the uphill battle that we had to endure in order to sell the non-RF world on wireless data. Most of the non-RF world (make that the vast majority of the human race) views radio as some form of (unreliable) black magic with maybe a bit of science thrown in to confuse everyone. Let's be honest with ourselves - we as a radio community have not always been successful demonstrating how reliable radio can be! Kudos, therefore, to both our 802.11 team of protocol/modulation experts and to our substantial marketing talent in proving to the Computer and MODEM community that 802.11 delivers its promises and that they can be comfortable deploying it in mass production.

At this time there are millions of 802.11 chipsets out there routinely performing data transfers at true Ethernet speed. I must confess that I tend to get very blasé walking around our campus from meeting to meeting with my little 802.11-equipped wireless laptop, surfing the net, keeping minutes, etc., and almost never ponder the considerable technical achievement of flawless Access Point communications that 802.11 provides. Now let's turn our attention to Bluetooth: I've been reading about its potential for several years now. Correct me if I'm wrong, but I'm not aware of any really mass deployment of Bluetooth technology to date. Also, let's admit that Bluetooth was never really intended for networking utilizing infrastructure devices such as Access Points. It was really only designed for relatively low data rate transfers over short distances, such as downloading a file from a laptop to a printer. As such, it is quite a bit less complex than 802.11.

With regard to your suggestions of possibly utilizing a non-standard device for communicating, I have to note the rapid emergence of public 802.11 WLANs (PUBLANS) in many major airports, hotel chains, etc. The near term possibilities here are mind boggling. This can only happen with a world wide interoperable standard. IEEE 802.11 devices are significantly dropping in price. Due to economies of scale, I can almost bet that most of the non standard devices will soon disappear.

Interestingly, we don't really view 802.11 and Bluetooth as competing technologies. Each has its own place where it shines. Bluetooth is cheap, slow, and only operates over relatively short distances. 802.11 is a bit more pricey, however fast, network-friendly and capable of range in excess of 30 meters at the full 11 Mb data rate. However, when comparing the complexities of the two and the effort it took to compose the protocol for each of these standards, I think that you've done 802.11 a great injustice! I think that IEEE 802.11 was well worth the wait!

The opinions expressed are strictly those of the author.

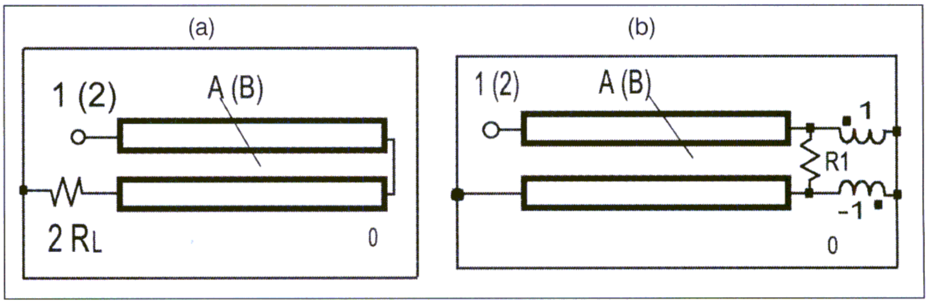
Richard L. Abrahams
Intersil Corp.
Wireless Applications Engineering

Product announcement correction

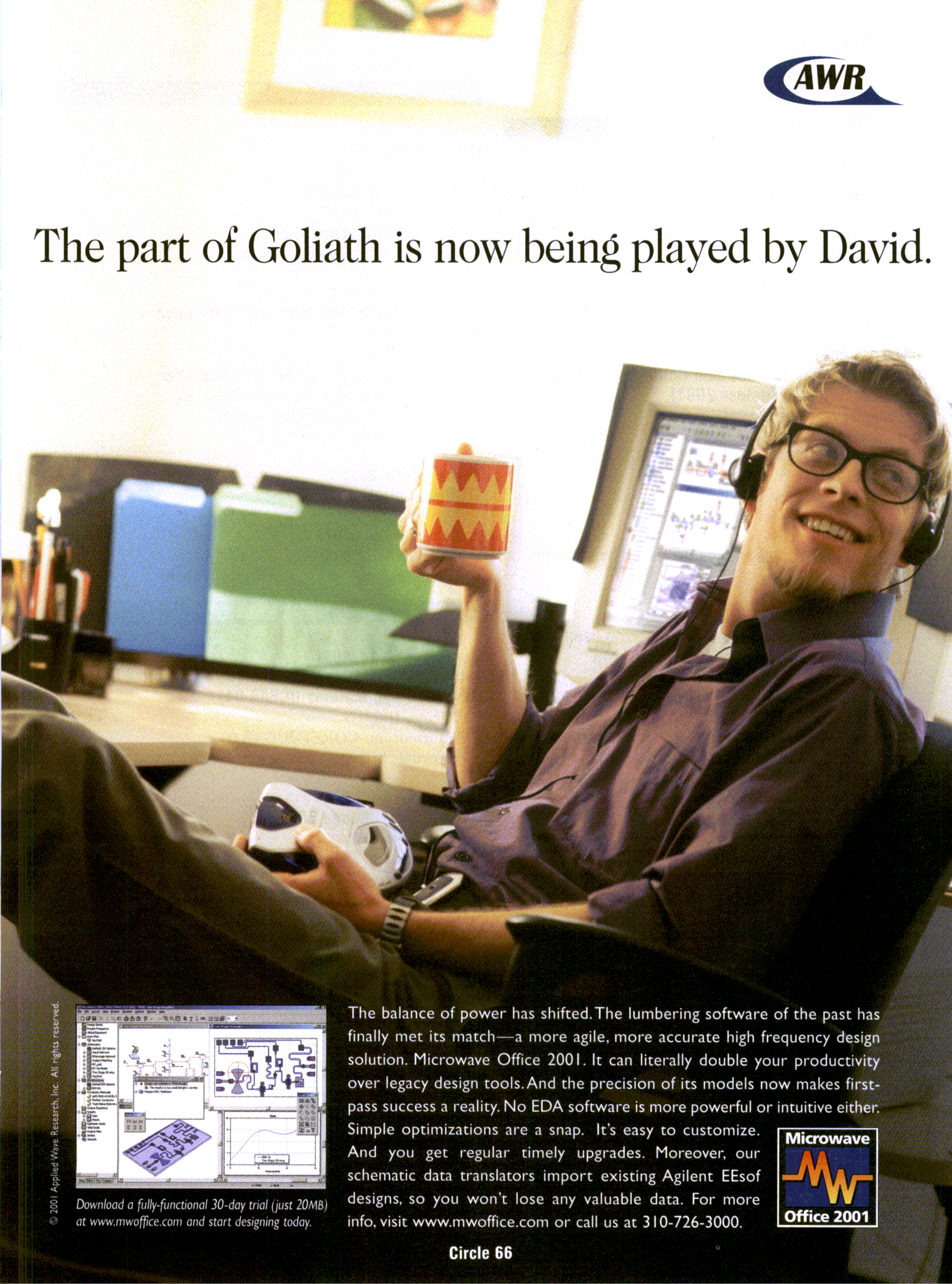
On page 116 of the May 2001 issue, we published the wrong photo with Raytheon's announcement of new chipsets for 23, 26 and 38 GHz. The photo was of Raytheon's 5 GHz Tondelayo devices. More information on these mm-wave products can be found online at: www.raytheon.com/micro/index.html#mwc

Figure correction

In the May 2001 article "A New Broadband Coupled-Line N-Way Power Combiner/Splitter," by Simon Y. London, Figure 2 was published incorrectly. The corrected figure is below. A complete copy of the article is available for download through the article archive available at our Web site: www.amwireless.com



▲ **(a) Even-mode decomposition cirucit and (b) odd-mode decomposition circuit.**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Internet: http://www.piers2001.gr.jp

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August 19-22, 2001
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Internet: http://rawcon.org

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Satellite Communications Payload and System Design
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Digital Signal Processing: Theory, Algorithms and Implementations
Los Angeles, CA . . . . August 13-17, 2001
Information: UCLA Extension, Short Course Program Office, Tel: 310-825-3344; Fax: 310-206-2815.

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DSP Made Simple for Engineers
Mountain View, CA . . . . . . July 16-18, 2001
RF Transceiver Design
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Wireless Digital Communications
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Applied RF Techniques I
Mountain View, CA . . . . . . August 13-17, 2001
Practical Design of Integrated and Discrete Wireless Circuits
Mountain View, CA . . . . . . August 20-22, 2001
RF Wireless System Design Fundamentals
Mountain View, CA . . . . . . August 22-24, 2001
RF CMOS Design
Mountain View, CA . . . . . . August 23-24, 2001
Bluetooth: Operation and Use
Mountain View, CA . . . . . . August 27-28, 2001
Behavioral Modeling
Mountain View, CA . . . . . . August 28-30, 2001
Information: Annie Wong, Tel: 650-949-3300; Fax: 650-949-4400; E-mail: info@bessercourse.com; Internet: www.bessercourse.com.

International Institute of Connector and Interconnection Technology (IICIT)

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Connector Failure Mechanisms
Detroit, MI . . . . July 19, 2001
Connector Testing
Detroit, MI . . . . July 18, 2001
Bandwidth, High Frequency and RF Effects
Detroit, MI . . . . July 19, 2001
Information: Suzanne Romeo, Tel: 1-800-854-4248; E-mail: sromeo@iicit.org; Internet: www.iicit.org.

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Cary, NC . . . . July 31-August 2, 2001
San Mateo, CA . . . . August 8-10, 2001
Amsterdam, Neth. . . . . . . August 29-31, 2001
Top Down MEMS Design
San Mateo, CA . . . . August 6-7, 2001
Information: Coventor Inc., Tel: 919-854-7500; Fax: 919-854-7501; E-mail: events@coventor.com; Internet: www.coventor.com.

Process Sciences Inc.

SMT Bootcamp
Chicago, IL . . . . July 23-24, 2001
Denver, CO . . . . August 2-3, 2001
Information: Process Sciences Inc., Tel: 512-259-7071; Fax: 512-259-7073; Internet: www.process-sciences.com.

University of California at Berkeley Extension

Advanced Digital Integrated Circuits
Berkeley, CA . . . . August 1-3, 2001
Design of Analog Integrated Circuits for Mixed-Signal Integrated Systems
San Francisco, CA . . . . . . August 6-10, 2001
Information: Continuing Education in Engineering, Tel: 510-642-4111; Fax: 510-642-0374; E-mail: course@unex.berkeley.edu; Internet: www.unex.berkeley.edu.

University of Wisconsin at Madison

Electrical Grounding of Communications Systems
Madison, WI . . . . August 1-3, 2001
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Monmouth University

Software-Defined Radio
West Long Branch, NJ . . . August 7-8, 2001
Information: Mickey Kuntz, Tel: 732-571-4491; E-mail: mkuntz@monmouth.edu; Internet: www2.monmouth.edu/ctdt/specialcourses.htm.

University of Missouri-Rolla

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Georgia Institute of Technology
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Circle 55

RIDE THE

BRIEFS

• Anritsu Company has announced the opening of a research and development and manufacturing facility in San Luis Obispo, CA, to accommodate demand for the company's optical and microwave and RF components.

• Andrew Corporation has opened a dedicated Technical Support Center in Sorocoba, Brazil. The facility is staffed by technical personnel and offers telephone and online technical support to the company's customers in English, Spanish and Portugese.

• Galtronics has announced the completion of its wireless design center in Phoenix, AZ. The new location includes an anechoic chamber, SAR testing equipment, network analyzers and other equipment designed for testing of the company's high performance antenna products.

• Xitron Technologies, a manufacturer of electrical power measurement devices, has relocated to a larger headquarters facility in San Diego, CA. The new 10,000-square-foot location includes space for research and development, production, warehouses and offices.

• Glassman High Voltage, a manufacturer of high voltage DC power supplies, has moved into a 56,000-square-foot facility in High Bridge, NJ. The new location houses the company's manufacturing, engineering, sales and administrative operations.

• Spectrum Control has updated its Web site, www.spectrumcontrol.com, to include access to instant product information, parametric and integrated search capabilities and custom product design.

• Gowanda Electronics has unveiled a new Web site at www.gowanda.com, offering product, technical and company information. The site also includes a product search feature allowing customers to search by either part number or properties.

Agere Systems, RF Micro Devices team for chip manufacturing

Agere Systems and RF Micro Devices have announced the signing of definitive agreements to form a strategic alliance to develop, design and manufacture high performance chips for next-generation, data-capable digital cellular phones and other products.

Under one part of the agreement, RF Micro Devices will invest approximately $58 million over two years to upgrade manufacturing clean room space and purchase semiconductor manufacturing equipment. This equipment will be set up in Agree's Orlando, FL, manufacturing facility and will be used to fulfill the terms of the alliance.

Production from the equipment will be allocated to RF Micro Devices first, providing the company with silicon capacity while giving both companies the benefits of combined operations and increased manufacturing volume. RF Micro Devices will provide silicon engineers for the Orlando operation.

The two companies also plan to create an RF center of excellence to jointely advance RF chip process technology and design methology.

Agere Systems Inc., based in Allentown, PA, was formerly the Microelectronics Group of Lucent Technologies. The company provides integrated optoelectronics and integrated circuits solutions for communications. RF Micro Devices, based in Greensboro, NC, designs and manufactures proprietary radio frequency integrated circuits for wireless communications.

Modelithics created for CAD/CAE services

A new company, Modelithics, has been created to provide characterization and CAD/CAE modeling services for telecommunications.

The company, based in Lutz, FL, stems from a successful university research program and was founded by Drs. Lawrence Dunleavy and Thomas Weller. Services offered include models on demand, libraray development and management and model validation. A database of chip component models is planned for release in late 2001.

Further information is available at the company's Web site, www.modelithics.com.

Sheldahl, GIL Technologies partner for roll-to-roll circuitry

Sheldahl Inc. and GIL Technologies Inc. have announced a joint development effort to produce high performance, thin, reinforced roll-to-roll circuitry.

The alliance combines GIL's expertise in roll-to-roll reinforced circuit products with Sheldahl's circuit fabrication technologies. The companies will develop a new line of products offering lower cost and improved performance for RF and microwave products, high speed digital circuits and IC packages.

Sheldahl, based in Northfield, MN, provides high-density substrated and other products for telecommunicationss. GIL Technologies, based in Collierville, TN, offers substrate solutions for printed circuit board designers, fabricators and assemblers.

Hitachi, TRW join forces for InP amplifier modules

Hitachi Ltd. and TRW's new semiconductor company, Velocium, have signed a joint development agreement to design and develop very high-efficiency power amplifier modules for 3G wireless handsets and other wireless devices. Hitachi will manufactur the modules using Velocium's indium phosphide (InP) semiconductors.

Hitachi, based in Tokyo, Japan, manufactures semicondutors, power and industrial equipment and other electronics products. Velocium, based in Manhattan Beach, CA, manufacturs semiconductor products for telecommunications.

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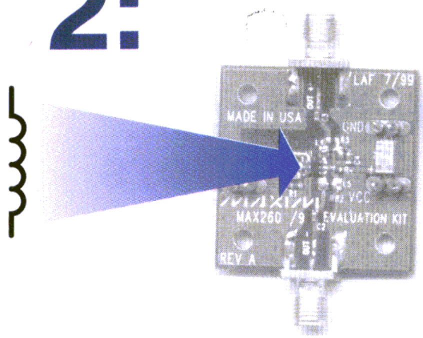

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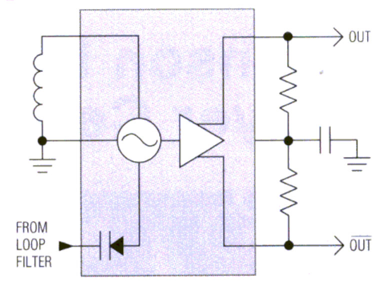

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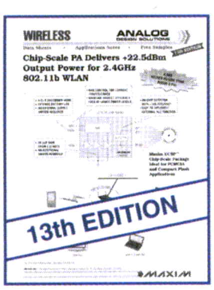
MAX2605	45 to 70	1.9	-117
MAX2606	70 to 150	2.1	-112
MAX2607	150 to 300	2.1	-107
MAX2608	300 to 500	2.7	-100
MAX2609	500 to 650	3.6	-93



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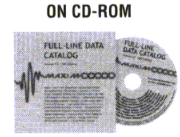

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Circle 21 (US) **Circle 22 (International)**

BUSINESS AND FINANCE

Motorola wins contracts for wireless networks

Motorola Inc.'s Global Telecom Solutions Sector has received a number of contract awards to provide wireless network installation and expansion services worldwide.

- Three contracts with China United Telecommunications Corporation (China Unicom) call for the expansion of GSM900 and 1800 networks in the Jiangsu, Shandong and Xinjiang provinces. The contracts are valued at $141 million.
- Oman's Ministry of Transport and Telecommunications Company (OmanTel) has awarded a contract for the expansion of the country's existing GSM digital cellular network, to offer additional capacity. The contract is worth $5.2 million.
- Three contracts with Brazil's Global Telecom call for the supply of 3G-capable cellular infrastructure in the country's Parana and Santa Catarina states. The awards are valued at $52 million.
- An agreement with Hellenic Telecommunications Company in Bulgaria provides for development of the first phase of a GSM900/1800 and GPRS digital cellular network. The contract is worth $31 million.

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

Conductus awarded Naval research contract

Conductus Inc. has been awarded follow-on funding from the Office of Naval Research to further develop advanced tunable filter technology.

The research is funded under the Frequency Agile Materials for Electronics (FAME) program, which is sponsored by the Defense Advanced Research Project Agency (DARPA). The contract is worth $800,000.

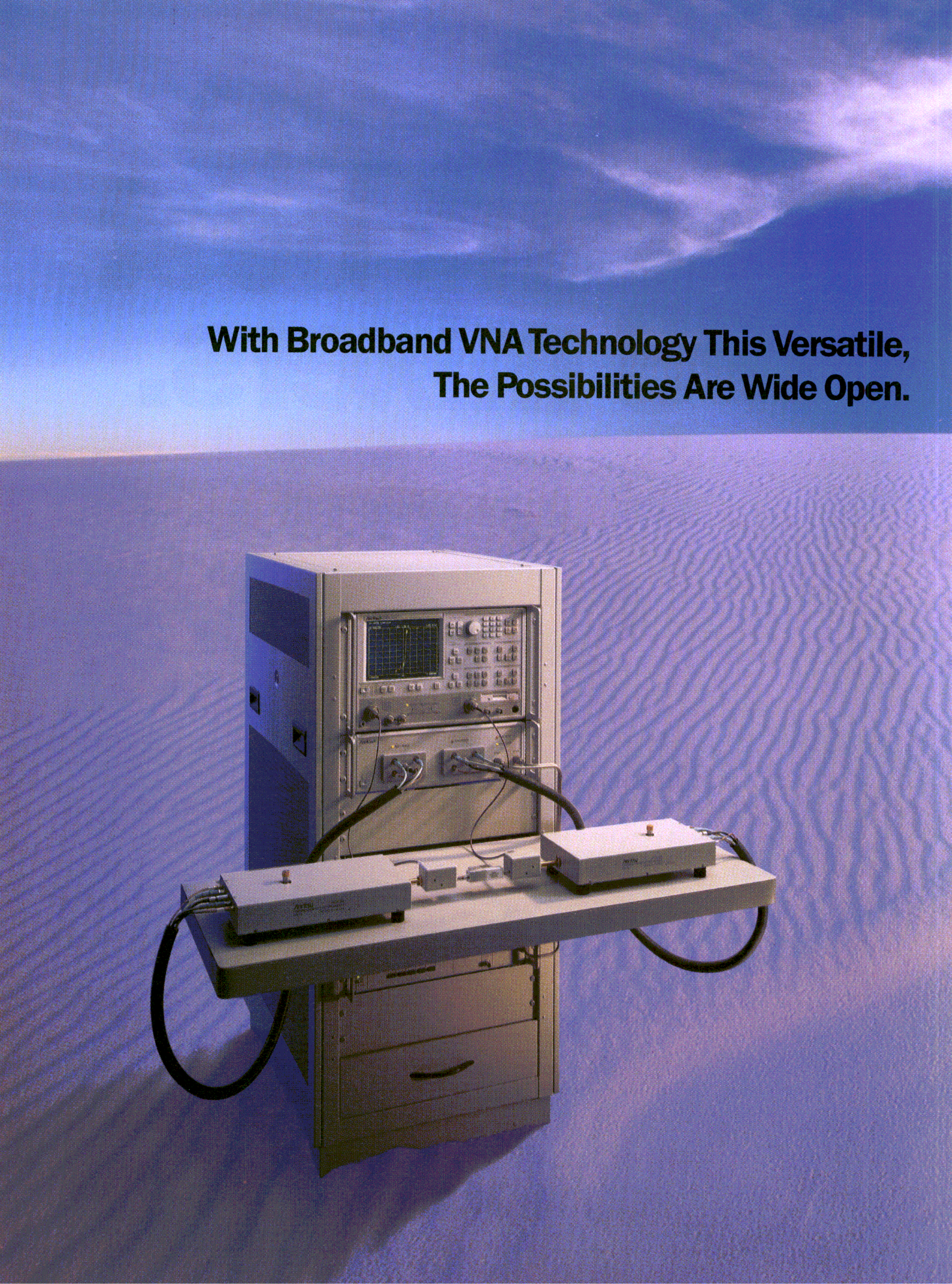
Conductus, based in Sunnyvale, CA, manufactures superconductor wireless systems.

Agilent to acquire Sirius

Agilent Technologies Inc. has signed an agreement to acquire all of the issued share capital of Sirius Communications. Financial terms were not disclosed.

Sirius is a Brussels, Belgium-based developer of CDMA application-specific integrated circuits for the 3G wireless and satellite communications market.

Agilent, based in Palo Alto, CA, provides a range of communications services worldwide.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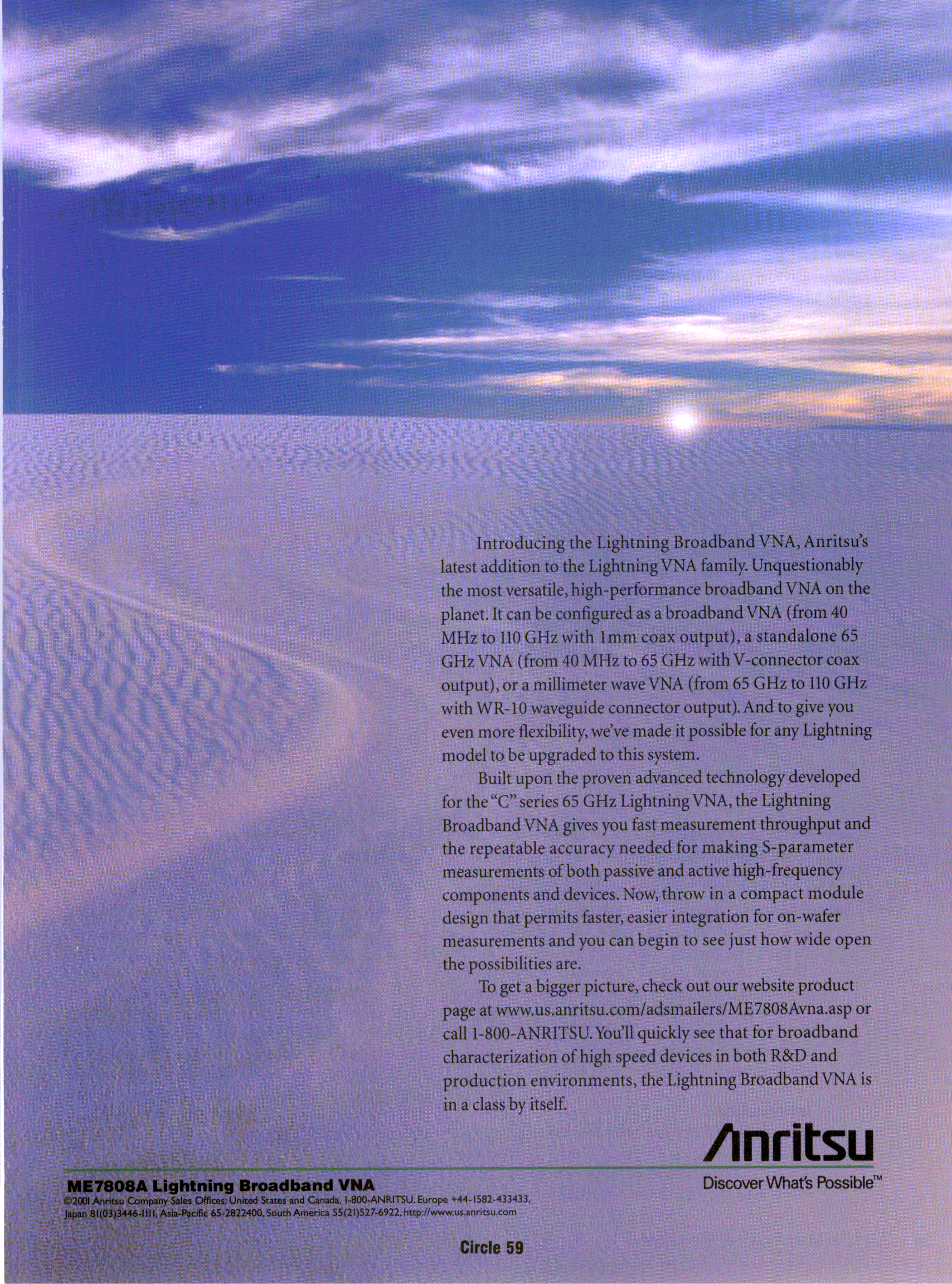

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Circle 59

Microwave Lowpass Filters with a Constricted Equi-Ripple Passband

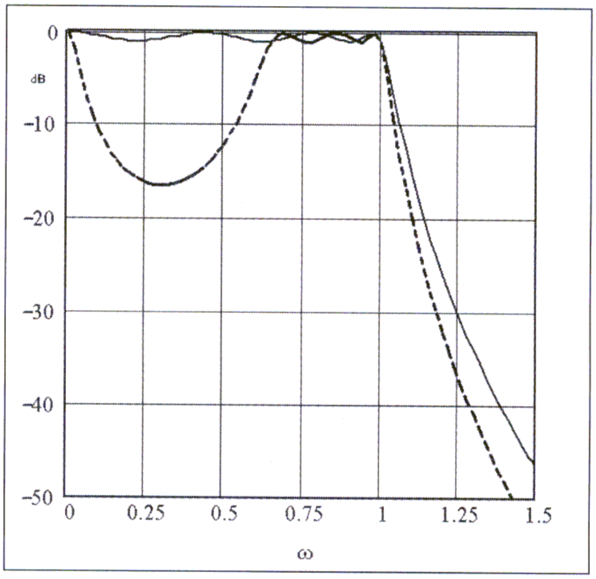
Improved lowpass filter performance is achieved by using a nonstandard prototype network

By Dieter Pelz
RFS Australia

Lowpass filtering requirements in modern systems with RF bandwidth-limited signals, such as cellular, PCS and UMTS, usually demand lowpass-type selectivity. The standard DC-to-cutoff equi-ripple passband, however, is seldom required. Here, standard lowpass prototypes may be considered non-optimum or even wasteful in terms of an excessive passband width.

Lowpass functions with a finite-interval equi-ripple passband produce higher selectivity and allow control of the impedance level within the lowpass network [1]. Levy [1, 2, 9] has shown that special Zolotarev functions are suitable as quasi-lowpass approximation functions. Horton [3] has described Zolotarev quasi-elliptic lowpass filters with finite transmission zeros. However, Zolotarev functions are relatively complicated for run-of-the-mill lowpass filter design work, and easy-to-use filter tables have only been published for limited cases.

This paper presents a quasi-lowpass prototype network similar to a standard Chebyshev prototype, but with a constricted equi-ripple passband of variable width. A fast-converging iterative approximation method is introduced. Tables of normalized prototype elements (g-parameters) for various network degrees, passband ripples and passband widths are given for direct use in lowpass filter design at RF- and microwave frequencies. A detailed design example is given at the end.



▲ **Figure 1. Attenuation responses of the standard lowpass filter and the passband-constricted lowpass filter.**

Introduction

Lowpass filters are vital for modern communication systems with strict limits on unwanted signal radiation/transmission. Bandpass filters often require additional external lowpass filtering for suppression of spurious- and higher-order passbands. In these cases, the lowpass filter is only required to provide a true passband for the frequency range given by the passband of the preceding bandpass filter. Hence, it is not advantageous to start the lowpass filter design process with standard prototype networks with passbands from DC (zero) to a cutoff frequency ω_C. Moreover, the selectivity of a "constricted passband" lowpass prototype is superior to that of a standard lowpass prototype, and the physical size is smaller (Figures 1 and 3).

Approximation

The desired lowpass attenuation function

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10 to 26,000	2	1.40 fc	2.50 fc	5.20 fc
	3	1.15 fc	1.70 fc	2.80 fc
	4	1.09 fc	1.40 fc	2.00 fc
	5	1.07 fc	1.26 fc	1.62 fc
	6	1.05 fc	1.18 fc	1.44 fc
	7	1.04 fc	1.14 fc	1.33 fc
	8	1.04 fc	1.11 fc	1.26 fc
	9	1.03 fc	1.08 fc	1.19 fc
	10	1.02 fc	1.06 fc	1.14 fc

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Circle 72

associated with a realizable network is established by approximation. The reflective insertion loss of a lossless passive 2-port network is given by

$$|S_{21}(\omega)|^2 = \frac{1}{1+K^2(\omega)} \tag{1}$$

where $K(\omega)$ is referred to as either characteristic function, filtering function or reflection function. For standard lowpass approximations, such as the Chebyshev type, $K(\omega)$ is directly given as a hyperbolic-cosine function with inherent equi-ripple properties.

For a lowpass filter with all its transmission zeros at infinity, $K(\omega)$ is a polynomial in $j\omega$ and can be written as

$$K(j\omega) = \varepsilon(j\omega)^{v}\prod_{\mu=1}^{n-v}\left(\Omega_{\mu}{}^{2} + (j\omega)^2\right) \tag{2}$$

where v = number of reflection zeros at DC (zero) and n = number of reflection zeros.

Here the reflection zeros Ω_μ can be placed freely between zero and the cutoff frequency ω_C to suit any desired passband reflection behavior. However, only a certain distribution of these reflection zeros will ensure an equi-ripple behavior within a finite frequency interval. Analytic equi-ripple-solutions involving special Zolotarev functions are available [1], and their application in commensurate microwave lowpass filters has been demonstrated [2].

A relatively simple and fast converging iteration process for generating a desired characteristic function directly can be found in bandpass filter approximation theory [6]. $K(j\omega)$ can be used for finding lumped lowpass filter elements, as well as for the synthesis of cascaded transmission line lowpass filters.

The iterative approximation process

Consider a characteristic function in the form of Equation (2). A linearized change ΔK of K [6] can be derived from the logarithmic form of Equation (2) as follows:

$$\Delta K(\omega) = \left[\frac{\partial K(\omega)}{\partial \varepsilon}\right]\Delta\varepsilon + \left[\frac{\partial K(\omega)}{\partial \Omega_1}\right]\Delta\Omega_1 + \ldots$$
$$\ldots + \left[\frac{\partial K(\omega)}{\partial \Omega_n}\right]\Delta\Omega_{n-\nu} \tag{3}$$

In the given case of a lowpass filter with $n - \nu$ reflection zeros in the passband, we obtain $n - \nu - 1$ reflection maxima plus two-band-edge frequencies giving a total of $n - \nu + 1$ critical frequencies where the reflection coefficient reaches exactly the passband ripple level. The unknown parameters in the characteristic function given by Equation (2) are ε, $\Omega_1 \ldots \Omega_{n-\nu}$ — a total of $n - \nu + 1$ parameters — which is a figure identical to the number of critical passband frequencies. Therefore, a system of $n - \nu + 1$ linear equations can be set up using Equation (3) with a set of starting values for the unknowns ε and Ω_μ. The starting values can be rough estimates (Equation (18) in [1] can be used for calculating starting values). Solving the equation system provides $\Delta\varepsilon$ and $\Delta\Omega_\mu$ for improving the starting values ε and Ω_μ with which a new iteration is then carried out. This process is repeated until the desired accuracy of $K(\omega)$ is achieved. Convergence is very fast; [a MathCAD version takes three seconds for six reflection zeros with an attenuation accuracy of 10^{-5} dB using 10 iterations]. The critical frequencies inside the passband (the reflection peak frequencies) depend on the reflection zeros. These peak frequencies are the zeros of the derivative of $K(\omega)$ within the passband and need to be calculated during each iteration cycle.

Synthesis

With the polynomial in Equation (2), the transfer function polynomial is given by the left s-plane roots of

$$H(s)H(-s) = 1 + K(s)K(-s) \tag{4}$$

For both $K(s)$ being an odd- or even function, only an n-th degree polynomial needs to be rooted for finding the zeros of $H(s)$ [7]. With the two polynomials $K(s)$ and $H(s)$, the chain-matrix of the desired ladder network is given. From the chain-matrix elements the short- and open-circuit reactances are determined and normalized circuit elements can be extracted by continuous pole removal at $\omega = \infty$.

Tables of normalized elements

Tables of normalized element values are shown in Table 1 (see Appendix). These tables can be used to design lumped-element and distributed-element lowpass filters with constricted equi-ripple passbands. If n is odd, the characteristic function has a simple zero at DC (ν = 1 in (2)). For an even n, the characteristic function has a double zero at DC (ν = 2 in (2)); thus is avoided the problem of having non-zero attenuation at DC ($g_0 = g_{n+1} = 1$ for all cases). The double-zero also ensures that the network is by and large symmetric, which is not the case with even-degree Chebyshev prototypes. Separate tables are provided for two different passband ripple values and different lower equi-ripple, band-edge frequencies. The rightmost column contains stopband attenuation values at 1.5 times the cutoff frequency for each set of normalized element values. The process for finding denormalized elements is identical to that for the standard Chebyshev filters with the normalization frequency being the cutoff frequency ω_C.

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The broadband units also offer exceptional IP3 performance and superior linearity for the power consumed.

Part Number	Bandwidth (GHz)	Gain @ 1 GHz (dB)	Gain (dB)	P1dB (dBm)	OIP3 (dBm)	Noise Figure (dB)	Vd (V)	Id (mA)
Low Voltage Gain Blocks								
SGA-0163	DC-4.5	13	12	-2	+9	4.7	2.1	8
SGA-0363	DC-5.0	20	17	+2	+14	3.0	2.5	11
High Reverse Isolation Gain Blocks								
SGA-1163	DC-6.0	12	11	-3	+8	3.1	4.6	12
SGA-1263	DC-4.0	16	15	-8	+3	2.7	2.8	8
General Purpose Gain Blocks								
SGA-2163	DC-5.0	10	10	+7	+21	4.2	2.2	20
SGA-2263	DC-3.5	15	14	+8	+20	3.2	2.2	20
SGA-2363	DC-2.8	17	16	+8	+19	2.9	2.7	20
SGA-2463	DC-2.0	20	17	+9	+20	2.7	2.7	20

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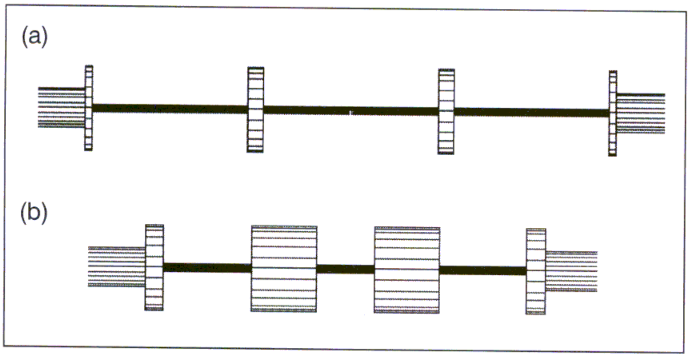
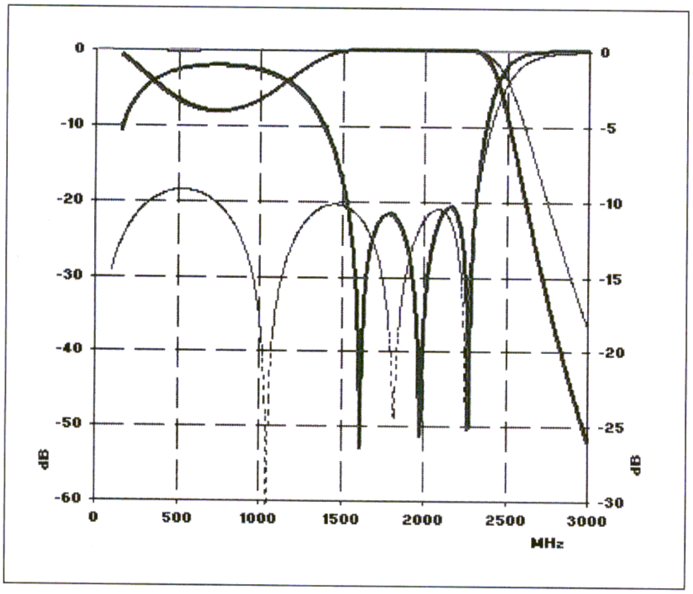


▲ **Figure 2. (a) Conductor of the standard prototype design. (b) Conductor of the constricted equi-ripple passband lowpass filter design example.**



▲ **Figure 3. Lowpass filter response curves obtained from 3D EM simulation (left y-axis = *RL*, right y-axis = *IL*).**

Design example

A seventh degree coaxial lowpass filter was designed and simulated on the 3D EM simulator HFSS. The lower band edge was chosen to be at a normalized frequency of $\omega = 0.65$.

Example filter design specifications

Cutoff frequency:	2.3 GHz
Lower passband edge frequency:	1.495 GHz
Passband return loss:	20 dB
Port impedances:	50 Ω

A. Physical realization

Coaxial lowpass filters can be constructed in many different ways [4, 5]. A realization using quasi-lumped capacitors was chosen (Figure 2). The inductive sections are made of 150 ohm lines. A dielectric tube ($\varepsilon_r = 2.2$) supports the capacitive sections. Corrections for the fringing capacitances at the discontinuities are necessary [4, 8]. Here, the complication of having a "mixed dielectric" at the discontinuities was overcome by extracting exact fringing capacitance data from 3D EM-simulation *S*-parameter data.

Coaxial geometry data

Outer diameter:	6.0 mm
Inner diameter of dielectric tube:	5.6 mm
(this is also the OD of the quasi-lumped capacitors)	
Diameter of inductive sections:	0.5 mm

B. Electrical performance

Given the excellent agreement between 3D electromagnetic simulation and prototype measurement, the former was chosen to determine the electrical performance of the designed lowpass filter (thick traces in Figure 3).

C. Comparison with standard Chebyshev design

A standard seven-pole Chebyshev lowpass filter was designed for comparison with the constricted passband lowpass filter (CPL). In addition to better selectivity of the CPL filter (thin traces in Figure 3), there is also a clear size advantage. The length of the CPL design is only 75 percent of the length of the standard lowpass design. This means that higher degree CPL filters can be accommodated in the same space occupied by lower degree standard prototype lowpass filters.

Lowpass stopband requirements in popular communication systems often exist up to 13 GHz. The example CPL design provides a monotonic attenuation increase up to and above 13 GHz (109 dB at 13 GHz). In the standard prototype lowpass design, the attenuation slope changes its sign at 10 GHz and can only provide 63 dB attenuation at 13 GHz.

Conclusion

Lowpass filter prototypes with a constricted equi-ripple passband have distinct advantages over standard prototypes for most common microwave lowpass design applications. The required approximation can easily be accomplished by employing a flexible iterative method. A set of tables of normalized element parameters enables direct application of restricted equi-ripple passband lowpass prototypes in practical lowpass filter design work. ■

Acknowledgement

The author wishes to acknowledge that gathering of reflection zeros in lowpass filter functions was first suggested to him by B. v. Kameke in 1979.

References

1. R. Levy, "Generalized Rational Function approximation in Finite intervals Using Zolotarev Functions,"

IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-18, No. 12, December 1970: 1052-1064.

2. R. Levy, "A new class of Distributed Prototype Filters with Applications to Mixed Lumped/Distributed Component Design," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-18, No. 12, December 1970: 1064-1071.

3. M.C. Horton, "Quasi-Lowpass, Quasi-Elliptic Symmetric Filter," *1987 IEEE MTT-S International Microwave Symposium Digest*, D-1: 129-132.

4. G.L. Matthaei, L. Young and E.M.T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*, New York: McGraw-Hill, 1964.

5. R.V. Snyder, "New Microwave Lowpass Structure," *IEEE Transactions on Microwave Theory and Techniques* (April 1968): 262-264.

6. R. Unbehauen, *Synthese Elektrischer Netzwerke*, Oldenburg Verlag 2. Auflage, 1984.

7. G. Fritzsche, *Entwurf passiver Analogvierpole*, Netzwerke II, Friedr. Vieweg & Sohn, 1980.

8. P.I. Somlo, "The Computation of Coaxial Line Step Capacitances," *IEEE MTT*, Vol. MTT-15, No. 1, 1967.

9. R. Levy, "Characteristics and Element Values of Equally Terminated Achieser-Zolotarev Quasi-Low-Pass Filters," *IEEE CT*, Vol. CT-18, No. 5, 1971.

Author information

Dieter Pelz (Dipl. Ing) joined RFS Australia in 1995. He has been involved in microwave filter design for more than 20 years and holds four patents on filters and multiplexers. He may be reached via e-mail at dpelz@compuserve.com.

Appendix

n	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10	Attenuation at =1.5
	0.1 dB ripple / 16.4 dB RL				normalized lower equi-ripple passband edge at = 0.5						
3	1.03156	1.1474	1.03156								4.60 dB
4	non existent										
5	1.27439	1.28243	2.19193	1.28243	1.27439						20.73 dB
6	1.05042	1.51196	1.79566	1.79676	1.51146	1.05042					26.65 dB
7	1.57515	1.10489	3.15826	1.02307	3.15826	1.10489	1.57515				39.27 dB
8	1.22100	1.43926	2.04059	1.78699	1.78612	2.03917	1.43939	1.23588			45.00 dB
9	1.90936	0.88365	5.13993	0.54663	7.32761	0.54663	5.13993	0.88365	1.90936		57.90 dB
10	1.45985	1.25478	2.57245	1.47858	2.11793	2.11062	1.47955	2.56911	1.25455	1.47700	63.59 dB
	0.044 dB ripple / 20 dB RL				normalized lower equi-ripple passband edge at = 0.5						
3	0.85495	1.10444	0.85495								2.61 dB
4	non existent										
5	1.06807	1.32100	1.94451	1.32100	1.06807						17.18 dB
6	0.90909	1.47702	1.72580	1.72648	1.47776	0.90731					23.07 dB
7	1.29823	1.21992	2.58993	1.21468	2.58993	1.21992	1.29823				35.67 dB
8	1.04493	1.45973	1.92370	1.78726	1.78847	1.92577	1.46026	1.03992			41.40 dB
9	1.56552	1.02581	3.83443	0.75501	5.03706	0.75501	3.83443	1.02581	1.56552		54.30 dB
10	1.22850	1.34127	2.27881	1.58697	2.03153	2.03653	1.58883	2.29055	1.34101	1.20923	60.00 dB
	0.1 dB ripple / 16.4 dB RL				normalized lower equi-ripple passband edge at = 0.65						
3	1.08651	1.13655	1.08651								5.07 dB
4	0.92937	1.43463	1.43499	0.92838							9.59 dB
5	1.67051	1.02212	3.05011	1.02212	1.67051						23.65 dB
6	1.21803	1.43823	1.87832	1.87666	1.43834	1.22618					28.71 dB
7	2.48372	0.63281	8.47624	0.34639	8.47624	0.63281	2.48372				44.10 dB
8	1.73611	1.09373	2.82300	1.61314	1.60960	2.83516	1.09270	1.72573			49.12 dB
9	3.01774	0.47731	19.80094	0.10111	51.20188	0.10111	19.80094	0.47731	3.01774		64.58 dB
10	2.37530	0.72603	5.79318	0.76445	2.97182	3.02747	0.75557	5.78325	0.73139	2.33083	69.60 dB
	0.044 dB ripple / 20 dB RL				normalized lower equi-ripple passband edge at = 0.65						
3	0.89562	1.10594	0.89562								2.94 dB
4	0.80064	1.35411	1.35360	0.80259							6.57 dB
5	1.34925	1.14466	2.46492	1.14466	1.34925						20.08 dB
6	1.03627	1.44707	1.79133	1.79032	1.44740	1.03067					25.12 dB
7	1.98884	0.77819	5.75880	0.51169	5.75880	0.77819	1.98884				40.51 dB
8	1.42857	1.21598	2.43672	1.66558	1.65881	2.44598	1.21681	1.41297			45.53 dB
9	2.50813	0.56856	13.76005	0.15077	32.16559	0.15077	13.76005	0.56856	2.50813		60.98 dB
10	1.96078	0.84981	4.56363	0.88918	2.71558	2.68475	0.89434	4.56979	0.84490	2.00569	66.00 dB

▲ **Table 1. Normalized prototype elements for lowpass filters with a constricted equi-ripple passband.**

Microwave Band Pass Filters: Is Tuning Necessary?

By Richard M. Kurzrok, PE
RMK Consultants

Microwave band pass filters can be designed and developed in various configurations. Some of these filters are manufactured, tested, and shipped with no in-plant tuning. Other filters require alignment of individual resonators prior to testing. This can include adjustment of center frequencies using mechanical or electronic techniques.

In some situations, filter couplings also entail adjustments [1]. In this article, various band pass filter design considerations will be discussed as an overview without delving into the intricate details of specific design requirements.

Types of microwave band pass filters

Field tunable band pass filters inherently entail adjustability. The need for these tunable units has been substantially reduced by refinements in microwave systems architecture. Many band pass filters are designed using approximate equations. Developmental procedures (2,3), that experimentally determine filter couplings, can be quite effective in overcoming the limitations of available design equations. Coaxial band pass filter structures, such as comb line and interdigital, and waveguide band pass filters are often designed using resonator tuning screws. Band pass filters using planar (microstrip, stripline, and coplanar waveguide) construction, in single or multiple layers, usually do not require alignment. Filters, printed as planar circuits, sometimes require several design iterations.

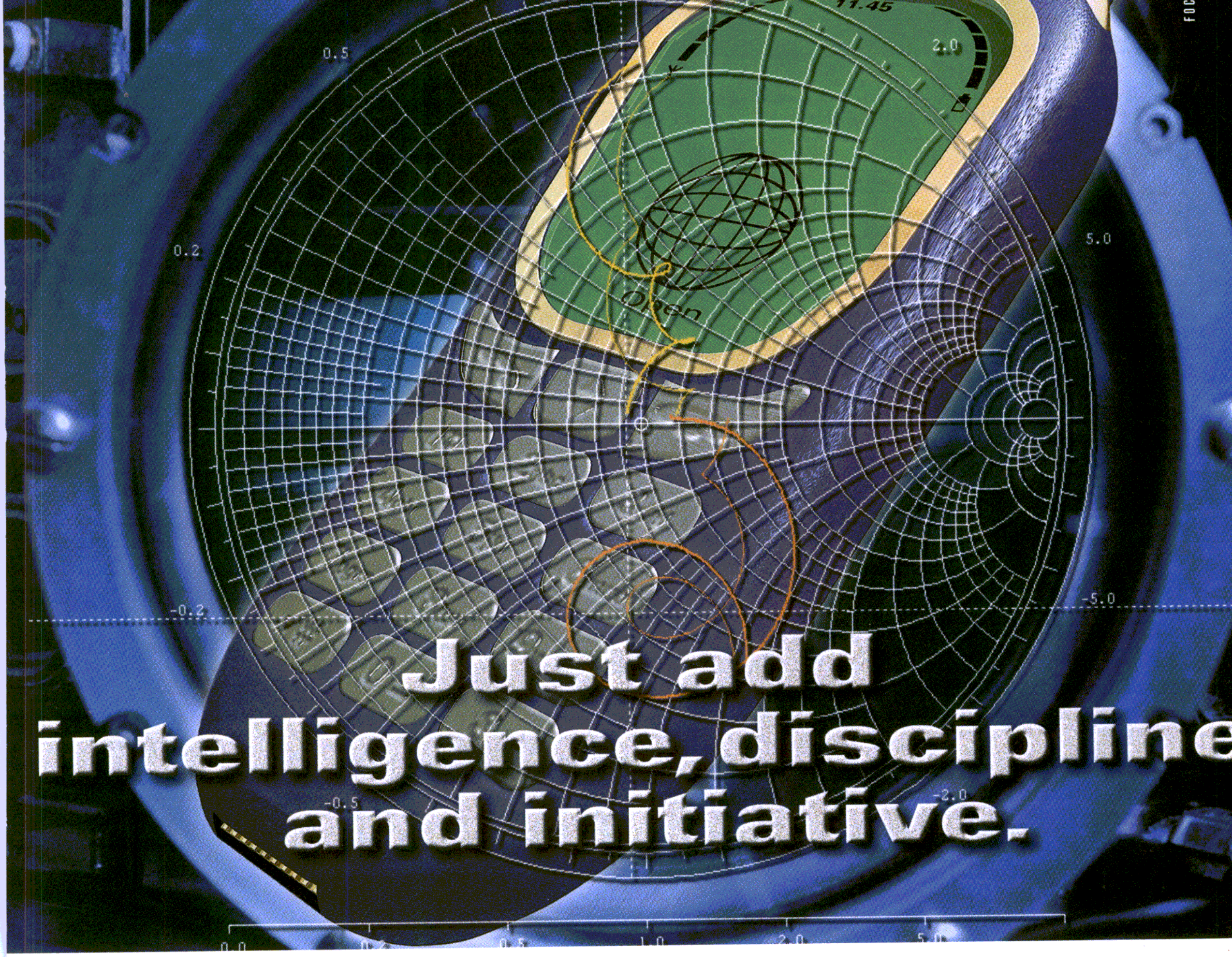
Basic considerations

In the era of government electronics, microwave band pass filter production quantities usually were not large. Primary considerations were performance and reliability. Unit costs were of secondary concern. In the current era of commercial electronics, cost has become a very important specification. Elimination of microwave band pass filter tuning provides two areas of cost reduction: filter hardware is simplified and alignment labor costs are eliminated. Furthermore, significantly lower unit cost can result in the demise of repairs. Some defective microwave filters can be treated as throw-aways replaceable by available spares.

In many situations, the need for band pass filter tuning depends upon filter percent bandwidth [4, 5]. Filters with percent bandwidths in excess of twenty percent, are rarely tuned. Some filters with moderate bandwidths of five to twenty percent can be realized without tuning. Narrow band pass filters of less than five percent usually have needed factory adjustment of individual resonators. With the advent of temperature stable ceramic filters for small percent bandwidths, low cost filters have been achieved without tuning screws.

Technical advances in many areas have affected the art of microwave band pass filter design. New materials and manufacturing processes have facilitated performance enhancement and cost reduction. The advent of personal computers (5,6) has permitted judicious use of optimization techniques and electromagnetic simulation. This can substantially reduce the number of iterations required during filter design and development.

Future realization of some microwave band pass filters will entail monolithic microwave integrated circuits (MMICS) at the sub-system and systems levels. During the past decade, lumped circuit band pass filters have replaced



Just add
intelligence, discipline
and initiative.

Band Pass Filters Without Tuning Screws	Band Pass Filters With Tuning Screws
Cost reduction	Can correct for manufacturing tolerances
Miniaturization	Can reduce model multiplicity
Reliability	Can correct for source/load mismatches
Unloaded Q not reduced by tuning screws	Can help optimize system or sub-system
Power handling not reduced by tuning screws	Can adjust for equalizations
Hermetic sealing not impacted (no bellows)	Can be adaptive units
No tuning screw vibration	Can help with stringent specifications
Can reduce or eliminate unit repairs	Electromagnetic simulation not always available
Compatible with system integration	Can provide comb line capacitive loadings

▲ **Table 1. Comparative features of microwave band pass filters without and with tuning screws.**

some transmission line filters at microwave frequencies. Active microwave band pass filters can ultimately engender total integration. Silicon germanium semiconductor material can provide an order of magnitude improvement in frequency coverage for some future personal computers and other microwave products.

Impact of mechanical and materials tolerances

Mechanical and materials tolerances can affect the performance of fixed tuned microwave band pass filters. Sometimes, filter requirements permit use of guard bands that can mitigate response shape aberrations that accompany actual tolerance variations. Stringency of filter specifications is intricately related to allowable performance degradation. As operating frequencies increase, resonator wavelengths become smaller. This exacerbates the impact of mechanical tolerances when manufacturing precision is approaching practical and cost effective limits. The current availability of computer-aided design and analysis software [5] is crucial in determining the sensitivities of band pass filter response shapes to mechanical and materials tolerances.

Impact of resonator quality

Microwave band pass filter performance is quite dependent on the unloaded Q's of the filter resonators [4, 5]. Unloaded Q's are dependent upon resonator size and geometry, conductor surface finish, and materials properties. Filter quality is a function of unloaded Q, percent bandwidth, and nominal filter response shape. Inadequate unloaded Q can result in unacceptable filter pass band dissipation losses. In an extreme situation, a band pass filter with sharp selectivity can deteriorate into a frequency sensitive attenuator. Filter quality also affects filter power handling capabilities. As average power increases, excessive filter dissipation losses can cause overheating that could lead to equipment failure. As peak power increases, narrow gaps, sharp corners, poor surface finish, and materials properties can contribute to voltage breakdown.

Impact of filter interfaces

Actual band pass filter response shapes are dependent upon both the filter and the source/load interfaces. Mismatched source impedances and load impedances can appreciably degrade band pass filter performance. Some current systems use passive interface buffers. Future integrated systems will use active buffers. Ultimate interface corrections can employ feedback control techniques with embedded microprocessors.

Computer-aided analysis software [5] can determine filter responses under specific conditions of source/load terminations. Other computer software can predict the effects of perturbed filter responses, on communications systems performance, for prescribed modulation techniques.

Advantages and disadvantages

The pros and cons of microwave band pass filter tuning are a complex area where considerations of cost, performance, and operations are interrelated. Some of these features have been summarized in Table 1. The applicability of these considerations can change as electronic technology advances and equipment cost considerations become more dominant.

Some application considerations

1. Wireless handsets entail very low unit cost and high production volume. They will probably never use tunable microwave band pass filters.

2. Digital data links at T1 rates have non-critical transmission specifications. Tunable microwave band pass filters will seldom, if ever, be required.

3. High speed digital data and video at satellite earth stations can have stringent transmission and reflection specifications. High quality tunable microwave band pass filters are often needed for current performance optimization.

4. Satellite repeaters in aerospace environment require equipment with no movable parts. Microwave band pass filters must be provided without tuning screws.

Conclusions

The elimination of tuning in microwave band pass filters is a desirable objective. This design simplification is not always viable. For short-term new applications, manufacturing volume, unit cost objectives, and the complete range of applicable electrical, mechanical, and environmental specifications will determine the appropriate design tradeoffs. Many existing products, using tunable microwave band pass filters, will be continued to be manufactured. The non-recurring costs of redesign will often prohibit some possible product improvements.

Enhanced communications systems architecture and ongoing advances in systems/subsystems integrated circuits will reduce and possibly eliminate the need for tuning microwave band pass filters in future equipment. This could entail further improvements in computer-aided design and analysis plus expanded use of embedded microprocessors. ■

References

1. R.M. Kurzrok, "Direct Coupled Coaxial and Waveguide Bandpass Filters," *IRE Transactions MTT*, Vol. MTT-10, May 1962: 218-219.

2. M. Dishal, "A Simple Design Procedure for Small Percentage Bandwidth Round-Rod Interdigital Filter," *IEEE Transactions MTT*, Vol. MTT-13, September 1965: 696-698.

3. R.M. Kurzrok, "Nodal Voltages Offer Key to Filter Design," *Microwaves & RF*, April 1999: 72-84 and May 1999: 67-69.

4. G.L. Matthaei, L. Young and E.M.T. Jones, "Microwave Filters, Impedance Matching Networks, and Coupling Structures," New York: McGraw-Hill, 1964.

5. R.W. Rhea, *HF Filter Design and Computer Simulation*, Atlanta: Noble Publishing Company, 1994

6. S. Bila, et al, "Direct Electromagnetic Optimization of Microwave Filters," *IEEE Microwave Magazine*, Vol. 2, March 2001: 46-51.

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Limitations on Inferring cdma2000 Functionality Based on cdmaOne Testing

By Ryan Hendrickson
Agilent Technologies, CDMA Mobile Test

Now that cdma2000 compatible mobile phone designs are beginning to increase volume production, many mobile manufacturers are deciding what testing needs to be implemented in their production process to incorporate the cdma2000 mobile functionality. Many of these manufacturers have existing lines that have been producing TIA/EIA/IS-95-A/B based CDMA mobile phones for several years. The new cdma2000 mobile phones or 3GPP2 compliant mobiles incorporate many advancements in spread spectrum technologies, such as the ability to maintain backward compatibility with the previous 2.5G technologies. There are many similarities between cdmaOne and cdma2000 compliant mobiles, but there are also significant differences in their physical RF implementations.

The two technologies may at first look similar enough to make assumptions on the ability to test one technology and make inferences on the functionality of the other. To some extent or fraction of the complete functionality, this may be true. But when it comes to providing reliably tested functionality across the entire product feature-set, it becomes a very high-risk position for mobile manufacturers to take.

It has been suggested in the industry that cdma2000 functionality can be inferred based on the testing and verification of cdmaOne functionality. This risky assumption is based on several factors:

- The physical RF channel structures in most cases is different.
- Modulation schemes vary between the cdma2000 RC configurations and cdmaOne modulation structure.
- The actual fully channelized cdma2000 waveform varies compared to cdmaOne.
- cdma2000 has a much higher peak-to-average ratio when fully channelized.

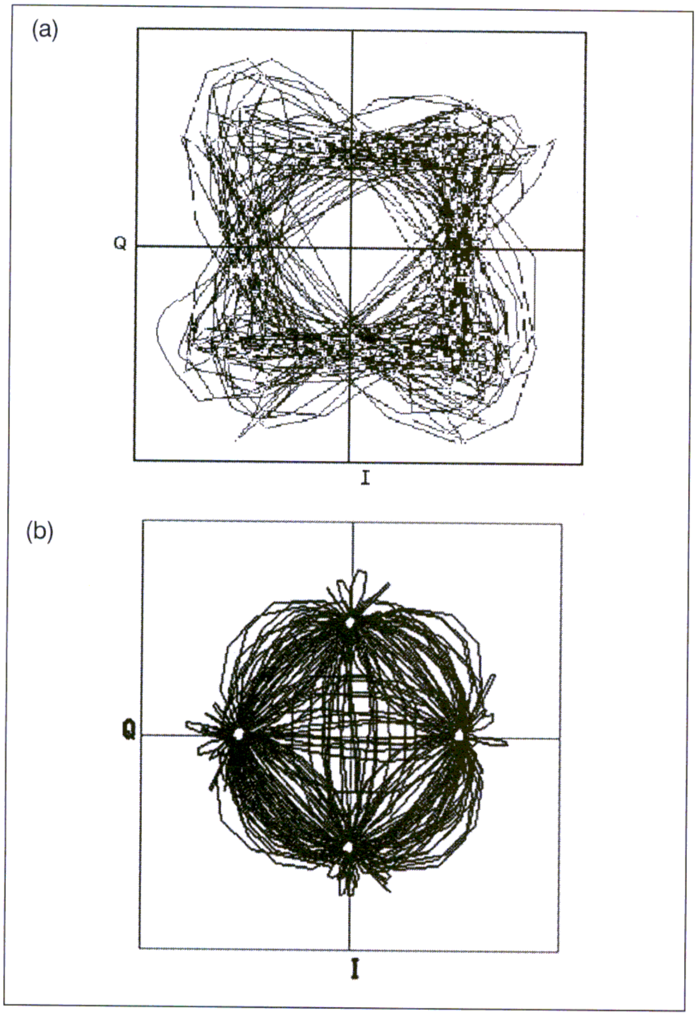
In regard to accurately testing the functionality of the device, the differences between the two technologies are significant. Specifically, if the cdma2000 mobile design is marginal in one specific RF performance, incorrect assumptions will lead to significant failures in what was assumed to be a passing functional parameter.

This article reviews and compares the differences between the modulation schemes used in cdma2000 and cdmaOne. It will be shown that inferring cdma2000 functionality from cdmaOne testing is not a recommended choice for mobile manufacturers. cdma2000 test considerations will also be discussed.

Modulation differences between cdmaOne and cdma2000

In order to understand the implications of inferring cdma2000 RC 3, 4 and 5 functionality from testing either cdmaOne or cdma2000 RC1 and 2, the differences between their respective modulation methods must first be understood.

cdmaOne technologies incorporate an Offset Quadrature Phase Shift Keyed (OQPSK) approach to deal with the transition of the reverse link through the I/Q zero-origin. OQPSK introduces a 1/2-chip delay in the Q channel as compared to the I channel. This causes the waveform to change amplitude and phase on the I axes first and then change amplitude and phase on the Q axes, eliminating the overall transition of the waveform through the I/Q origin, thus minimizing dynamic range



▲ **Figure 1. (a) OQPSK waveform; (b) HPSK waveform.**

requirements of the power amplifier. This method is successful because:

- The I and Q channels contain the same symbol data, both with common gain settings. These identical symbol streams are isolated by mixing with individual short code sequences.
- Only one channel, the traffic channel, is transmitted on the reverse link. This is a significant difference as compared to cdma2000, which incorporates multiple channels on the reverse link.

These two facts ensure that the I and Q channels are of the same amplitude, which provides a balanced transmitted I/Q waveform for cdmaOne mobiles.

To address the I/Q imbalance, zero-origin transition (180 degree phase transition), as well as repeated symbol transition (0 degree phase transition) issues of the cdma2000 waveform, a different modulation scheme has been incorporated in cdma2000 devices. This new modulation method is called hybrid phase shift keying (HPSK). This variant on a complex modulation scheme eliminates the transition through the I/Q zero-origin on every other chip by using standard orthogonal Walsh codes to designate the particular channels (R-PCH, R-FCH, and R-SCH1/R-SCH2). In addition, specific repeating sequences are used to scramble the signal to produce one of multiple of ±90-degree phase transitions. HPSK does not entirely eliminate the zero-origin and repeated symbol transition issues but reduces their number of occurrences. Amplifier compression remains a concern that must be tested for.

There are several significant differences between cdmaOne and cdma2000. First, the cdma2000 reverse link structure incorporates multiple channels: a pilot (R-PCH), a fundamental or traffic channel (R-FCH), and the option for up to two supplemental channels (R-SCH1/R-SCH2) and one dedicated control channel (R-DCCH) that can be used for obtaining higher reverse link data rates. Also, these multiple channels can have varying power levels which, when summed together, dramatically complicate the overall transmitted waveform, causing a much higher peak-to-average waveform. In addition, I and Q channel data is further isolated by assigning specific orthogonal codes of various lengths, depending on the rate at which the data is being sent.

These differences preclude the use of OQPSK modulation cdma2000 devices. Zero origin transitions, repetitive symbol transitions and unbalanced I and Q channel modulation become an issue when multiple channels are individually transmitted on the I or Q channels. HPSK reduces the effects of such issues as amplifier compression and I/Q zero origin transitions. Figure 1 shows a comparison of a cdmaOne reverse channel (using OQPSK) and cdma2000 channel (using HPSK).

cdma2000 test implications

By moving to the HPSK modulation methods for cdma2000, I/Q imbalance, as well as I and Q zero origin transitions, are reduced but not entirely eliminated. cdma2000 and cdmaOne modulation structures are entirely different and cannot be assumed to have similar test responses. By testing the transmission quality of OQPSK modulation, the transmission quality of HPSK cannot be inferred to be similar. They are two entirely different structures in the device, each with radically different characteristics on identical baseband signals. Following are several test considerations that are particularly important in verifying cdma2000 functionality as opposed to considerations that would be made for cdmaOne testing.

cdma2000 spectral mask

Typically, spectral mask, otherwise known as adjacent channel power (ACP) or TX spurious emissions, has not been tested in production of cdmaOne mobiles. But due to potentially large peak-to-average ratios of the cdma2000 waveform, especially when the reverse link is

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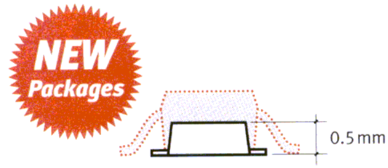

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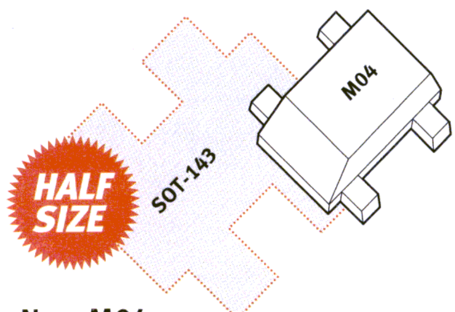

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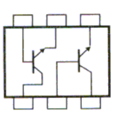

Part Number	Description	Q1 Spec	Q2 Spec
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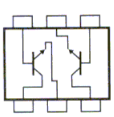
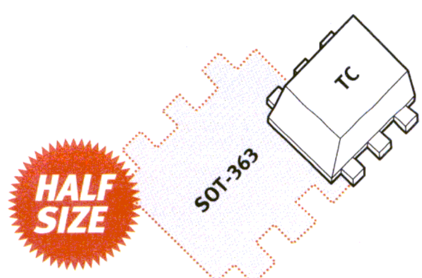
UPA814TC	Matched Die/Cascade LNA	NE688	NE688



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



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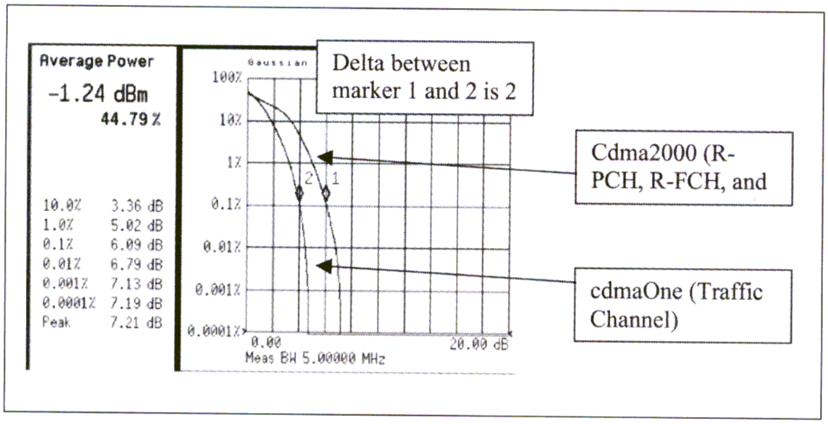


▲ **Figure 2. CCDF plots for cdmaOne and cdma2000.**

transmitting multiple channels at the same data rates, the amplifier has more potential for becoming compressed. This in turn will produce increased power leakage into the frequencies outside of the channel. Thus, the capacity of adjacent channels that might be utilizing cdmaOne technologies or other cdma2000 deployments will be affected. Service providers are especially concerned with spurious emissions that may end up in their competitors frequency blocks. Service providers will rely heavily on this measurement for determining cdma2000 mobile quality. As cdma2000 networks are deployed and populated.

Figure 2 shows a comparison of CCDF plots for cdmaOne and cdma2000 waveforms. As shown, the plot for the cdma2000 waveform is 2 dB greater in its peak-to-average ratio when incorporating a reverse waveform with the R-PCH, R-FCH, and R-SCH1. Relying on the ACP results of a cdmaOne device to be similar to a cdma2000 device will lead to the potential for releasing cdma2000 devices that interfere with other adjacent services, especially when the device is transmitting the maximum channel options at full rate.

Multicode Rho

Waveform quality, known as Rho, is the primary test used in manufacturing CDMA mobiles to determine the quality of the mobile's transmitter. Since cdmaOne compliant mobiles only have one channel (the traffic channel on the reverse link), TIA/EIA/IS-98-C (cdmaOne minimum performance standards) only specified this measurement on the traffic channel. Because cdma2000 compliant devices have multiple channels during normal operations, the standards defined a waveform quality test measured as preamble waveform quality or pilot only waveform quality. TIA/EIA/IS-98-D (cdma2000 minimum performance standards) specifies this test to be performed during the preamble associated with a hard handoff, where the pilot is the only channel that is transmitted. This may be problematic because the mobile is being tested for transmission quality in a mode that rarely occurs and is not realistic to the typical waveforms that can impact the capacity of a cdma2000 network.

As a result, Agilent Technologies has developed an alternate method of measuring the waveform quality of a cdma2000 mobile phone. This method allows the waveform quality to be determined with all code channels active (R-PCH, R-FCH, R-SCH1/R-SCH2/R-DCCH). This provides the user with the flexibility to perform concurrent transmitter tests while performing receiver sensitivity tests. In addition, the mobile is tested in a realistic operating mode, with all applicable channels active as would be in an active network. This is the preferred method.

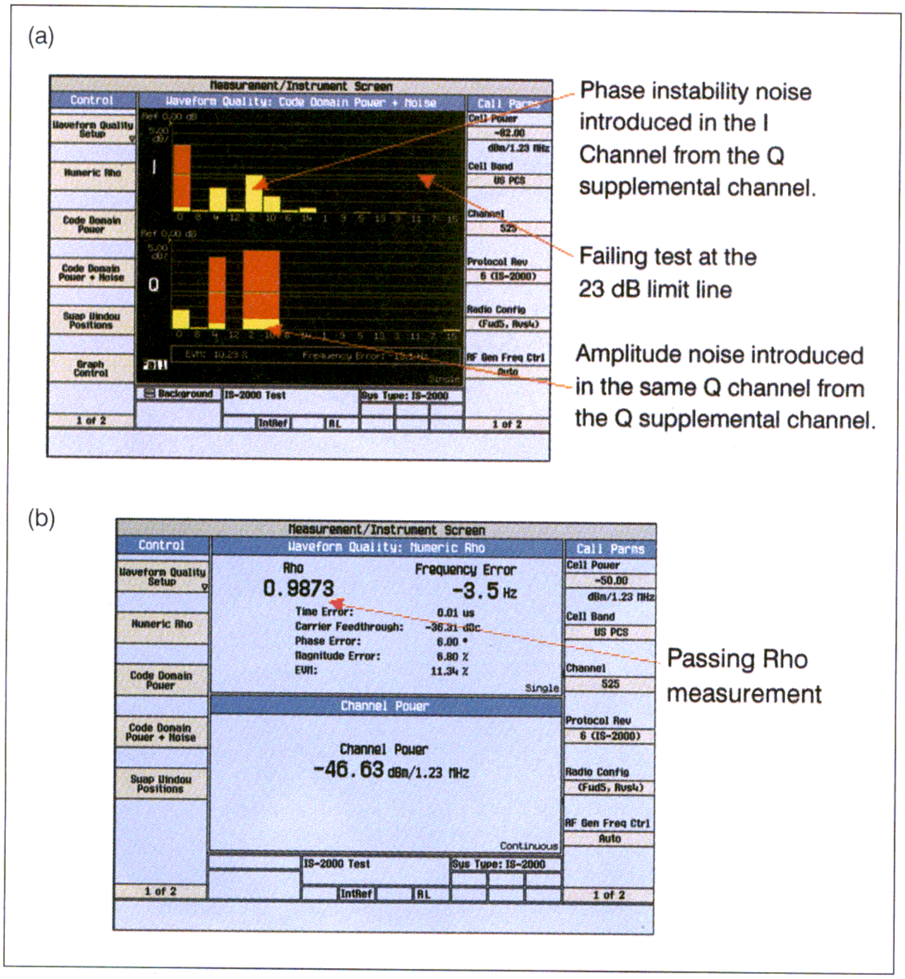
Code domain power

TIA/EIA/IS-98-D has incorporated an additional minimum recommended test called code domain power. This measurement is capable of demodulating and analyzing the specific Walsh channels that make up the composite cdma2000 waveform. Due to the complex modulation scheme used in cdma2000 as compared to a BPSK based modulation scheme used in cdmaOne, significant noise in the active, as well as inactive Walsh channels can be detected.

Waveform Quality is a key measurement for cdma2000 mobiles, but it is not sufficient to fully test the functionality of the cdma2000 transmitter as compared to the cdmaOne transmitter. Simply testing the waveform quality of the cdma2000 waveform, or worse yet, testing the waveform quality of cdmaOne functionality and inferring cdma2000 transmitter quality will not reveal anything about the noise contributions in and out of the code channel. It is entirely possible to have a passing Rho value (0.97 as compared to the 0.944 specification) and still have a code domain noise issue. The TIA/EIA/IS-98-D standards specify that the code domain noise in inactive channels must be below 23 dB of the overall power that is transmitted. The primary source for code domain noise, in and out of the active Walsh channels, is from either amplitude error or phase error in the cdma2000 Modulated waveform. Figure 3 shows a comparison of the waveform quality passing value and the failing code domain power measurement.

Maximum power calibration

Since the waveforms of a cdma2000 mobile can incur much higher peak-to-average ratio transmission, especially when transmitting all channels, accuracy in measuring the transmitted power becomes more difficult. In the past, standard diode slope detectors were sufficient to accurately measure the average power of a cdmaOne transmission. Now that cdma2000 incorporates multiple channels at high data rates, the high peak-to-average



▲ **Figure 3. (a) Code domain power display on the Agilent E5515C/E1962B. (b) Waveform quality or Rho on the Agilent E5515C/E1962B.**

ratio potential increases the inaccuracy of a standard diode power detection method.

The desired accuracy for a power detector used for maximum power detection is around 0.2 dB. Since many service providers require that mobile devices transmit as little power as possible, while still passing the maximum power specification. By calibrating the mobile device's maximum power gain to as close to the lower limit of the specification as possible, battery life is increased and possible noise contributions in neighboring base stations is reduced. Therefore, the capacity of the network is increased overall. For example, by maintaining a 0.5 dB or better accuracy in the maximum power calibration and verification process, the resolution to which the maximum power can be calibrated and verified becomes at least 0.5 dB. This example takes into account other potential system uncertainties.

Due to the waveform differences in cdma2000 mobiles, a thermal power detector should be used to provide a comparable level of accuracy in maximum power calibration as compared to a diode slope detector method used in cdmaOne power calibration.

Temperature compensation

Temperature compensation is often used in the calibration process of a mobile device. Because cdma2000 devices have a high peak-to-average ratio, the power amplifiers used to generate the RF waveforms require more bias current. This in turn will cause the power amplifier (PA) to heat up differently as compared to a cdmaOne device. Heat generated from the PA causes adjacent components to potentially change their characteristics. Filters and mixers are primarily subject to variations due to temperature changes.

The cdma2000 implementation has a much higher potential peak-to-average ratio compared to the cdmaOne implementation. Therefore, the power amplifier heats up differently for the various channel implementations compared to the single traffic channel that is always transmitted by the cdmaOne mobile. Accuracy of the temperature compensation will be degraded by directly inferring cdma2000 calibration factors from the temperature calibration factors of a cdmaOne transmission.

The effects of temperature on mixer and filter performance will vary as the transmission channelization of the cdma2000 reverse link changes. A particular temperature calibration for a cdma2000 reverse link with the R-PCH and R-FCH active may not be valid for a cdma2000 reverse link with the R-PCH, R-FCH, R-SCH1, and R-SCH2 active. It is not correct to assume that the temperature effects and power transmission accuracy of a reverse link with R-PCH and R-FCH active is the same as a reverse link with all possible channels active. Ideally, each transmission possibility should be considered individually with respect to temperature compensation. Without considering each case separately, it is likely that unintended performance at the various channel configurations will become an issue.

The same argument is true for the receiver temperature compensation. The sensitivity point of the mobile must be different due to the temperature effects on the receiver front end. This will be especially noticeable if the cdma2000 mobile device is marginal in sensitivity, meaning that the actual sensitivity point of the receiver is close to the test specification.

Conclusion

At first glance, cdma2000 and cdmaOne technologies may seem similar. To some extent this is true, but in terms of accurately calibrating and verifying functionality, there are substantial differences that will impact the quality of the mobile if inferences are made based on cdmaOne performance. Inferring cdma2000 functionality based on cdmaOne test processes should not be made:

- cdma2000 and cdmaOne have different modulation structures, which affect the overall transmitted waveform and causing variations in peak-to-average power transmission.
- The physical component biasing is primarily different between the cdma2000 and cdmaOne transmitter and receiver paths. By testing the cdmaOne functionality with its unique biasing, the functionality of the cdma2000 components is not truly determined. This is especially true when it comes to accurately calibrating the receiver and transmitter paths for power level accuracy and temperature compensation.
- Due to the difference in the cdma2000 waveform, new measurements must be introduced into the verification process to fully verify the functionality of the individual cdma2000 device. These new measurements are multi-code Rho, code domain power and spectral mask.

Marginality of the mobile's design and the implemented channelization (R-PCH, R-FCH, and R-SCH1/R-SCH2/R-DCCH active) in which the cdma2000 mobile is tested will have an effect on the quality of the cdma2000 device that is produced. It is always desirable to test for the worst case, or at least test to the most realistic "real life" scenario. This paper has offered suggestions for determining a production test process and the equipment used to test cdma2000 functionality in order to meet these objectives. Each implementation should be based on an evaluation of costs and benefits. ■

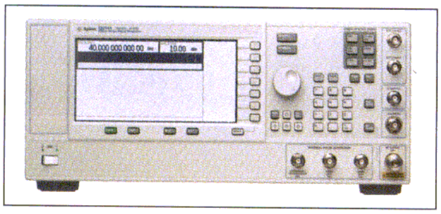
Author information

Ryan Hendrickson is a product manager for CDMA Mobile Test Solutions for the Spokane Division Marketing Department of Agilent Technologies. He received a 1997 BSEE from Montana State University and was hired by Hewlett Packard but transitioned from HP to Agilent Technologies during the company split. He has published numerous technical articles on CDMA and mobile testing. He may be contacted via e-mail at ryan_hendrickson@agilent.com.

Featuring: New Products Introduced at the 2001 IEEE International Microwave Symposium

Microwave signal generator

Agilent Technologies has introduced two performance signal generator (PSG) series designed to allow broadband component manufacturers who design and test systems with high frequencies, wide

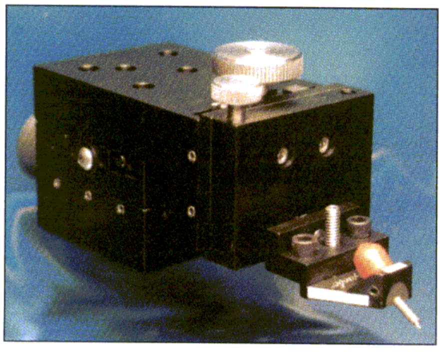


bandwidths and complex modulation formats to accelerate design, simplify test and streamline production through incorporation into their design and production cycles. Agilent's PSG consists of two series; the Microwave PSG-L Series is optimized for local oscillators (LOs), while the PSG-A Series is optimized for analog modulation. Both series are available in 20 and 40 GHz models.

Agilent Technologies, Inc.
Circle #165

Personal probe station

J microTechnology has announced that its KRN-18A precise positioners have been improved to offer smoother control, larger "Z-axis" travel and improved knob adjustable planarity. Vertical translation, "Z-axis" is now 0.45 inches



on a cross roller bearing slide assembly. A knob adjustable planarity, KRN-KAP module can be bolted to the front of the compact positioner to allow ±10 degree adjustment, suitable for the widest pitch microwave cpw probes.

J microTechnology
Circle #166

Cable assembly series

Semflex has introduced its new LAI series of interconnect assemblies, designed for telecommunications and military/aerospace applications up to 18 GHz, where low loss and relatively long length

interconnects are required. Constructed of double shielded cable with a standard FEP Teflon® or optional polyurethane jackets, the LAI series delivers a low loss performance of 20 dB per 100 feet at 18 GHz, along with phase and temperature stability of 15 ppm degrees Celsius.

Semflex, Inc.
Circle #167

Co-siting diplexers

M/A-COM, a division of Tyco Electronics, has introduced a new line of custom co-siting diplexers

for wireless communications infrastructure applications. This product family allows for co-siting various air interface systems at a common base station. The diplexers feature high Q filter technology for low loss and high selectivity in a relatively small package size. These units provide passive intermodulation products of less than –100 dBm tested with two 20-watt input signals. Type N connectors, as well as 7/16-inch DIN connectors, are available.

M/A-COM
Circle #168

One-instrument solution synthesizer

Anritsu has introduced the MG3690A synthesizer, a single-instrument solution that combines the bandwidths of separate RF and microwave signal generators with the spectral purity and frequency stability of a phase-locked source.

The MG3690A achieves frequency resolution of 0.1 hertz over the full frequency range, with leveled output power adjustable in 0.01 dB steps from –120 dBm to +17 dBm.

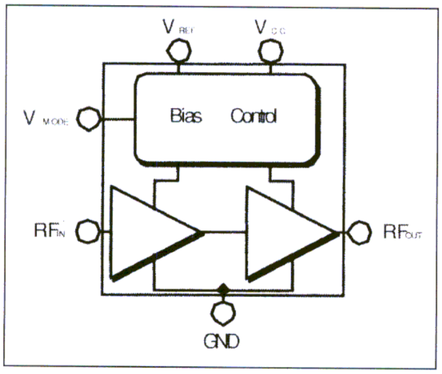
Anritsu Company
Circle #169

Circle 64

Products

Amplifiers for dual-mode wireless applications

Anadigics has introduced two new InGaP HBT power amplifiers for use in multi-mode, multi-band CDMA handsets that support 2.5 G

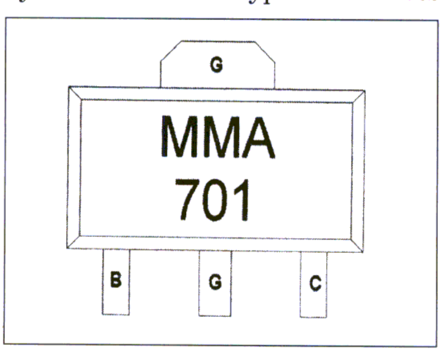


CDMA applications. The AWT6105 is specifically designed for cellular CDMA, CDMA-1X and AMPS applications in the 824 to 849 MHz range, and the AWT6106 is targeted for PCS CDMA and CDMA-1X applications operating at 1850 to 1910 MHz. Both devices combine all of the necessary passive components for full compensation and 50-ohm input/output matching. The AWT6105 and AWT6106 are +3.5 VDC devices with a 6 × 6 mm footprint, 1.6 mm profile and low leakage.

Anadigics, Inc.
Circle #170

High-linearity HBT

Metelics has introduced the MMA701, an InGaP HBT amplifier in a SOT-89 surface mount package. The MMA701 will produce +45 dBm OIP3 at the minimum bias voltage and is suited for cellular/PCS, 2.5/3G, WLL and MMDS systems and other types of wireless



applications where high-gain, high P_{1dB}, high OIP3 and convenient power down are required. Custom packages and die options are also available.

Metelics
Circle #171

Design software update

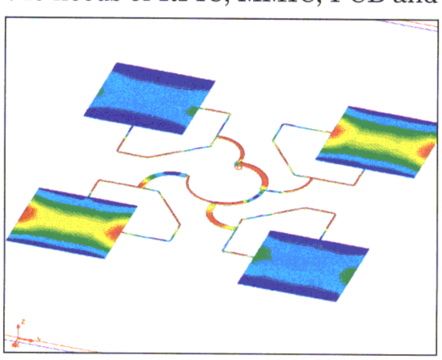
Applied Wave Research has updated its Microwave Office™ 2001 software. Improvements

include a new COM-based design automation interface; a new harmonic balance simulator; new layout editing features and design rule checking; and new nonlinear and linear models.

Applied Wave Research
Circle #172

Antenna design software

Ansoft has announced the latest release of Ensemble, [Version 8.0], with new functionality targeting the needs of RFIC, MMIC, PCB and

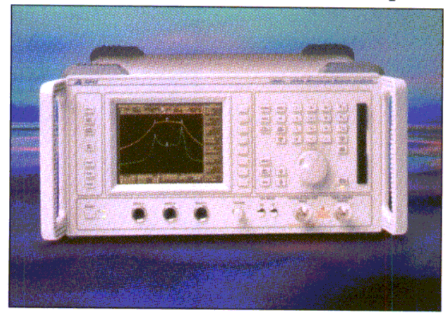


planar antenna designers. New features in Ensemble 8.0 include Full Wave™ Spice capability, improved modeling, speed and user-interface enhancements and second-generation Optimetrics™.

Ansoft Corporation
Circle #173

System analyzer

IFR Systems has added group delay measurement capability to its 6845 microwave system analyzer (MSA). Previously available up to



24 GHz, the 6845 group delay option adds group delay measurements and frequency modulation for microwave test applications up to 46 GHz. Now all 6840 series models can be offered with a group delay module using an expansion slot inside the instrument.

IFR Systems, Inc.
Circle #174

Commercial VCO

Vari-L's new Model VCO191-915W generates frequencies from 902 to 928 MHz, with control voltages from 0.4 to 2.5 Vdc. The unit typically requires 7.0 mA of current from a 3.0 V supply voltage. Typical phase noise is 100 kHz, offset is –127 dBc per hertz, typical output power is –3.0 dBm, second harmonic suppression is typically –15 dBc and third harmonic supporession is typically –20 dBc. The unit is housed in a 8 × 6 × 2 mm surface mount, pick and place/reflow compatible package.

Vari-L Company, Inc.
Circle #175

RF modulator

Analog Devices introduces its new AD8345, a 1 GHz quadrature modulator designed for use as an IF modulator in cellular IS95, IS136,

BLINDMATE
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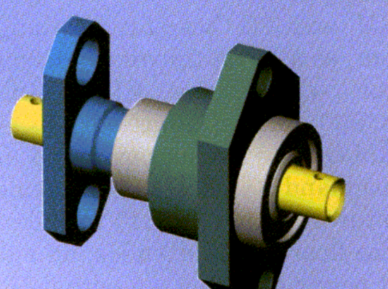
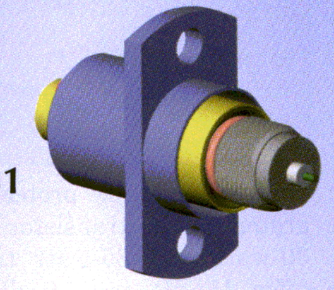
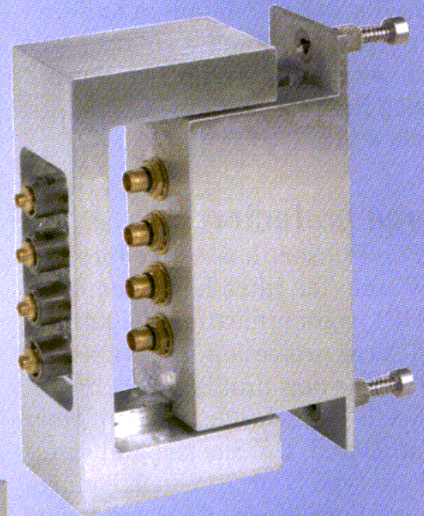
Connectors & Components

Features



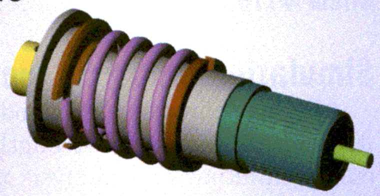
- Offers the advantage of slide-on mating while providing superior microwave performance
- Unique spring-loading mechanism allows for axial and radial misalignment
- Increased package densities
- Quick connect/disconnect
- Lower applied cost
- First QPL source for Mil PRF-31031

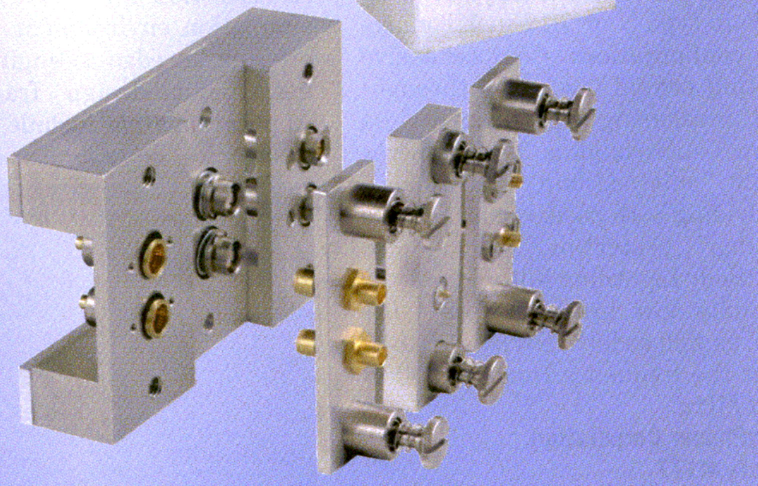




Configurations

- Semi-rigid and flexible cable connectors
- Hermetic versions and adapters
- Fixed and floating versions
- Low profile
- High power
- Stripline and microstrip launchers
- Adapter
- Terminations





Typical Applications

- Radars and sensors
- Integrated avionics
- Missile systems
- Navigation systems
- Automated test equipment
- Satellite communication
- Wireless/broadcast

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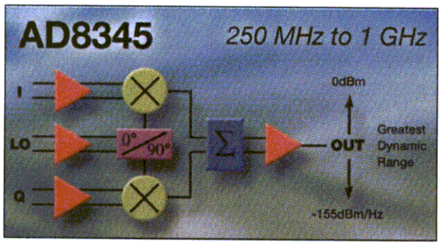
Circle 27

Products



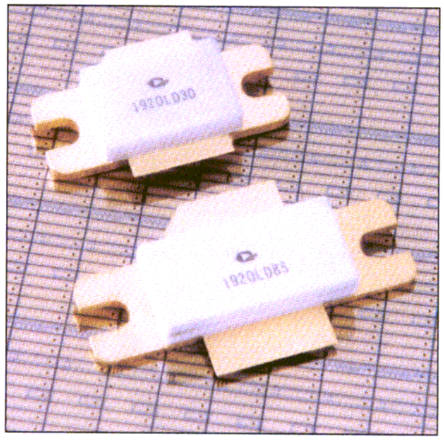
GSM and 3G basestation equipment, as a direct conversion modulator within the CDMA/GSM 800/900 MHz bands or as a QAM/QPSK modulator found in broadband access systems. Features of the AD8345 include a noise floor of 155 dBm/Hz, an output power of 0 dBm, an output IP3 of +25 dBm, a simplified interface to ADI's TxDAC® family, a buffered 50 output stage and a single 3 volt or 5 volt supply with power down.
Analog Devices
Circle #176

Surge protector

PolyPhaser has introduced a new unit for ultra-high frequency (UHF) communications lightning and surge protection. Known as the UF50, the new unit is approximately 5 × 1-3/4 inches long, completely weatherized, DC blocked and available in type N or 7/16-inch connector configurations. Comprehensive testing proved low surge throughout measuring significantly less than 5 microjoules at 3 kiloamperes (8/20 microsecond waveform). Providing both positive and reverse voltage protection, the Micro UniBody Lightning Filter Protector exhibits low insertion loss (≤0.1 db), as well as low VSWR (≤1.1 to 1) over the frequency range of 300 to 700 MHz.
PolyPhaser Corporation
Circle #177

LDMOS transistors

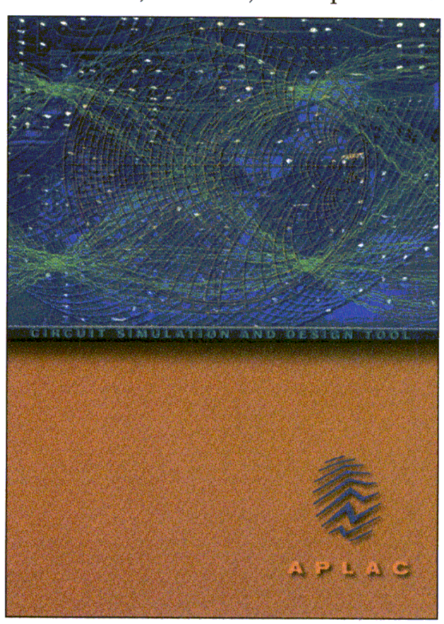
GHz Technology has debuted its first two designs in a series of lateral diffusion metal oxide semiconductor (LDMOS) transistors developed for the wireless infrastructure marketplace. GHz Technology offers two LDMOS transistors: a 30-watt (1920LD30) and a 85-watt (1920LD85). Both transistors initially target the 1.9 GHz personal communications band and offer gold metalization for enhanced reli-



ability and ESD protection integrated on the transistor chip. The 30-watt and 85-watt transistors offer 11 dB and 10 dB of gain respectively.
GHz Technology, Inc.
Circle #178

Simulation, analysis tools

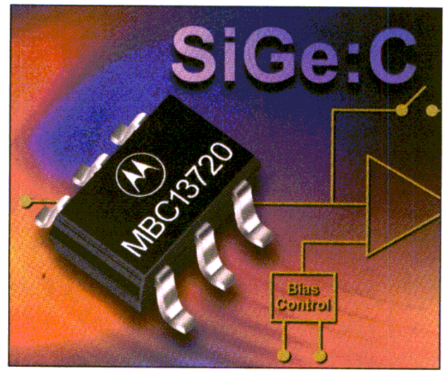
APLAC Solutions has introduced its family of industrial-strength circuit simulation and analysis tools. APLAC 7.61 introduces an open-simulation environment approach, offering an edge to engineers who use major design frameworks. Application areas include consumer electronics, defense, aerospace and



the automotive industry. APLAC technology covers applications ranging from ICs to board- and system-level simulations, from DC to RF and microwave frequencies.
APLAC Solutions Corp.
Circle #179

Low noise amplifier

Motorola's Semiconductor Products Sector has introduced its first SiGe:C low noise amplifier with an on-chip bypass switch. This device uses the SiGe:C module of Motorola's advanced 0.35 micron RF BiCMOS process. Features include an integrated bypass



switch, low noise figure, high input IP3, receive/enable pins, selectable current settings, simplified off-chip matching, packaging in an ultra-small SOT-363 surface mount package, usable frequency range of 400 to 2400 MHz, low standby current < 20 microamps and supply voltage from 2.5 to 3.0 volts.
Motorola
Circle #180

CDMA power amplifier

TriQuint Semiconductor announces the release of a jointly developed CDMA/AMPS power amplifier, the TQ7135. This power amplifier is the first product released by TriQuint and Atmel's CDMA345™ joint development project. A companion PCS-band CDMA power amplifier is scheduled for release later this year. These introductions represent the first step in the planned release of a complete CDMA RF transmit solution this year. Features of the tyco | Electronics M/A-COM

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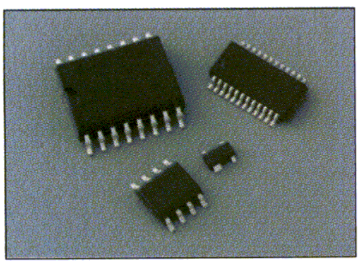
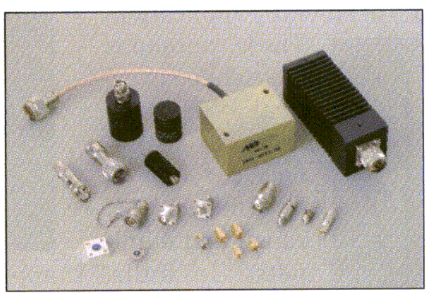
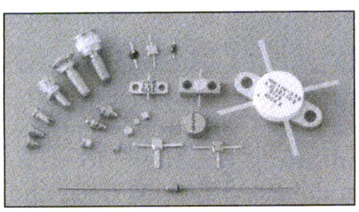
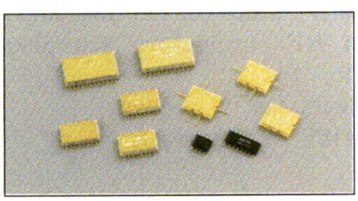
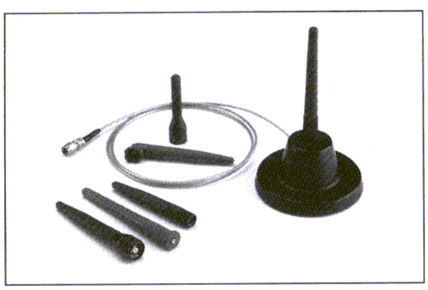


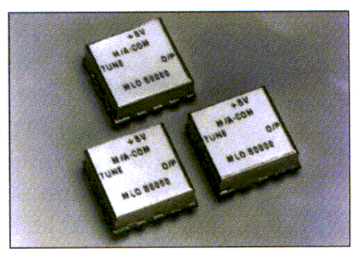


- Antennas
- Cable Assemblies
- Circulators & Isolators
- Connectors
- Couplers
- Fixed Attenuators
- Integrated Circuits
- Mixers and Modulators
- Power Dividers & Combiners
- Power Transistors & Amplifiers
- Schottky and PIN Diodes
- Switches & Attenuators
- Terminations
- Transformers
- VCOs and Synthesizers









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Circle 26

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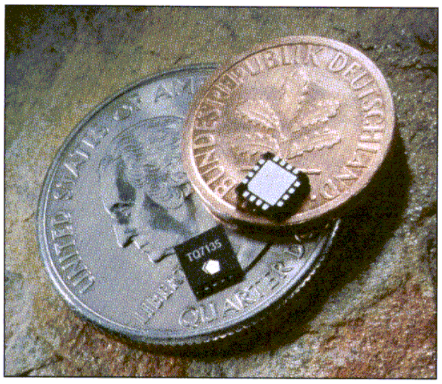


TQ7135 include high efficiency, ACP and ALT; quiescent current switch and low quiescent current; a single +3.0 volt operation; a small 16 pin, 4 mm square surface mount fine pitch lead-less package; few external components; and full ESD protection.

TriQuint Semiconductor, Inc.
Circle #181

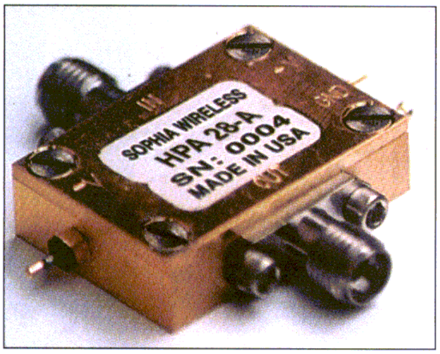
High-Q-cavity oscillator

The free running high-Q oscillator of Huber+Suhner provides a stable, fixed frequency microwave signal source for application as reference or local oscillator in autonomous electronic systems for airborne, satellite and terrestrial communications. Features include temperature stability, low phase noise and no moveable parts, resulting in low impact of shaking and low microphonic effects.

Huber+Suhner AG
Circle #182

High power amplifiers

Sophia Wireless has introduced a new family of high power amplifiers, which offer output power for LMDS, point-to-point digital radio, satellite transmitters and other

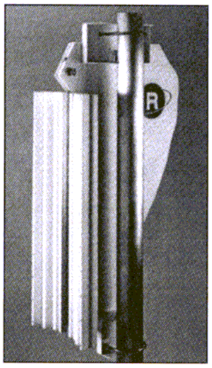


millimeter-wave applications. The HPA28 and HPA38 amplifier families have many features and benefits, including 2.9 mm (f) input/output connection with DC isolation, small footprint and low profile, high thermal conductivity housing for long-term reliability, low DC power consumption, low cost, high and low gain varieties and block/mounting hole compatible with DRVR and LNA series. Nominal output power is +30 dBm at 28 GHz for LMDS and +26 dBm at 38 GHz for point-to-point applications, with enough bandwidth to cover surrounding frequency bands with the same amplifier.

Sophia Wireless, Inc.
Circle #183

Sectorized hub antennas

REMEC Magnum has announced the latest in its family of SectorShape™ antennas. The Series AMH2000 SectorShape antennas are designed for a 3.5 GHz hub (head-end) application.



These antennas have shaped vertical patterns that provide uniform coverage as a function of range and eliminate nulls. Three horizontally polarized and three vertically polarized standard models operate over the 3400 to 3600 MHz frequency range. Azimuth sector coverage of 45, 60 and 90 degrees Fahrenheit is available, and power capacity is rated at 450 watts.

REMEC Magnum
Circle #184

High frequency laminates

GIL Technologies has introduced its new GML 2000 Series of high frequency laminate materials. The series uses new TPA resin chemistry to combine electrical properties with the advantages of a thermoset, providing an alternative for printed circuit materials in flat panel antennas, transceivers, LNBs, LNAs and other high-demand applications. The first new product in the series, GML 2032, has a dissipation factor of 0.0029 and a dielectric constant of 3.20 at 10 GHz.

GIL Technologies, Inc.
Circle #185

Coaxial switch

DB Products has introduced a 2SB Series SPDT coaxial switch for the commercial wireless and telecommunications industry. This DC to 3 GHz switch is ideal for PCS, ISM and broadband systems

applications. Standard options include failsafe or latching operation, indicating circuitry, arc suppression diodes, TTL interface and mini-SMB snap-on connectors. Custom RF connectors are also available.

DB Products, Inc.
Circle #186

Bandpass filter

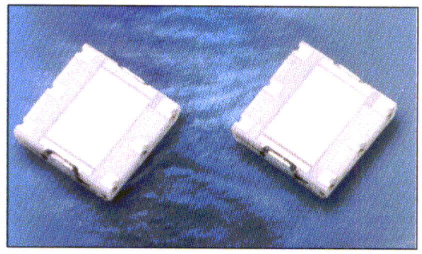
Compel Electronics has announced the availability of a small size filter for clock recovery circuits in OC 192 10 Gb/s optical communications architectures. Operating at 10 GHz, the new Model FDR10-4 bandpass filter offers maximum insertion loss of 0.7 dB, VSWR of 1.1:1 maximum, frequency stability of 14 ppm

degrees Celsius and power handling of 10 watt maximum. Package size measures 2.83 × 0.67 × 0.87 inches, plus connectors. SMA female connectors are standard; however, alternate connector or pin requirements can be satisfied upon request.

Compel Electronics, Inc.
Circle #187

HBT amplifiers

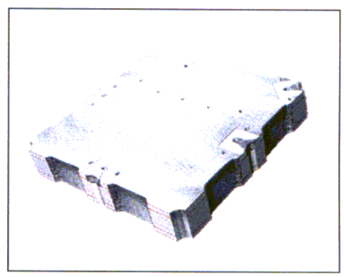
Mitsubishi Electric & Electronics USA has rolled out two new radio frequency amplifiers for the PCS cellular phone market. This new chipset boasts increased performance over the previous model, with a 25 percent reduction in idle current and a 35 percent reduction in overall size. The BA01202 is designed for the 1.9 GHz CDMA band and is complemented by the BA01203, designed for the 800 MHz CDMA band.



Mitsubishi Electric & Electronics USA
Circle #188

Vector modulator

The Multi-Mix® VMD-Q series provides a vector modulator with variable IQ control of phase and amplitude in a surface mount outline. Features include frequency from 2.04 to 2.24 GHz, 30 dB attenuation range, 360 degree phase range, surface mount, and tape and reel. The series is cost effective for commercial wireless applications and offers surface mount outline, operating temperature range of –55 to +85 degree Celsius range. It can be integrated with other Multi-Mix® components in a multi-function module.



Multi-Mix Microtechnology
Circle #189

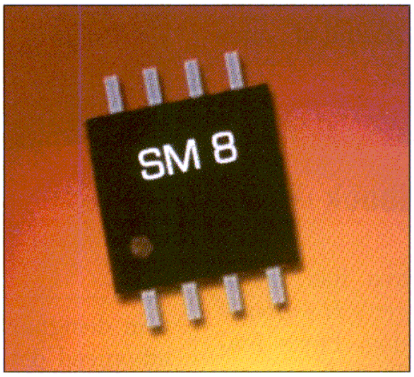
Bluetooth™ module

Murata Electronics North America has introduced Blue Module™, the world's smallest Bluetooth™ module. Developed using low temperature co-fired ceramics (LTCC) technology, the module integrates both active devices (ICs) and passive components onto a single surface mount ceramic chip that supports universal serial bus, universal asynchronous receiver transmitter and pulse code modulation interfaces.

Murata Electronics North America
Circle #190

Compact RF components

Toshiba has broadened its portfolio of ultra-compact radio frequency components with new devices designed for use in cable TV tuners, cable modems and Bluetooth™ applications. Called cell packs and designated the TA4107F and the TA4018F, these devices provide a way for designers to implement a variety of communications functions. Toshiba's growing cell pack lineup, which now includes more than 20 products, helps reduce time, component count and board space by allowing RF engineers to use one cell pack instead of multiple discrete devices.



Toshiba America Electronic Components, Inc.
Circle #191

PLL for wireless market

TEMEX has introduced a complete line of phase locked loops for the wireless market. These PLLs have been designed for high volume, surface mount and low cost applications including GSM, DCS, PCs and the UMTS BTS market. The PLLs cover the frequency from 750 MHz to 2.2 GHz, with bandwidth up to 20 percent. SSB phase noise is as low as –148 dBc at 800 kHz for GSM application and – 140 dBc at 800 kHz for DCS; and output power from –1 to +4 dBm. The PLLs offer fast switching speed, 5-volt power supply and charge pump (available) and programming by one three-wire port (clock, enable and data).

TEMEX Components
Circle #192

Connector system

EZ Form Cable has introduced its EZ QuickSnap Connector System. The system offers snap-on convenience, can be used with any SMA jack and is ideal for test fixtures. Specifications include characteristic impedance of 50 ohms nominal, a frequency range of DC to 20 GHz, insulation resistance of 5000 megohms minimum, dielectric withstanding voltage of 1000 V_{RMS} and a voltge rating of 335 V_{RMS}.

EZ Form Cable Corporation
Circle #193

Coaxial connector series

Sabritec's SMP coax connector line features a snap-in vibration proof connection, suitable for high shock mobile applications and space level connector require-

ments of extreme random vibration, thermal shock and outgassing environments. Frequency range is DC to 40 GHz. The small package size allows for high density board-to-board applications.
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Adapter kit

J microTechnology has introduced a printed circuit card chuck adapter kit (LMS-10) for the Jr-2727 personal probe station. This product improvement makes the test system, with its coplanar RF/microwave probes, compatible with the PCBs and substrates made of epoxy glass, PTFE glass, polystyrene and ceramic materials. Printed circuit cards are ideal test fixtures in that they reflect the actual environment of the devices under test. The PCB card chuck kit will capture a substrate/pcb up to 2.25 inches wide and greater than 4.0 inches long of thicknesses from 5 to 25 mils.
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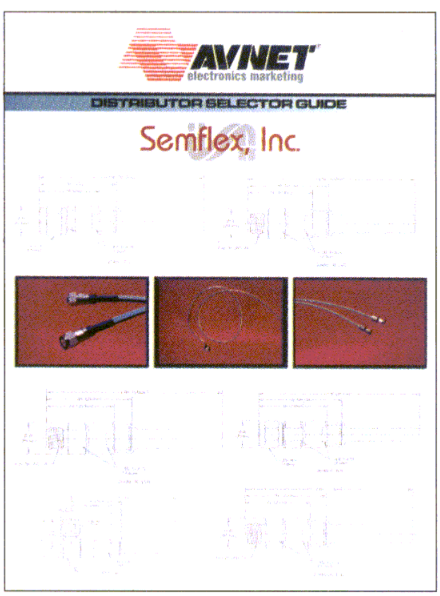
Catalog of coaxial cable assemblies

Avnet is stocking more than 150 coaxial cable assemblies from Semflex for test and measurement and production applications. These cables are ideal for communications infrastructure and test, where performance and repeatability are required. Frequency response is up to 50 GHz on the test and measurement cables and 18 GHz on the production cables. Connector styles include 2.4, 2.9, 3.5 and 7 mm, SMA, N and TNC.



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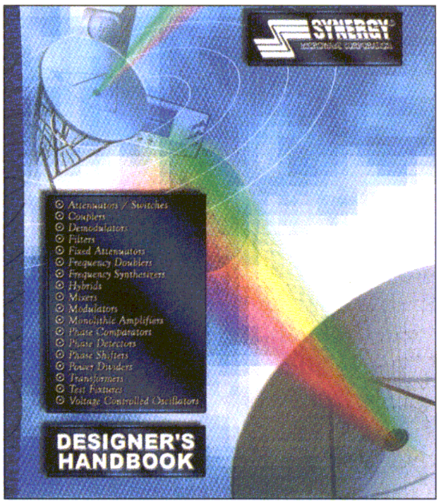
Designer's handbook catalog

Synergy Microwave has introduced its new *Designer's Handbook* standard parts catalog. Parts featured in the catalog include attenuators, switches, couplers, demodulators, filters, fixed attenuators, frequency doublers, frequency synthesizers, hybrids, mixers, modulators, monolithic amplifiers, phase comparators, phase detectors, phase shifters, power dividers, transformers, test fixtures and voltage controlled oscillators.



Synergy Microwave Corporation
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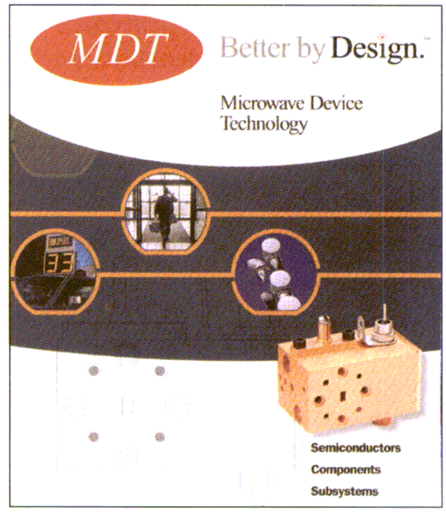
Product brochure

Microwave Device Technology has released its newest product brochure, which highlights the company's current capabilities. MDT manufactures gallium arsenide diodes, sensors, sources and millimeterwave components in support of the commercial, as well as military markets. MDT is a custom designer and manufacturer of advanced devices, components and subsystems for telecommunications, wireless, automotive, security, safety, industrial processing and traffic management applications.



Microwave Device Technology
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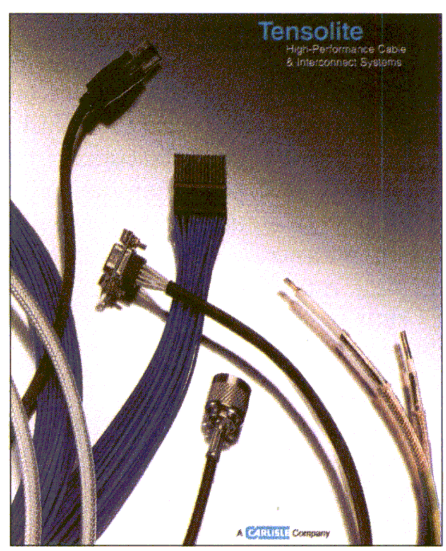
Cable and interconnect systems catalog

Tensolite's new catalog features its high-performance cable and interconnect systems. Products featured in the catalog include high-density cable assemblies, RF and microwave assemblies and connectors, precision coaxial and multiconductor harnesses and assemblies and high-performance wire and cable.
Tensolite Company
Circle #199



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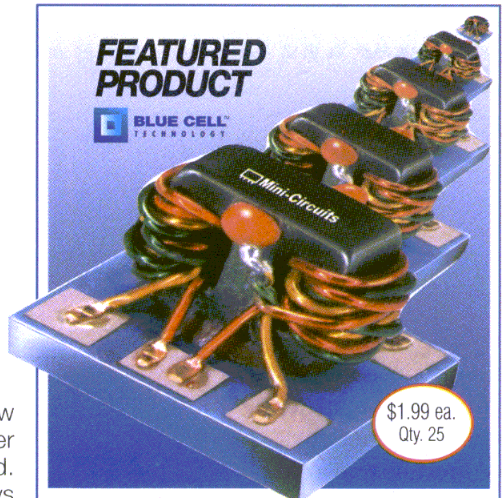

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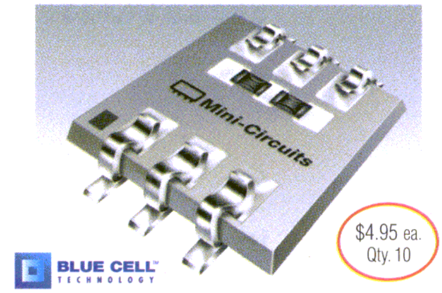

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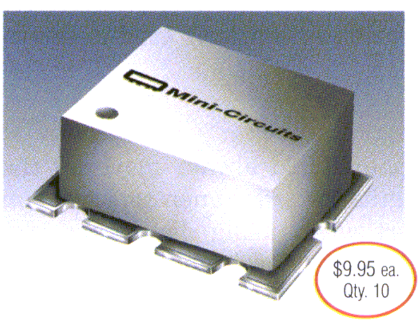

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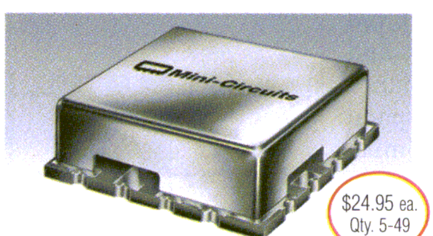

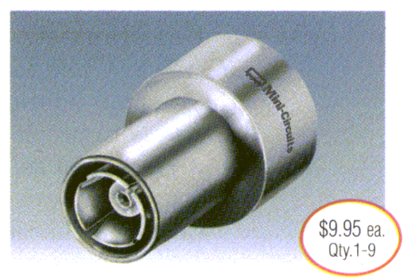

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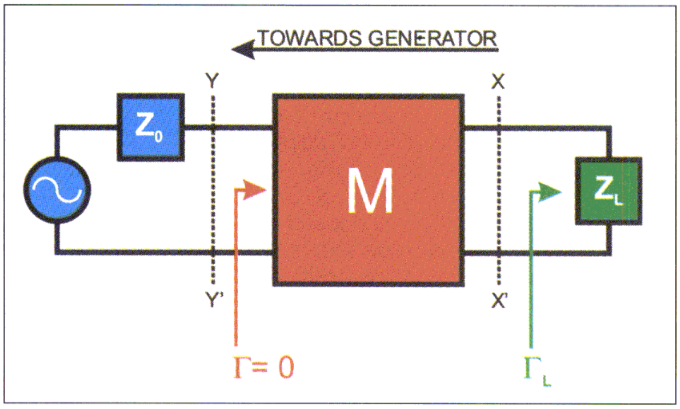
Common Mistakes (and How to Avoid Them) in Impedance Matching Network Synthesis

By Justin Magers
Anritsu Company

Frequently, students or those new to impedance matching will synthesize the wrong matching network when applying textbook methods to real designs, such as the small-signal transistor amplifier. The two problems which manifest themselves most often are whether to start with the reflection coefficient or the conjugate reflection coefficient (i.e., where to start on the Smith chart), and whether to move towards the generator (load-to-source) or towards the load (source-to-load).



▲ **Figure 1. Textbook matching problem: Load-to-source matching.**

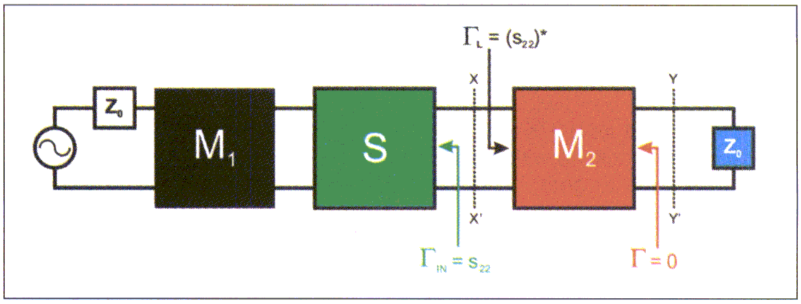
Unfortunately, many popular microwave textbooks fail to point out these small subtleties. The goal of this article is to provide a simple and consistent method of setting up the correct matching network synthesis problem.

Consider the standard textbook impedance matching network design problem (Figure 1). The student is presented with a load impedance Z_L and is asked to synthesize the matching network M, which matches the load impedance Z_L to the generator impedance Z_0.

For this article, the color blue has been intentionally mapped to the "generator" impedance (port Y–Y'), red to the matching network and green to the "load" impedance (port X–X'). These correspond to movement on the Smith chart.

The problem can easily be solved by plotting the "load" reflection coefficient Γ_L, using a single-stub tuner or other matching network and keeping in mind that one should always move on the WTG (wavelengths towards generator) scale on the Smith chart when using distributed elements. Moving toward the "generator" on the Smith chart is analogous to moving to the left on the circuit schematic as indicated.

Now, consider the practical design of an output matching network M_2 for a small-signal unilateral transistor amplifier (Figure 2). Here, the



▲ **Figure 2. Design of an output matching network for a small-signal unilateral transistor amplifier.**

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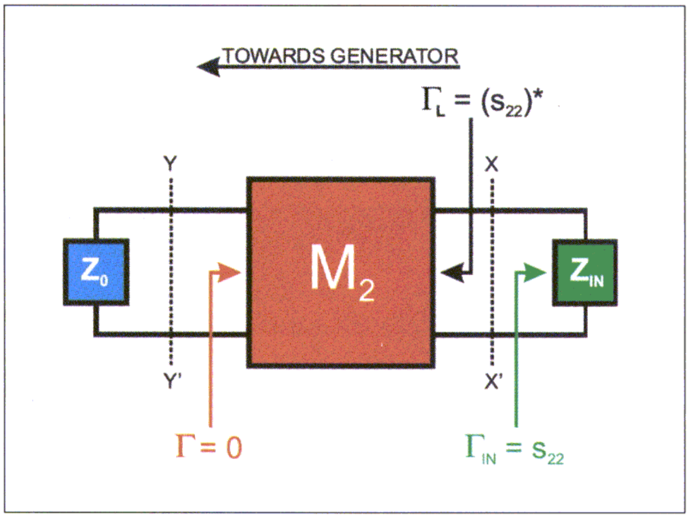


▲ **Figure 3. Matching the load impedance Z_{IN} to the generator impedance Z_0.**

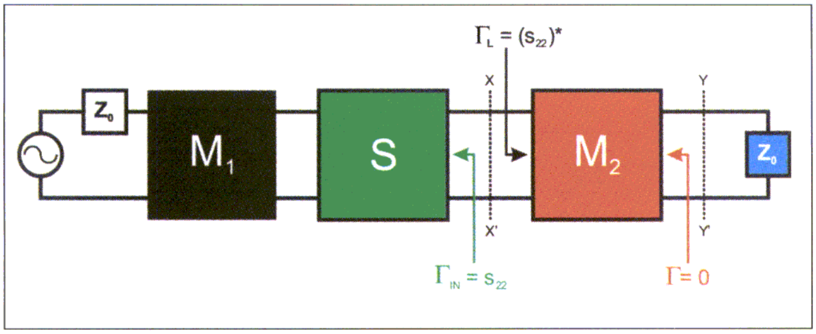
appropriate direction to move on the Smith chart is less trivial.

The student is asked to provide a conjugate matching network such that $\Gamma_L = (\Gamma_{IN})^*$. At this point, confusion can arise: which way is "towards the generator"? Should Γ_L or $(\Gamma_L)^*$ be plotted? The student might even be inclined to follow the textbook method presented in the first example by plotting Γ_L on the Smith chart and moving towards the generator impedance (of the whole system). Clearly, there is room for error if one is not careful. One should also keep in mind that Smith chart software packages can be set up differently — some work from source-to-load, some from load-to-source, and their placement of matching elements can be different as well.

One good method for avoiding these pitfalls is to redraw the network so that it resembles the textbook example given in Figure 1. In Figure 3, the output network of Figure 2 has been redrawn such that moving "towards the generator" is to the left in both Figure 1 and Figure 3.

Further visual simplification is achieved by representing the output impedance of the transistor with load Z_{IN}. Note the similarity to Figure 1 and that the "load" reflection coefficient is Γ_{IN}, not Γ_L. In Figure 1, we would say we are going to match the "load" impedance Z_L to the "generator" impedance Z_0. In Figure 3, we would say that we are going to match the "load" impedance Z_{IN} to the "generator" impedance Z_0. In Figure 3, we are *not* matching Γ_L to the generator impedance.

The original problem of Figure 2 has been effectively redrawn in terms of the classic textbook impedance matching problem (Figure 1), and the solution can be found using the matching network of the student's choice. For clarity, Figure 3 is inserted back into the original network transistor amplifier (Figure 4).



▲ **Figure 4. Network transistor amplifier with Figure 3 inserted.**

Conclusion

When presented with impedance matching problems, mistakes can be avoided by redrawing the network carefully in a form that is consistent with textbook approaches to matching, thus avoiding confusion with the direction of movement and the appropriate starting location on the Smith chart. Furthermore, when using software tools for matching, be sure to understand how the software works in terms of direction and element placement. ■

References

1. G. Gonzalez, *Microwave Transistor Amplifiers Analysis and Design*, 2nd edition, Upper Saddle River, NJ: Prentice-Hall, 1997.

2. F.T. Ulary, *Fundamentals of Applied Electromagnetics*, Upper Saddle River, NJ: Prentice-Hall, 1997.

3. G.D. Vendelin, A.M. Pavio and U.L. Rohde, *Microwave Circuit Design Using Linear and Nonlinear Techniques*, New York: John Wiley & Sons, 1990.

Author Information

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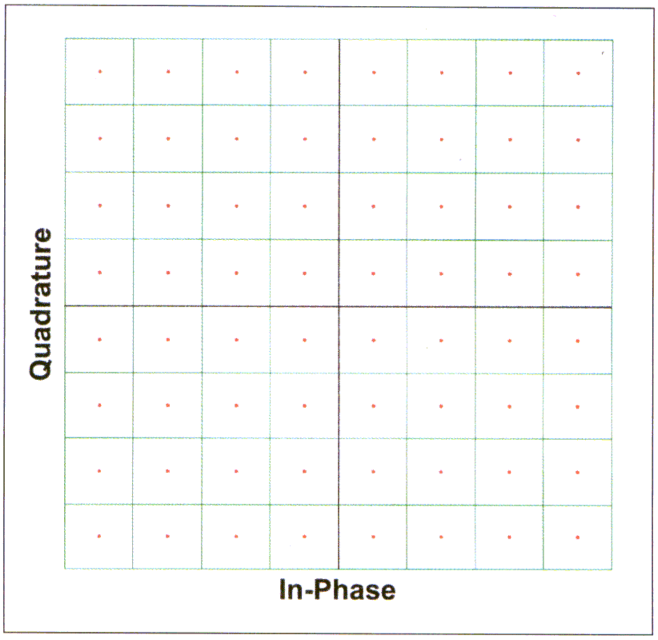
Phase Noise Effects on OFDM Wireless LAN Performance

This article quantifies the effects of phase noise on bit-error rate and offers guidelines for noise reduction

By John R. Pelliccio, Heinz Bachmann and Bruce W. Myers
Raytheon RF Networking

Consumers are looking to wireless data transceivers to convey all types of information. From 3G cell phones to wireless LANs, the convergence of voice, data and video is driving the demand for wireless gear that is capable of transmitting farther, faster and more efficiently than ever before.

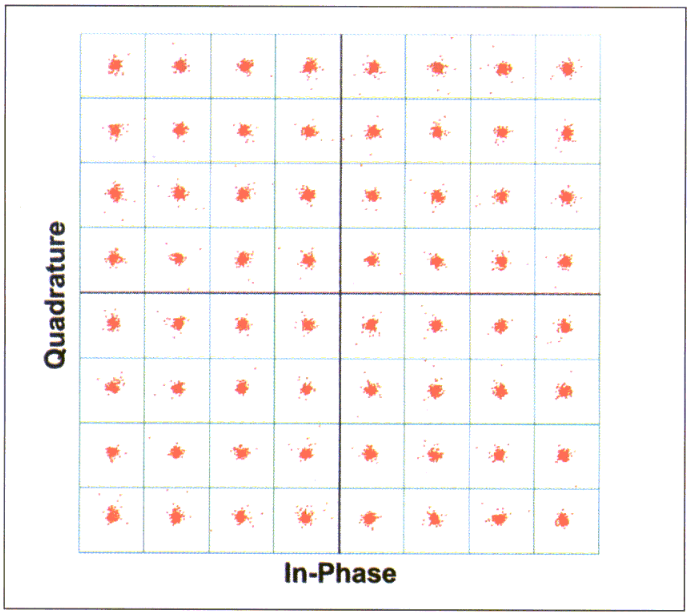
In the wireless LAN industry, for example, the past few years have seen a migration from 1 and 2 megabit per second (Mbps) radios to the recent proliferation of 11 Mbps devices. Driven by the insatiable demand for bandwidth, manufacturers are rolling out plans for products capable of data rates as high as 54 Mbps at frequencies in the 5 to 6 GHz range. These products, based on industry standards such as the IEEE's 802.11(a) and the European Telecom Standards Institute's HiperLAN 2, use a unique and spectrally efficient modulation scheme known as orthogonal frequency division multiplexing (OFDM) to communicate.



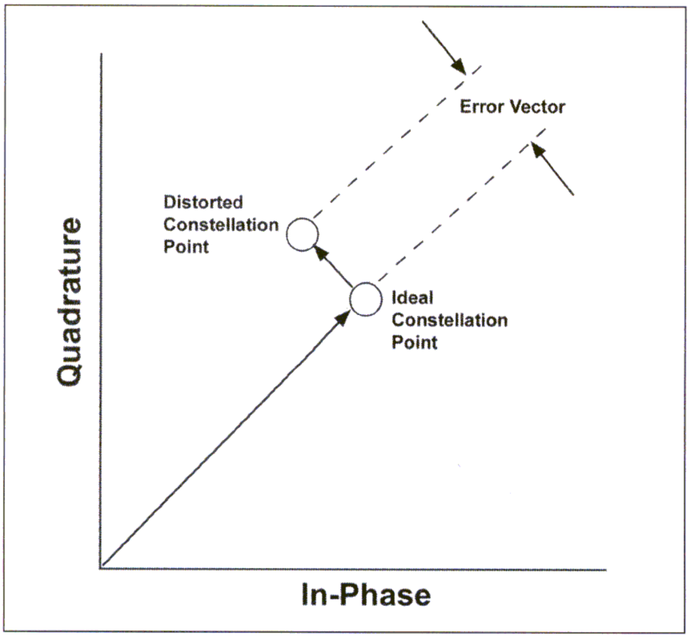
▲ **Figure 1. Constellation diagram of a 64-QAM subcarrier with no distortion.**

OFDM is essentially a series of orthogonally separated subcarriers each with its own modulated waveform. OFDM is very robust against multipath signals and amplitude and group delay variations in the channel. Although this waveform type is very well suited to an indoor environment, it presents some unique challenges to system designers. The waveform properties that most affect the analog design are accommodation of an inherently high peak to average power ratio (up to 21 dB), sensitivity to non-linearities of the analog components (i.e., gain compression and AM to PM conversion), and sensitivity to phase noise. A system designed without the appropriate amount of margin in any of these categories will generate an unacceptable number of bit errors.

An 802.11(a) transceiver uses a total of 64 separate subchannels, each spaced 312.5 kHz apart, for a total channel bandwidth of 20 MHz. Of these subchannels, 48 are used for data, while 12 are unpopulated to allow for guardbands at the channel edges, and four are reserved exclusively for pilot tones. The 48 data subchannels are each modulated independently. Modulations range from BPSK for 6 Mbps data transfer through 64-QAM for 54 Mbps service. A single QAM symbol of modulation level 2^n can



▲ **Figure 2. Constellation diagram of a 64-QAM subcarrier with distortion.**



▲ **Figure 3. Constellation error vector definition.**

carry *n* bits, so one 64-QAM symbol can convey 6 bits of information. The constellation diagram of a 64-QAM subcarrier is shown in Figure 1.

The constellation diagram shows all possible states on the complex plane that a 64-QAM symbol can assume. However, additive white Gaussian noise (AWGN), transmitter and receiver nonlinearities and multipath effects affect QAM symbols. A received QAM symbol may look like the example in Figure 2.

Every QAM receiver has a processor that takes each bit and determines its position in the constellation relative to the origin and a set of predefined decision boundaries. When a symbol crosses a decision boundary, a bit error results. The system must therefore be designed so that this happens infrequently. Since the decision boundaries are placed closer together as the QAM order increases, the requirements placed on the modulated signal become more restrictive as higher order modulations are used.

In principle, the error contribution could be allocated between the transmitter and receiver in any proportion. However, 802.11(a) specifies that each transmitter must, over the course of a defined number of symbols and packets, provide an average error vector (defined as the distance from the ideal symbol point to the location in the constellation at which it is actually received) less than a certain magnitude. This magnitude decreases as the data rate (and QAM order) increase, from –5 dB at 6 Mbps to –25 dB at 54 Mbps. This "constellation error" specification allows interoperability between different vendors' products by ensuring that neither transmitters nor receivers are designed so that they produce so much error that an interoperable product will not be able to resolve the signals with a good degree of accuracy.

Several factors can impact this error vector. AM/AM conversion in the transmit amplifier due to gain compression can cause errors in the intended amplitude of the transmitted symbol. AM/PM conversion and phase noise can cause errors in the phase component of the error vector. There are two important points to note regarding the contributors to constellation error. One is that since the magnitude of the error vector is derived from a combination of all these factors, reducing the magnitude of one error contributor allows more latitude for the others. For example, if an extremely linear amplifier is used, amplitude distortion will be minor and so AM/PM conversion and phase noise can be allowed to be larger. The second important note is that while AM/AM and AM/PM conversion can be predicted and proactively corrected (for example, through digital predistortion), phase noise is by definition a random process. Thus, the amount of phase noise in a system will always have a direct and irreversible effect on the quality of the received signal.

Every active component in a transmitter and receiver can generate phase noise. However, for practical purposes the frequency synthesis components of the system tend to contribute far more noise than amplifiers and other types of circuits. Everything in the frequency synthesizer, from the reference frequency generator to the phase locked loops to the local oscillators, contributes to the overall phase noise power of the system. If the phase noise power is too high, the resultant error vector in the received constellation will be large, decision boundaries will be crossed, and bit errors will result.

Like most parameters in a system design, the amount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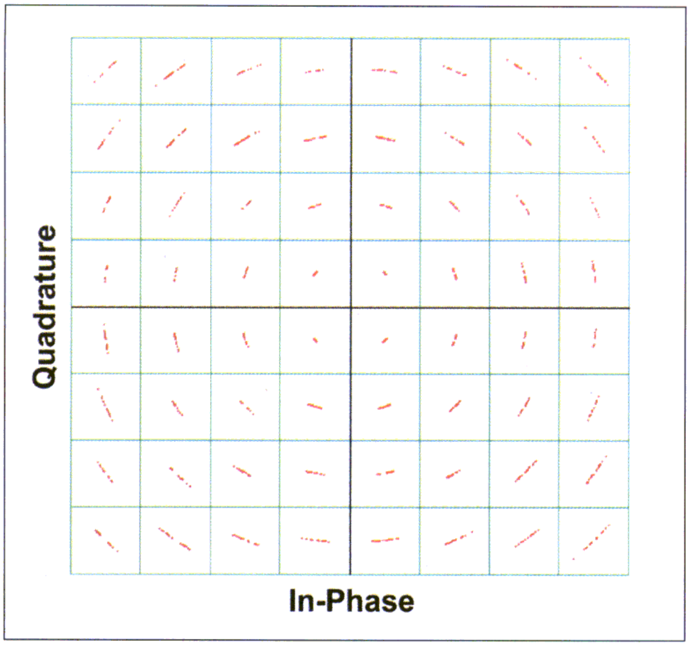
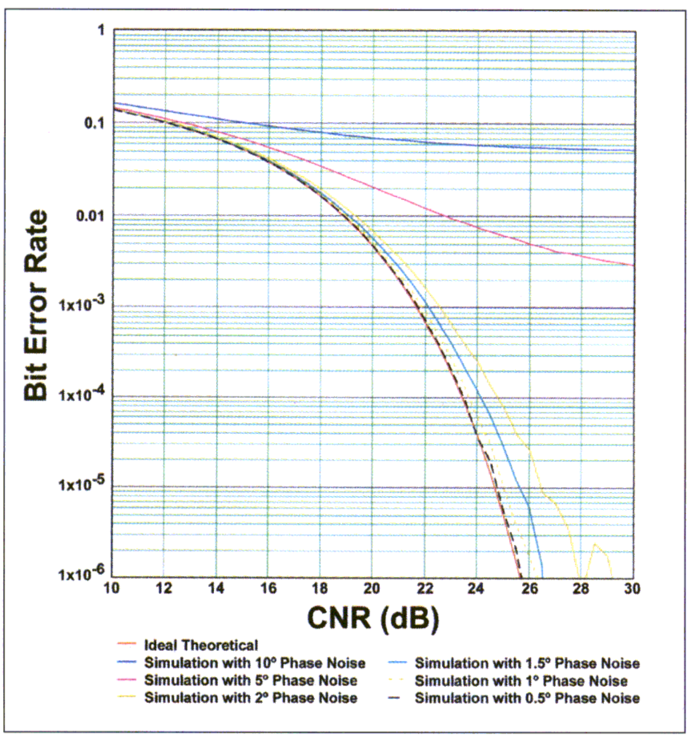


▲ **Figure 4. Constellation diagram of a 64-QAM subcarrier with phase noise.**



▲ **Figure 5. BER for OFDM signal with different amounts of phase noise.**

of allowable phase noise in an OFDM system becomes a question of compromise. Components with ultra-low phase noise specifications are readily available, but are often large and expensive. Conversely, trying to "over-integrate" a system to save on parts count or board space can cause problems if the processes or components used do not have phase noise specifications that will lead to an acceptable phase noise power in the final analysis.

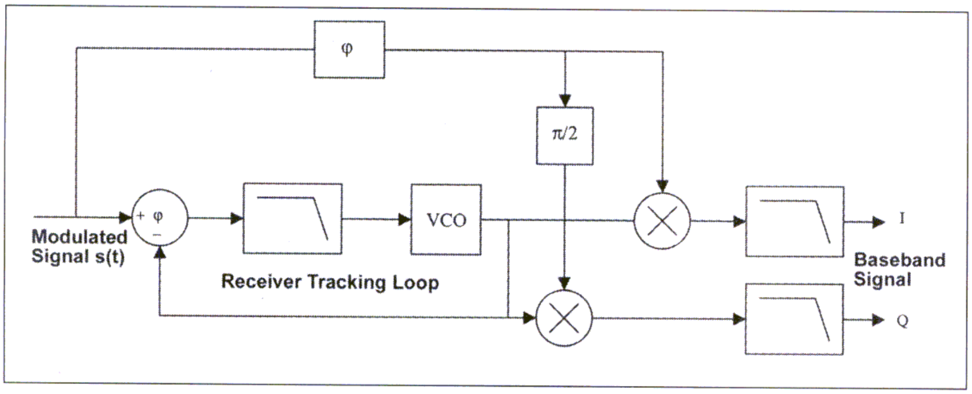
How, then, can the effect of phase noise be determined? Phase noise has two effects on an OFDM system. The first is that it causes a phase shift in the received signal so that its constellation might appear as shown in Figure 4. The second effect of phase noise is to cause the receiver frequency reference to not align properly with the transmitted signal, causing loss of orthogonality and thereby introducing interchannel interference (ICI).

These effects are not difficult to alleviate. As discussed earlier, phase noise is mostly due to the synthesizer, with most of the noise power being near the nominal carrier frequency. To compensate for differences in the frequency sources of the transmitter and receiver, some tracking of the received signal must be employed. The tracking algorithm will also follow and thus compensate for any low-frequency phase noise. In fact, it has been determined that the presence of the frequency tracking algorithm allows us to negate the effects of phase noise located closer to the carrier than about 10 percent of the subcarrier spacing. IEEE 802.11a requires that the RF frequency and data clocks be derived from the same source. By tracking the carrier frequency, it is possible to also compensate for differences in data clocks at the same time, thus maintaining orthogonality.

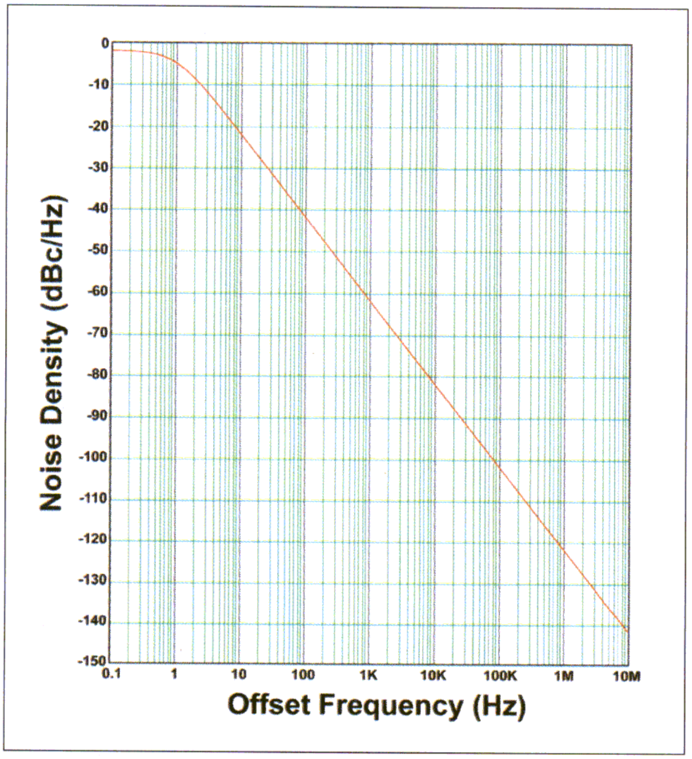
It is evident, then, that the amount of allowable phase noise in an OFDM system needs to be quantified so that the frequency synthesis section of the OFDM radio is neither overdesigned nor underdesigned. Since the primary system design goal is a low bit error rate, the designer must decide upon an acceptable increase in the carrier to noise ratio (CNR) at the operating bit error rate due to phase noise. Figure 5, obtained through simulation, shows the effect of residual phase noise with a few different RMS values on an OFDM signal using 64-QAM subcarriers. Note that the CNR required for a specific bit error rate will decrease depending on the decoding algorithm employed. Figure 5 shows raw results, without the benefit of decoding.

The residual phase noise depends upon the implementation of the tracking loop. The following example may serve to illustrate the considerations needed to design the frequency sources used in the transceiver.

Consider the demodulation scheme illustrated in Figure 6 (note that this is an oversimplification presented for discussion purposes only). An OFDM signal $s(t)$ with quadrature amplitude-modulated subcarriers is passed to a tracking loop, a second order phase locked loop, with a corner frequency f_C. Because f_C is much smaller than the bandwidth of s, the VCO output is close to the ideal carrier frequency with no modulation. Multiplying this with the modulated signal and removing the high-side mixing product results in recovery of the baseband signal.



▲ **Figure 6. Demodulator functional block diagram.**



▲ **Figure 7. Lorentzian phase noise power spectrum with 1 hertz linewidth.**

For this discussion we will assume that the VCO itself does not generate any noise. Phase noise at frequencies that are smaller than the corner frequency will then be tracked by the PLL and therefore introduce no errors into the demodulation process. Phase noise outside of the loop bandwidth, however, will cause misalignment of the FFT spacing as well as phase rotations to the recovered symbols and therefore increase the bit error rate.

Let us assume that the degradation caused by 1.5 degrees of phase noise is acceptable. The question is how to design the synthesizer and select the tracking loop bandwidth so that the remaining RMS phase noise not tracked does not exceed 1.5 degrees.

We begin with the power transfer function of the second order PLL in the tracking loop that can be approximated by

$$S_{Track}(f) = \frac{1}{1+\left(\frac{f}{f_C}\right)^4} \qquad (1)$$

Let us further assume that the source used to generate the carrier has phase noise that follows the Lorentzian model [1], the single-sided noise density spectrum of which is defined by

$$S_d(f) = \frac{2}{\pi \cdot f_1 \cdot \left(1+\left(\frac{f}{f_1}\right)^2\right)} \qquad (2)$$

where f_1 is the 3 dB linewidth of the oscillator and f is the offset from the carrier frequency at which the phase noise density function $S_d(f)$ is evaluated as depicted in Figure 7.

Then the remaining phase noise at the output of the VCO would be

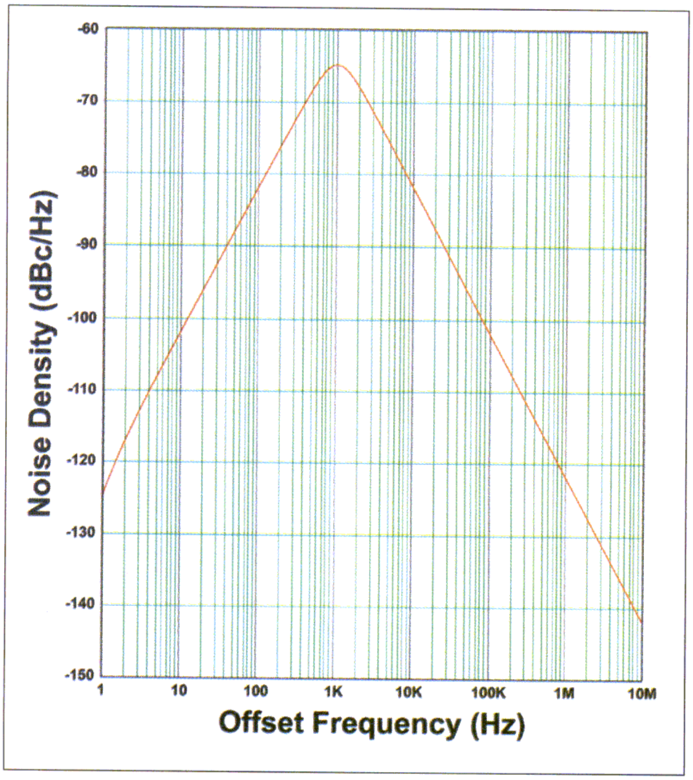
$$S_{VCO}(f) = \frac{2}{\pi \cdot f_1 \cdot \left(1+\left(\frac{f}{f_1}\right)^2\right) \cdot \left(1+\left(\frac{f}{f_C}\right)^4\right)} \qquad (3)$$

At the baseband output, the noise power density affecting the demodulation would then be the difference between that of the receiver input and the tracking loop output, or

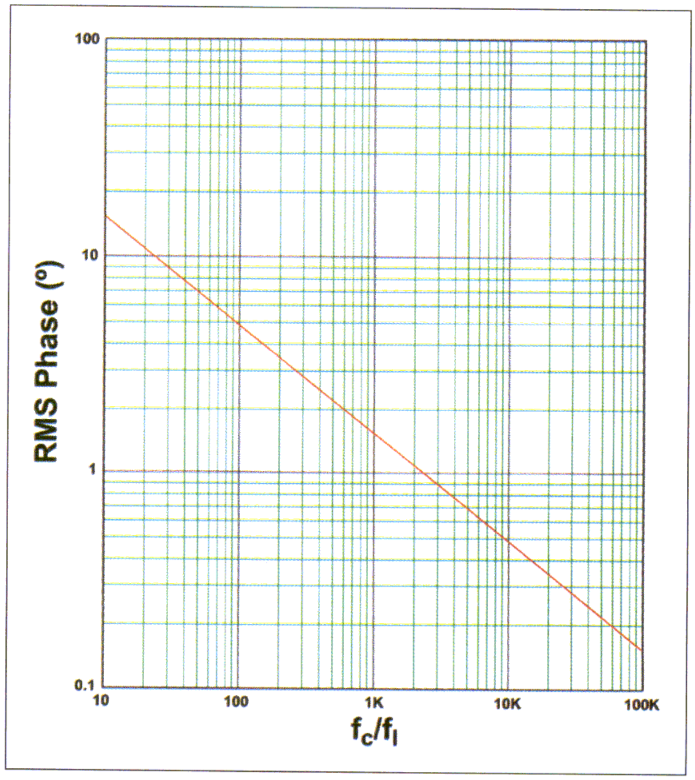
$$S(f) = \frac{2}{\pi \cdot f_1 \cdot \left(1+\left(\frac{f}{f_1}\right)^2\right)} \cdot \left(1 - \frac{1}{1+\left(\frac{f}{f_C}\right)^4}\right) \qquad (4)$$

and might appear as shown in Figure 8.

Figure 8 was generated with a 3 dB linewidth of 1 hertz and a tracking loop bandwidth of 1 kHz. The remaining phase noise introduces a phase error that follows a Gaussian distribution. The RMS value for small RMS phase angles φ (that is, for φ << 1 radian) (standard deviation) can be determined in radians as



▲ **Figure 8. Phase noise power spectrum density after demodulator.**



▲ **Figure 9. RMS phase noise versus f_C/f_1.**

$$\varphi_{RMS} = \sqrt{\int_0^{0.5 \cdot B} S(f)df} \qquad (5)$$

where B is the channel bandwidth. Evaluation of the integral in Equation (5) is straightforward but quite tedious, and the derivation is not presented here. Although only the power within the channel bandwidth need be considered, the integral is easier to evaluate from 0 to infinity. This is a legitimate approximation because the loop bandwidth must be much smaller than the carrier bandwidth for this demodulation scheme to work, and power in the bandwidth outside of B will be very small. The so evaluated integral can be written as

$$\int_0^{\infty} S(f)df = \frac{1}{1+\left(\frac{f_C}{f_1}\right)^4} \cdot \left[1 + \frac{1}{\sqrt{2}} \cdot \left(\left(\frac{f_C}{f_1}\right)^2 - 1\right) \cdot \frac{f_C}{f_1}\right] \qquad (6)$$

It follows that

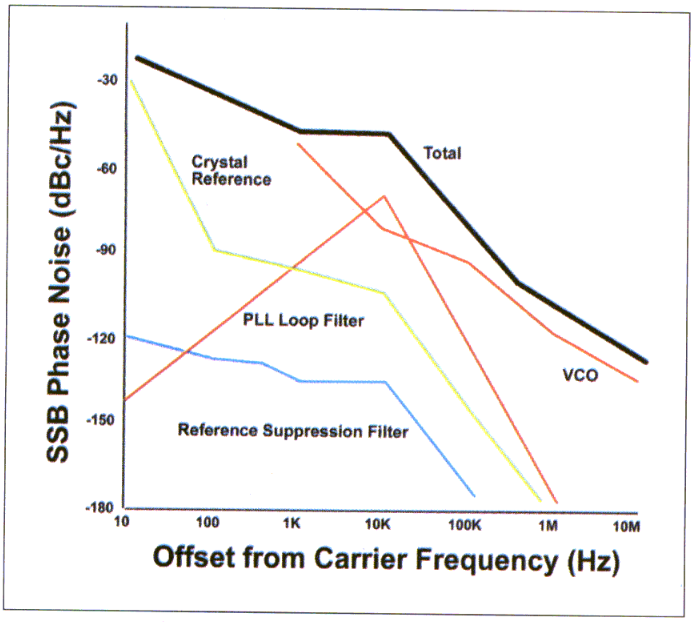
$$\varphi_{RMS} = \sqrt{\frac{1}{1+\left(\frac{f_C}{f_1}\right)^4} \cdot \left[1 + \frac{1}{\sqrt{2}} \cdot \left(\left(\frac{f_C}{f_1}\right)^2 - 1\right) \cdot \frac{f_C}{f_1}\right]} \qquad (7)$$

where φ_{RMS} is in radians. Equation (7) shows that the RMS phase noise angle is a function of the ratio of the receive tracking loop bandwidth to the Lorentzian linewidth, as shown in Figure 9.

It remains to select values for receive tracking loop bandwidth f_C and Lorentzian linewidth f_l. In general, f_C must be narrow enough so that no modulated information is lost. In the case of IEEE 802.11(a), the subchannel at the center frequency is not used and therefore contains no information. The edge of the first occupied subchannel is at 156.25 kHz. Let us assume that we want the tracking loop to suppress any modulation at that frequency by 30 dB. We determine the loop bandwidth by solving (I) for f_C, inserting 156.25 kHz for f and 10^{-3} (– 30 dB) for S_{Track}, and arrive at a value f_C = 27.8 kHz as the largest allowable tracking loop bandwidth. From Figure 9 we see that, if the phase noise into the receiver is Lorentzian, the 3 dB linewidth must be no greater than 10^{-3} the tracking bandwidth, or 27.8 Hz.

In reality, the models of the carrier phase noise and receive tracking loop are more complex. However, the following basic design rules can be used:

- Determine an acceptable tracking bandwidth for your application. Design a tracking loop with a response $S_{Track}(f)$ that provides sufficient suppression in the bands of interest.
- Design a synthesizer with a noise profile $S_d(f)$ so



▲ **Figure 10. Phase noise profiles of frequency synthesis components.**

that the most of the phase noise spectrum falls well within the receiver tracking bandwidth.

- Determine the RMS phase noise (in radians) at the demodulator output as

$$\varphi_{RMS} = \sqrt{\int_0^{0.5 \cdot B} Sd(f) \cdot \left(1 - S_{Track}(f)\right) df} \tag{8}$$

- Determine (perhaps through simulation) whether this phase noise will degrade performance to an unacceptable level.

Equation (8) is valid only if there is no significant phase noise contribution from the receive tracking loop. This should be the case if tracking is implemented as a digital PLL.

In implementing the transmit synthesizer, care must be taken to use components that minimize phase noise far removed from the carrier. An actual synthesizer constructed of real components tends to have a phase noise spectrum dominated by VCO noise from the edge of the loop filter bandwidth to the edge of the system noise bandwidth, encompassing frequencies far from the carrier frequency. Reference frequency generators such as crystals generally possess phase noise spectra concentrated close to the carrier. While we have established that this noise will be negated by the tracking loop in the receiver, a low phase noise crystal is important for other system considerations such as meeting the 802.11a transmitter constellation accuracy requirements. The crystal frequency is generally much lower than the LO frequencies, and must be multiplied by n inside the PLL. The crystal phase noise is correspondingly multiplied by 20 log (n) where n is the multiplication factor required to arrive at the output frequency from the reference frequency. Therefore, a better approximation of a phase noise spectrum for an OFDM system would include the crystal phase noise, PLL loop response, and VCO phase noise as well as other, less prominent contributors, such as reference supression filters, summed together to generate a total SSB phase noise spectrum. A sample of such a summation is presented in Figure 10.

Care should be taken to specify components (or analog cells and processes, if synthesizer components are to be integrated into larger functional blocks) that are capable of meeting the phase noise requirements for a given system BER.

Conclusion

It has been established that phase noise causes an uncancellable and detrimental effect on the accuracy of an OFDM system, measurable as an increase in bit error rate. Simulation results depicting the effect of various levels of phase noise upon the BER of a 64-QAM system have been presented. An example of how to define the tracking filter bandwidth necessary to comply with the chosen level of residual phase noise has been presented.

Once the tracking filter bandwidth is defined, some guidelines for designing a real-world synthesizer with a noise spectrum largely within the stated tracking bandwidth are presented and some general design guidelines for choosing real-world components capable of suiting the system phase noise specifications have been established. ■

References

1. Richard Van Nee and Ramjee Prasad, *OFDM for Wireless Multimedia Communications*, New York: Artech House, 2000.

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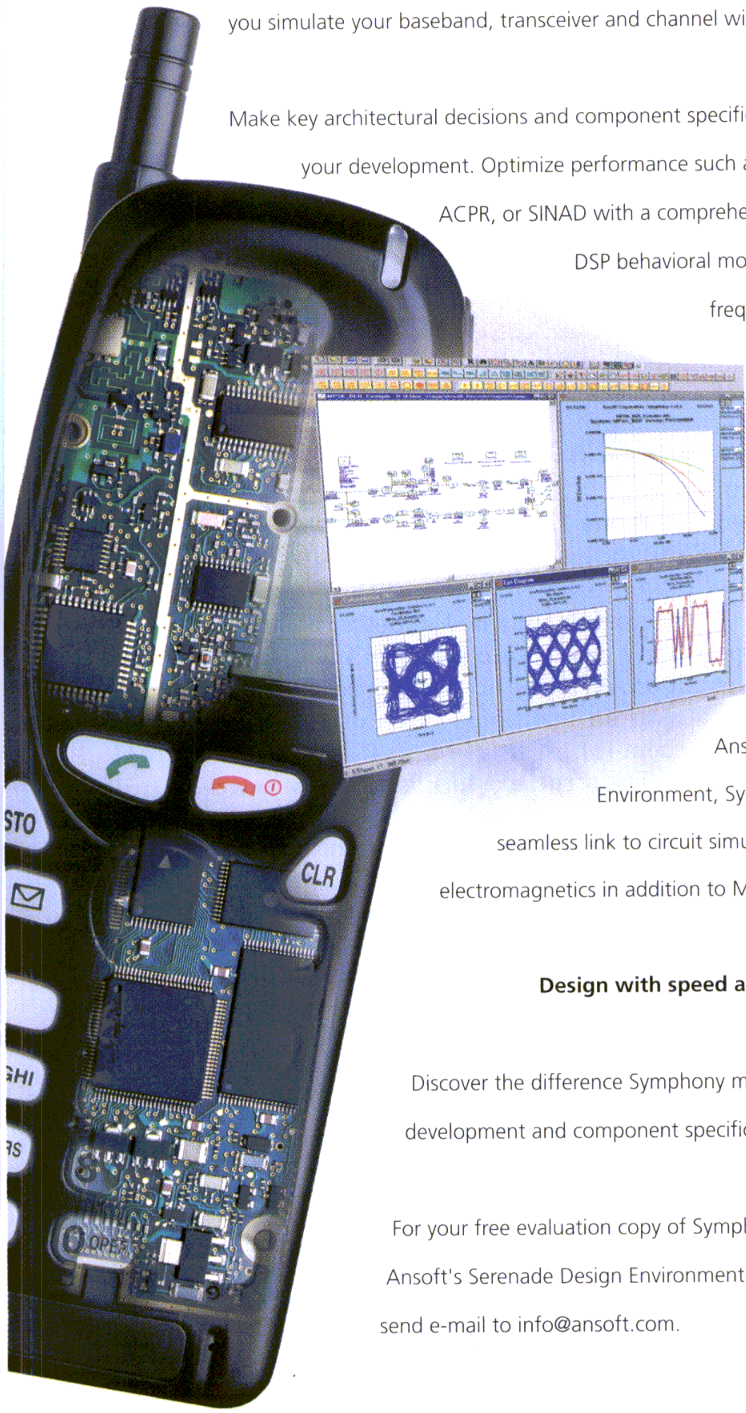

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Circle 30

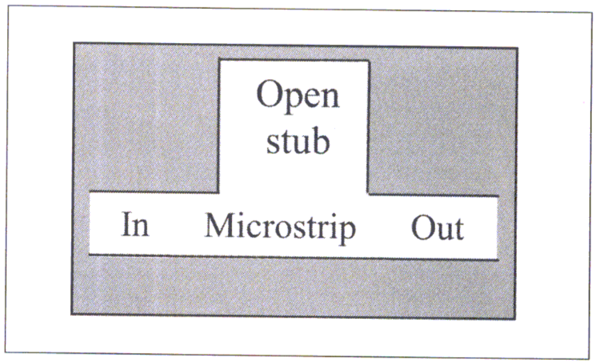
Design of Tunable Bandstop Filters using Multilayer Microstrip

These shielded filters are readily simulated and analyzed using CAD programs

By Nasreddine Benahmed, Mohammed Feham and Saliha Dali
University of Tlemcen, Algeria

This article introduces the analysis of bandstop filters using multilayer microstrips designed to operate in a given frequency range. These filters can be used to reject unwanted carrier frequencies in the IF processing unit of a digital communication system (DCS).

A modification of the short circuit position of the bandstop filter presented by Jaisson [1] permits the realization of a tunable bandstop filter in a frequency range. Other structures that can be easily realized are analyzed and simulated using CAD programs [2].



▲ **Figure 1. Open stub for bandstop filter.**

Introduction

A bandstop filter with multilayer micro-strips has been presented by Jaisson [1]. The filter consists of a double layer microstrip resonator coupled to a microstrip line and was designed to operate around f_0 = 1842.5 MHz and reject unwanted carrier frequencies in the IF processing unit of a DCS.

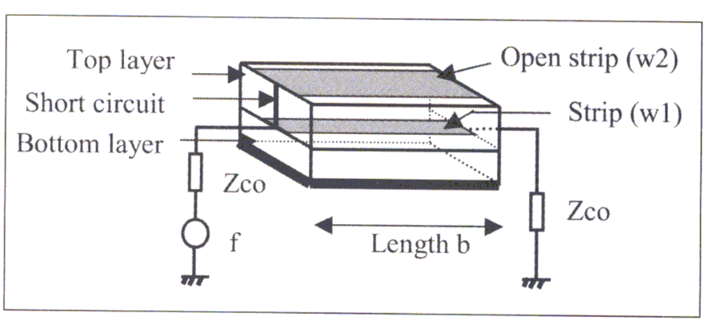
In this article, we present the analysis of shielded bandstop filters and the design of tunable bandstop filters. Our analysis is based on a numerical resolution of the electrostatic problem using the finite element method (FEM). The filter can be modeled by determining the ($[L]$), ($[C]$) parameters and the scattering coefficients (S_{11}, S_{12}) of the equivalent circuit.

Description

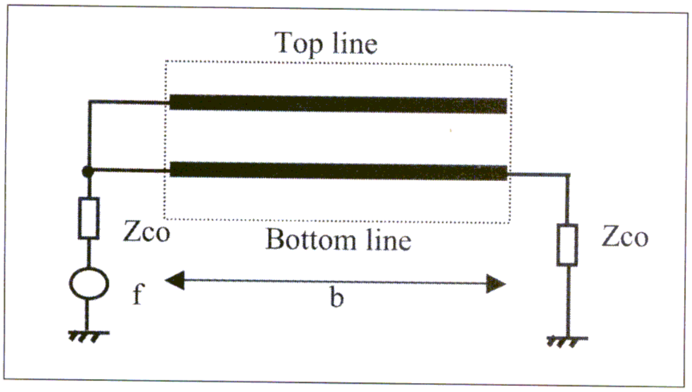
Figure 1 shows a microstrip line with a parallel open stub, which brings about a stopband effect around some frequency f_0. In MICs, where space is restricted, a somewhat more compact microstrip may be the better choice. One possibility is to rotate the open microstrip and place it on top of the access line, as shown in Figure 2, with an additional layer of substrate between them [1].

The structure in Figure 2 was selected in [1] for use as a bandstop filter. Figure 3 gives the equivalent circuit of the bandstop filter, where its output is matched with Z_{co} = 50 Ω.

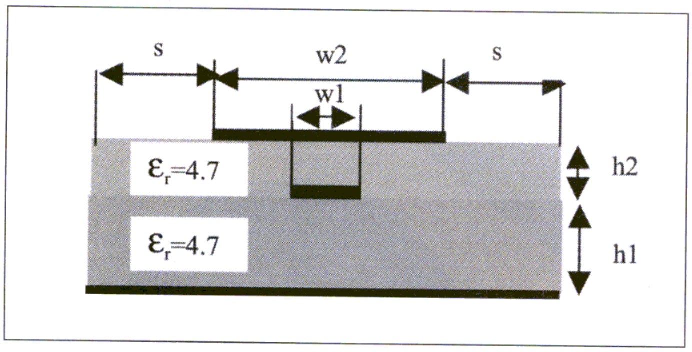
It shows that for a chosen length b, the bandstop filter is constituted by two coupled TEM or quasi-TEM transmission lines. The left end of



▲ **Figure 2. Bandstop filter using multilayer with asymmetrical microstrip.**



▲ **Figure 3. Equivalent circuit of the bandstop filter.**



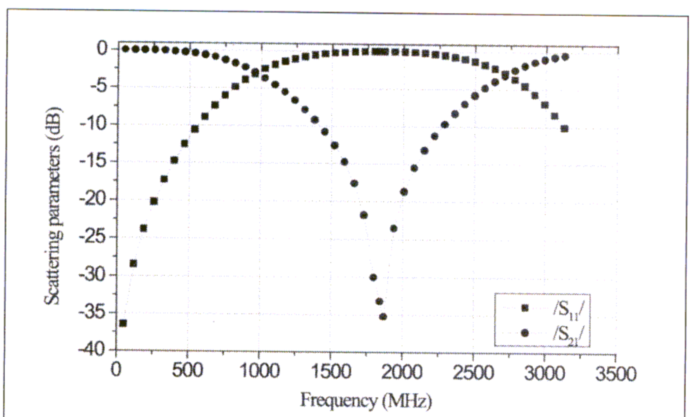
▲ **Figure 4. Cross section of the filter showing homogenous multilayer construction and using asymmetrical microstrips.**

the top line is connected to that of the bottom line, and its right end is kept open.

The cross section of the filter showing in homogeneous multilayer with asymmetrical microstrips construction is presented in Figure 4.

For asymmetrical strips, and using this numerical model, capacitances $C_i\,(\varepsilon_r)$ are computed for

$$V_i = 1 \text{ volt} \tag{1}$$



▲ **Figure 5. The bandstop filter response using a homogenous multilayer microstrip.**

where all other conductors are grounded.

Setting $V_1 = V_2 = 1$ volt yields capacitance C_3, so that the coupling capacitance C_m is calculated by the following relation [3]:

$$C_m = \frac{1}{2}\left(C_1(\varepsilon_r) + C_2(\varepsilon_r) - C_3\right) \tag{2}$$

Inductances L_i are given in terms of capacitances, as in the case of a single quasi-static line [4]. The mutual inductance L_m is calculated as follows:

$$L_m = L_1 \frac{C_m(\varepsilon_r)}{C_2(\varepsilon_r)} = L_2 \frac{C_m(\varepsilon_r)}{C_1(\varepsilon_r)} \tag{3}$$

A CAD program was used to calculate the matrices [L] and [C] of the bandstop filter. Once these matrices are determined, the filter response can be analyzed using an adapted numerical model [2].

Bandstop filter using homogeneous multilayer microstrip

To validate our numerical results, we first studied the bandstop filter using homogeneous multilayer microstrips [1]. The cross section of this bandstop filter is shown in Figure 4.

The features of this filter are:

- Bottom strip width — $w1 = 0.5$ mm
- Top strip width — $w2 = 5$ mm
- Bottom material thickness — $h1 = 1$ mm
- Top material thickness — $h2 = 0.165$ mm
- Separating length — $s = 2.5$ mm
- FR4 material — $\varepsilon_r = 4.7$
- Length of the filter — $b = 19.44$ mm
- Strip thickness is neglected

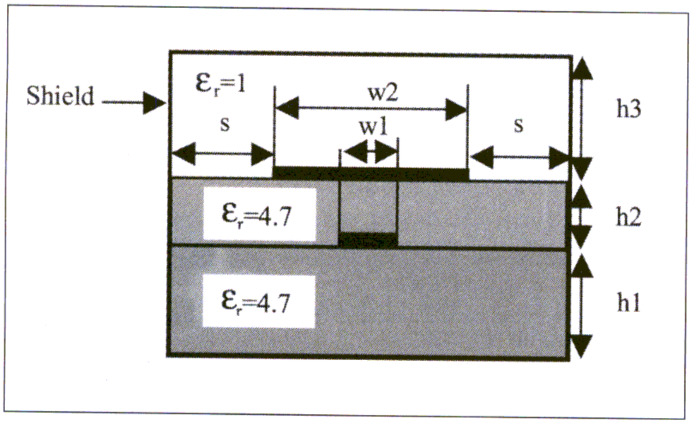
$$[L] = \begin{bmatrix} 778.672 & 116.36 \\ 116.36 & 248.741 \end{bmatrix} \left(\frac{\text{nH}}{\text{m}}\right)$$

$$[C] = \begin{bmatrix} 67.065 & -31.37 \\ -31.37 & 209.946 \end{bmatrix} \left(\frac{\text{pF}}{\text{m}}\right)$$

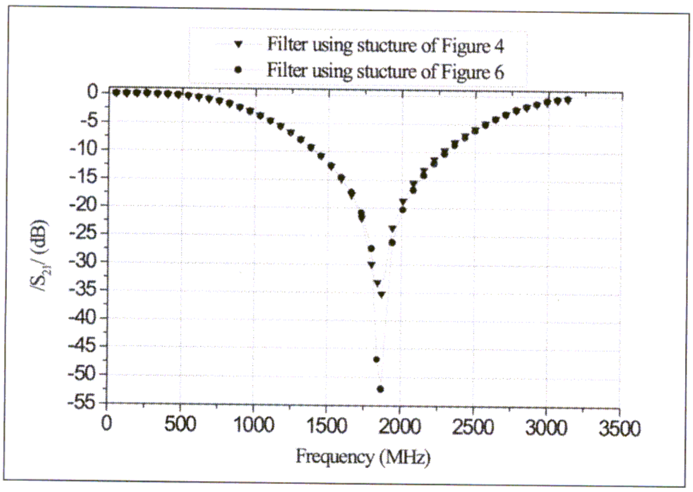
The bandstop response in the frequency range [50; 3200] MHz is presented in Figure 5. Figure 5 shows that a minimum $|S_{21}| = -35.24$ dB is obtained at 1870 MHz. At $f_0 = 1842.5$ MHz, $|S_{21}| = -33.195$ dB. The minimum measured at 1836.8 MHz is $|S_{21}| = -27.287$ dB.

Bandstop filter using shielded multilayer microstrip

To show the influence of the shield on the properties of the bandstop filter, we analyzed a shielded bandstop filter using multilayer asymmetrical microstrip. The



▲ **Figure 6. Bandstop filter using a shielded multilayer microstrip.**



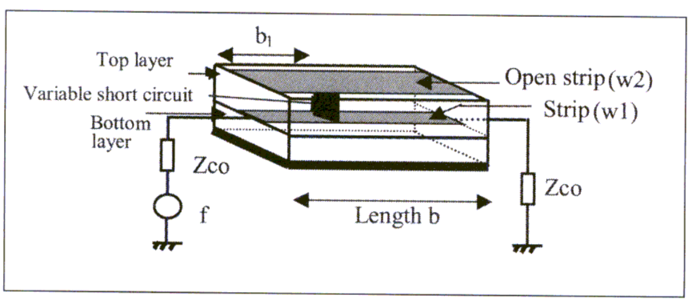
▲ **Figure 7. Shielded bandwith filter response.**

cross section of this filter is presented in Figure 6.

For $h3$ = 3 mm, the central frequency f_0 = 1842.5 MHz is obtained when the filter has a length b = 22 mm.

$$[L]=\begin{bmatrix}560.157 & 83.095\\ 83.095 & 166.453\end{bmatrix}\left(\frac{\text{nH}}{\text{m}}\right)$$

$$[C]=\begin{bmatrix}76.6064 & -35.6868\\ -35.6868 & 240.57\end{bmatrix}\left(\frac{\text{pF}}{\text{m}}\right)$$



▲ **Figure 8. Tunable bandstop filter using multilayer asymmetrical microstrip.**

Figure 7 shows the filter response in the frequency range [50; 3200] MHz. The minimum obtained is $|S_{21}|$ = –52.02 dB at 1870 MHz. At f_0 = 1842.5 MHz, $|S_{21}|$ = –46.8852 dB.

Tunable bandstop filter using multilayer microstrip

Figure 8 shows a bandstop filter using a homogeneous multilayer with asymmetrical microstrips. To change the value of the operating frequency f_0 of the reject filter, we can change the short circuit position along the strips.

The features of this filter are:

- Bottom strip width — $w1$ = 0.5 mm
- Top strip width — $w2$ = 5 mm
- Bottom material thickness — $h1$ = 1 mm
- Top material thickness — $h2$ = 0.165 mm
- Separating length — s = 2.5 mm
- FR4 material — ε_r = 4.7
- Length of the filter — b = 19.44 mm
- Strip thickness is neglected

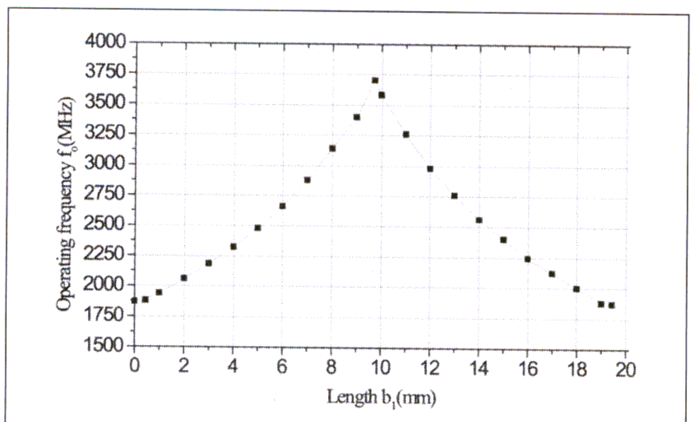
Figure 9 shows the influence of the short circuit position along the strips on the operating frequency f_0. For this structure, the operating band of frequency is [1870; 3700] MHz, obtained for a variation of the short circuit position between 0 and $b/2$. Between $b/2$ and b, the same band frequency is browsed in the opposite direction.

This structure is difficult to realize and it is presented here only to show the concept for tuning a bandstop filter in a frequency range.

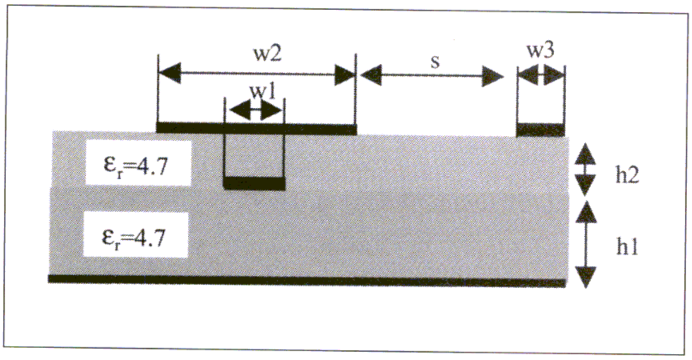
Bandstop filter using three asymmetrical microstrips

To realize a bandstop filter that is easy to manipulate, we propose using three asymmetrical microstrips. The cross section of this filter is shown in Figure 10.

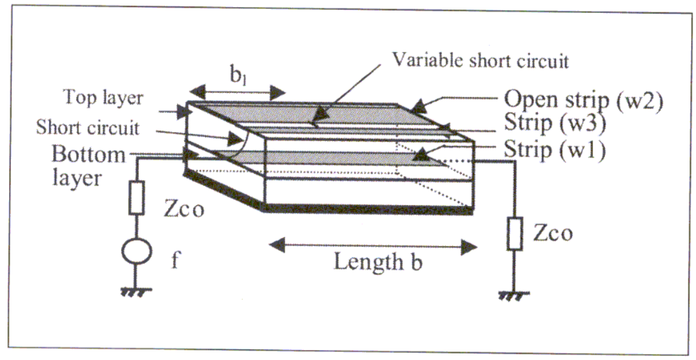
The first short circuit is realized at the input of the circuit between the strip ($w1$ and $w3$). A variable short circuit is placed between strips ($w3$ and $w2$), as shown in Figure 11.



▲ **Figure 9. Influence of the short circuit position on the operating frequency.**



▲ **Figure 10. Cross section of the filter using three asymmetrical microstrips.**



▲ **Figure 11. Tunable bandstop filter using three asymmetrical microstrips.**

This structure is analyzed with the following features:

- Bottom strip width — $w1 = 0.5$ mm
- Top strips width — $w2 = 5$ mm, $w3 = 0.5$ mm
- Separating length — $s = 2$ mm
- Bottom material thickness — $h1 = 1$ mm
- Top material thickness — $h2 = 0.165$ mm
- FR4 material — $\varepsilon_r = 4.7$
- Strip thickness is neglected.

The obtained matrices $[L]$ and $[C]$ are:

$$[L] = \begin{bmatrix} 399.5 & 162.4 & 30.48 \\ 162.4 & 189.2 & 35.51 \\ 30.48 & 35.51 & 614.8 \end{bmatrix} \left(\frac{\text{nH}}{\text{m}}\right)$$

$$[C] = \begin{bmatrix} 201.1 & -172.6 & -3.89e-5 \\ -172.6 & 377.9 & -4.186 \\ -2e-3 & -4.186 & 58.3 \end{bmatrix} \left(\frac{\text{pF}}{\text{m}}\right)$$

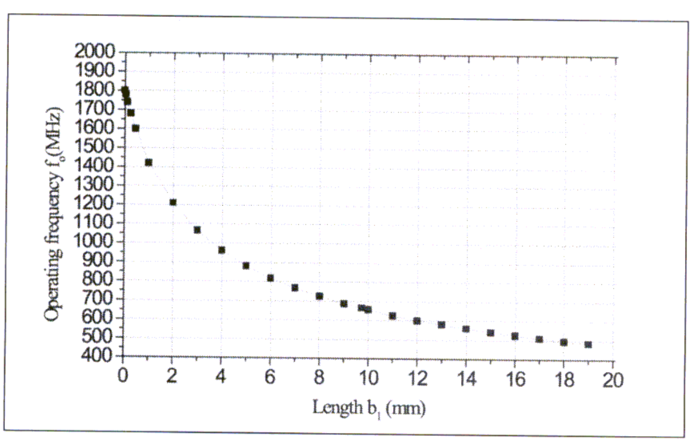
We have designed two tunable bandstop filters (Figure 11). The first one is designed to operate in the frequency range [485; 1800] MHz (Figure 12) for b = 19.44 mm, and the second is designed to operate in the frequency range [1880; 6335] MHz for b = 5 mm (Figure 13). For the second tunable bandstop filter, at 1880 MHz, the 10 dB rejection is 140 MHz; at 6335 MHz, the 20 dB rejection is 490 MHz.

Additional/alternative configuration of tunable bandstop filter using two strips

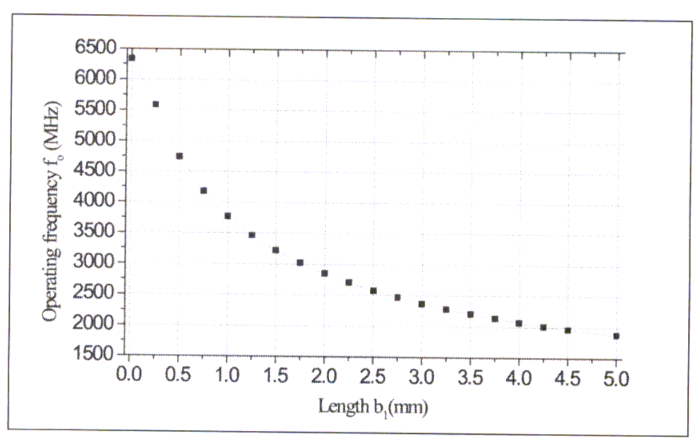
To reduce the number of microstrips and complexity of the structure, the following configuration (Figure 14) of a tunable bandstop filter is used. The short circuit is realized between lines of width $w1$ and $w2$. Figure 15 shows the cross section of this type of bandstop filter.

For the following features:

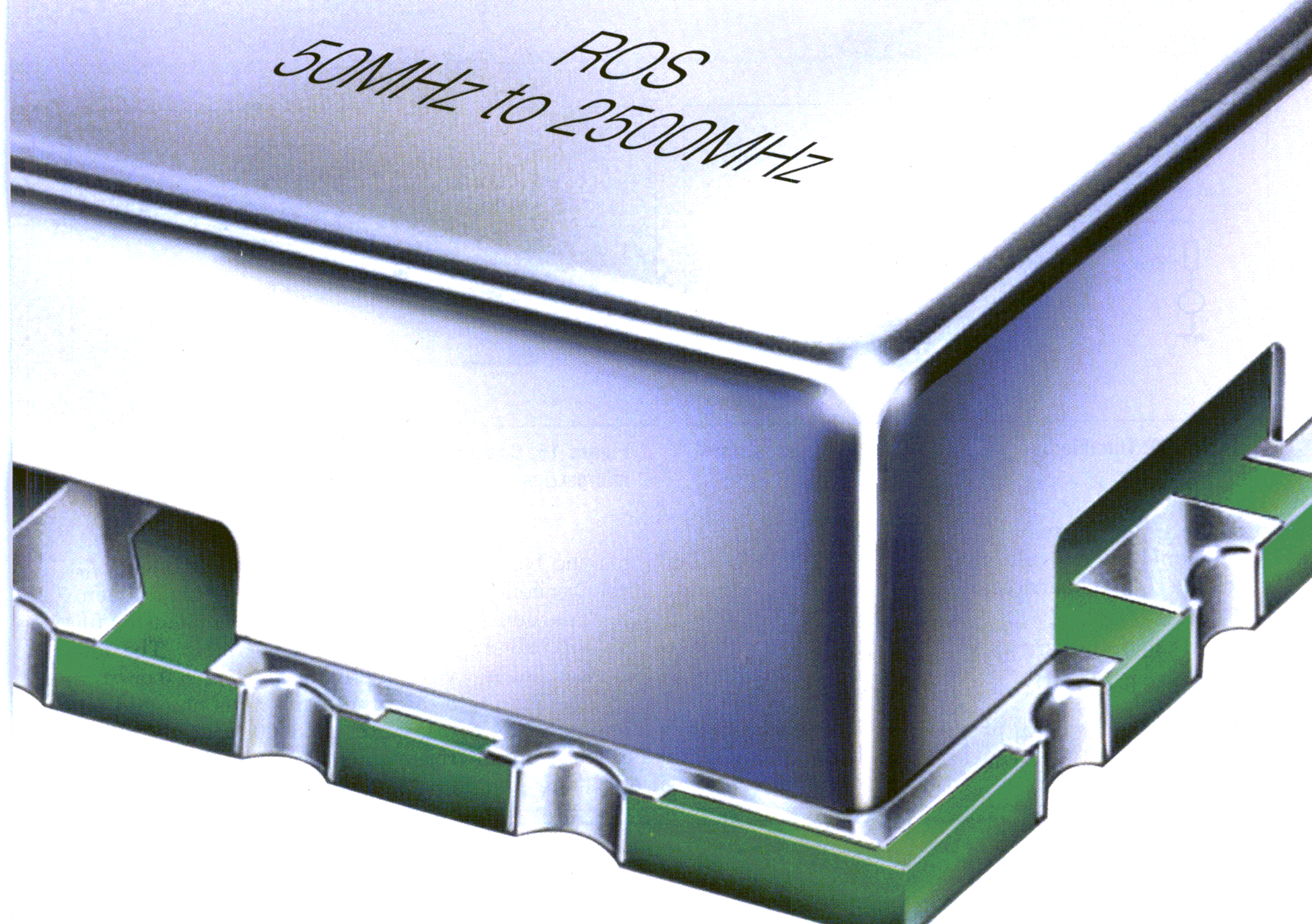
- Right strip width — $w1 = 0.5$ mm
- Top strip width — $w2 = 5$ mm
- Bottom material thickness — $h1 = 0.75$ mm
- Top material thickness — $h2 = 0.25$ mm
- Separating length — $s = 0.25$ mm
- FR4 material — $\varepsilon_r = 4.7$
- Length of the filter — $b = 22$ mm
- Position of the short circuit — $b1 = 0$ mm
- Strip thickness is neglected



▲ **Figure 12. Influence of the short circuit position on the operating frequency (*b* = 19.44 mm).**



▲ **Figure 13. Influence of the short circuit position on the operating frequency (*b* = 5 mm).**



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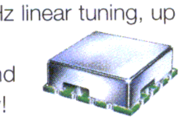

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ROS-300	150-280	16	-102	-28	12	20	14.95
ROS-400	200-380	16	-100	-24	12	20	14.95
ROS-535	300-525	17	-98	-20	12	20	14.95
ROS-765	485-765	16	-95	-27	12	22	15.95
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*Phase Noise: SSB at 10kHz offset, dBc/Hz. **Specified to fourth.

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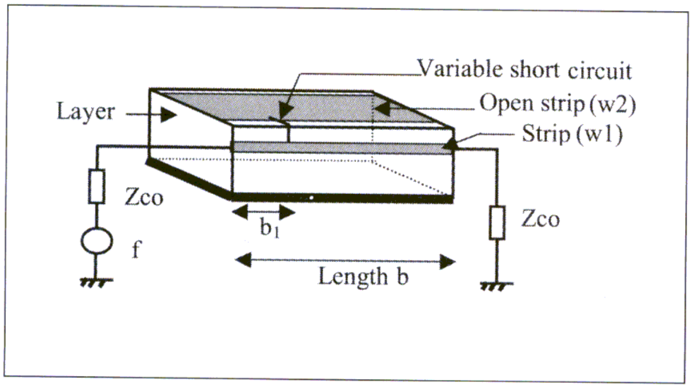
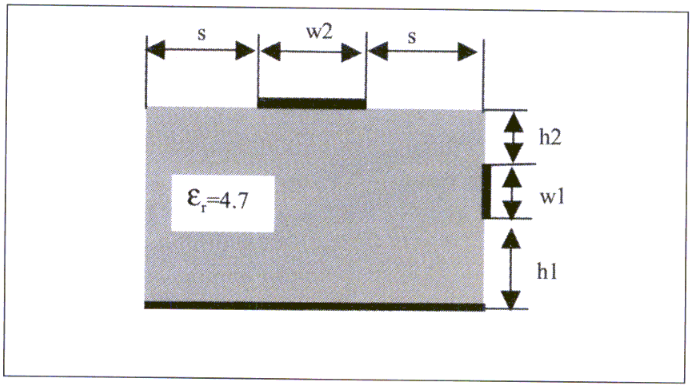


▲ **Figure 14. Tunable bandstop filter with two microstrips.**



▲ **Figure 15. Cross section of the bandstop filter using two microstrips.**

The analysis of this structure yields the $[L]$, $[C]$ matrices:

$$[L] = \begin{bmatrix} 546.0 & 146.6 \\ 146.6 & 254.9 \end{bmatrix} \left(\frac{\text{nH}}{\text{m}}\right)$$

$$[C] = \begin{bmatrix} 73.44 & -44.81 \\ -44.81 & 191.1 \end{bmatrix} \left(\frac{\text{pF}}{\text{m}}\right)$$

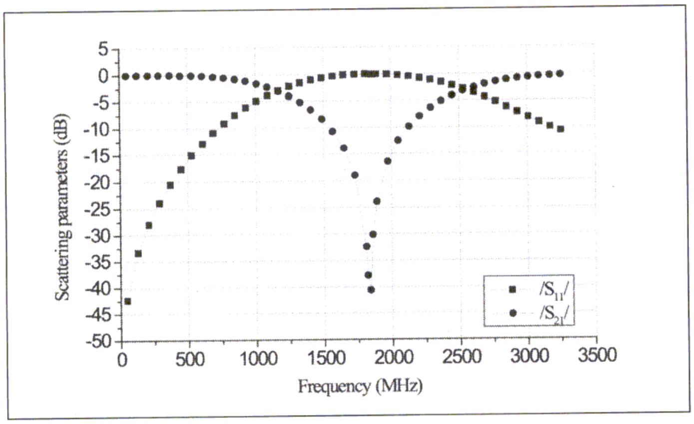
Figure 16 illustrates the bandstop filter response in the frequency range [50; 3250] MHz. The minimum obtained is $|S_{21}| = -40.7$dB at 1840 MHz. The 10 dB rejection is 680 MHz and the 20 dB rejection is 180 MHz. For the same structure, Figure 17 shows the influence of the short circuit position along the strips on the operating frequency f_0. It shows that the operating frequency range of the tunable bandstop filter is [1840; 3660] MHz. The low value is obtained for ($b1 = 0$ or $b1 = b$) and the high one is obtained for ($b1 = b/2$). At 3100 MHz, the 20 dB rejection is 420 MHz and the 30 dB rejection is 120 MHz.

Conclusion

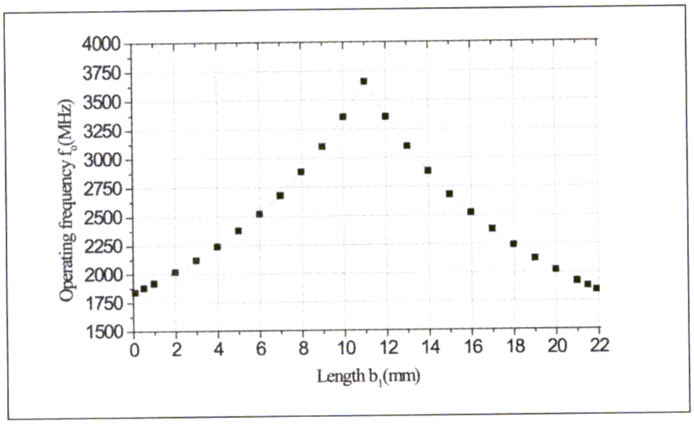
Several configurations of tunable filters have been presented and simulated. The main idea is to achieve a variable short circuit that allows for a variation of the stub length and its position on the transmission line. Structures as shown in Figures 11 and 14 can be realized without major difficulties. ■

References

1. D. Jaisson, "A Multilayer Microstrip Bandstop Filter for DCS," *Applied Microwave & Wireless*, Vol. 10, No. 2, March 1998: 64-70.
2. N. Benahmed, M. Feham and M. Kameche, "Finite Element Analysis Of Planar Couplers," *Applied Microwave & Wireless*, Vol. 12, No. 10, October 2000: 28-38.
3. D. Jaisson, "A Microstrip Coplanar Waveguide Coupler For Use With an Attenuator," *Microwave Journal*, Vol. 38, No. 9, September 1995: 120-130.
4. T.C. Edwards, *Foundations for Microstrip Circuit Design*, New York: John Wiley & Sons, 1991.



▲ **Figure 16. Bandstop filter response using two microstrips.**



▲ **Figure 17. Influence of the short circuit position on the operating frequency.**

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Nasreddine Benahmed received a master's degree in signal and electronic systems (communication) from the University of Tlemcen, Algeria, in 1996. Since 1997, he has been an assistant professor of communication systems. He is currently involved in the RF and microwave transmission lines.

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Saliha Dali is an engineer in communications. She is working on a master's degree in signal and electronic systems (communication) at the University of Tlemcen, Algeria.

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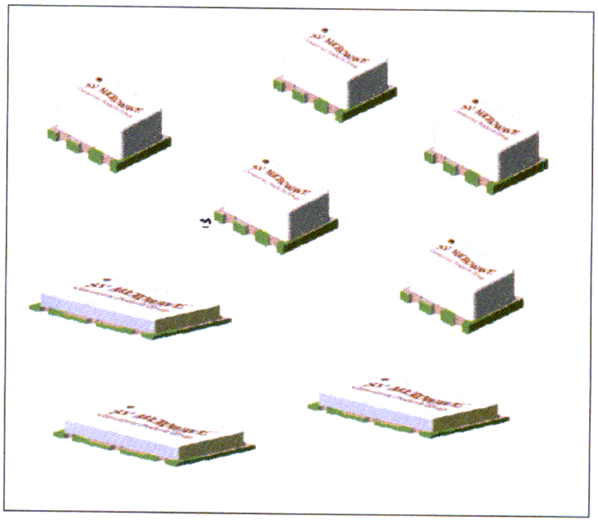

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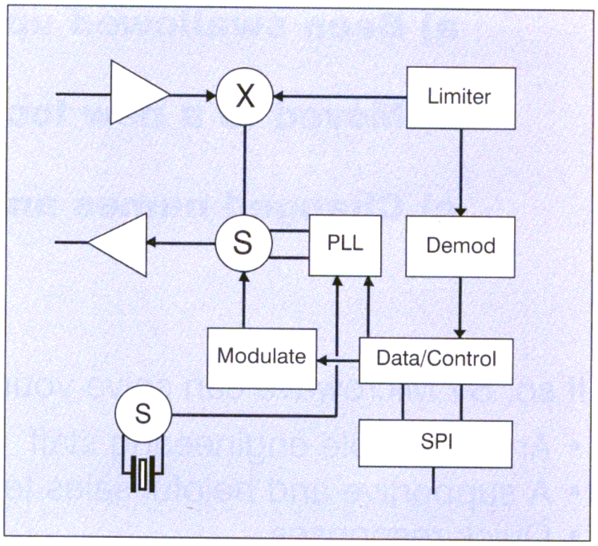

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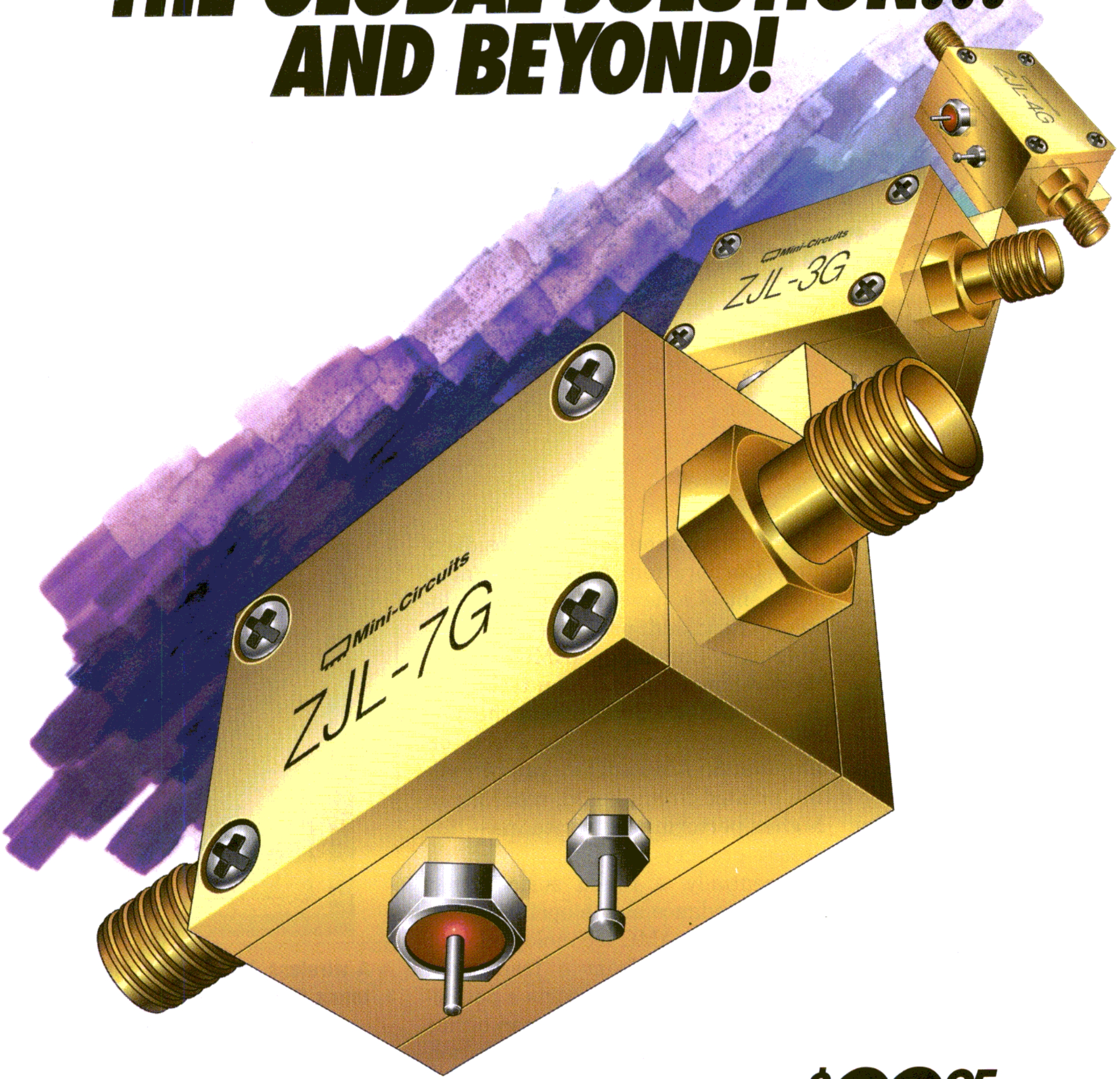

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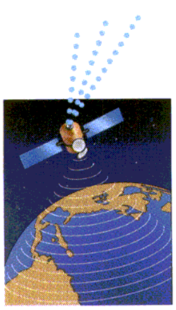

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ZJL-4G	20-4000	12.4	±0.25	13.5	5.5	30.5	75	129.95
ZJL-6G	20-6000	13.0	±1.6	9.0	4.5	24.0	50	114.95
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ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0	31.0	120	149.95
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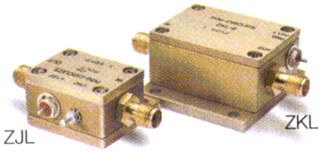
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0	31.0	115	149.95

NOTES:
1. Typical at 1dB compression.
2. ZKL dynamic range specified at 1GHz.
3. All units at 12V DC.



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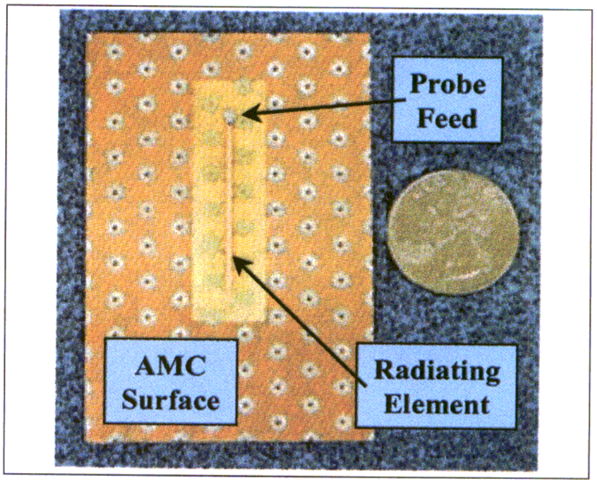
Antenna Technology Improves Radiation and Front-End Performance

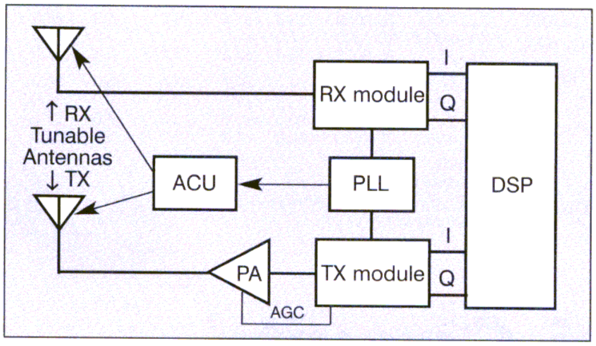
The Titan Corporation and its subsidiary e-tenna Corporation have announced development of a new antenna technology for wireless handheld products. e-tenna's Artificial Magnetic Conductor (AMC) is the heart of this development. AMC is a technique that isolates a radiating element from the surrounding environment, reducing its effects on antenna radiation. An AMC surface can be realized on a thin printed circuit board, resulting in smaller, higher-performance antennas for portable wireless products.

AMC is, essentially, a tuned surface that exhibits a high impedance at the operating frequency. Antennas using AMC technology do not rely on return currents from a traditional "ground plane." The company reports a performance gain of more than 2 dB, which can either reduce the power required for communication or increase range.

Another characteristic of AMC is that it can be made tunable, which is the key to e-tenna's next development effort. Using two high-Q tunable antennas instead of switches, diplexers and filters, a frequency-agile wireless transceiver can be developed that simplifies many of the factors faced by engineers designing multi-band, multi-standard handsets and wireless terminals. The company is designing MEMS-based technology for tunable antennas and AMC surfaces, which will simply the design of reconfigurable systems. e-tenna intends to license these technologies to interested wireless product developers and manufacturers. ■



▲ A wireless AMC-based antenna developed by e-tenna Corporation.



▲ Block diagram of a reconfigurable handset.

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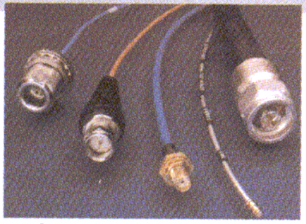

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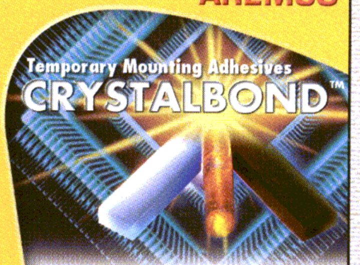

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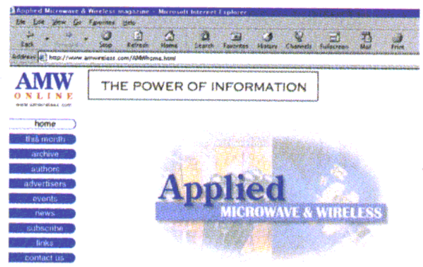

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The New FCC Begins to Take Shape

Activity from the Federal Communications Commission has been limited recently, as a new Chairman and Commissioners build their staffs and begin their work in a new administration. Four of the five Commissioner positions have been filled at the time of this writing (mid-June). A brief biography of each is provided here.

Michael K. Powell, Chairman

Powell was nominated by President Clinton and sworn in as a Commissioner in 1997. President Bush named Powell FCC Chairman on January 22, 2001. His present term ends June 30, 2002. Powell has previously served as Chief of Staff of the Antitrust Division in the Department of Justice. He has practiced law and been a judicial clerk. Powell is a graduate of the College of William and Mary, with a J.D. from Georgetown University.

Gloria Tristani, Commissioner

Tristani has served as Commissioner since 1997, after being nominated by President Clinton. She previously served on the New Mexico State Corporation Commission and has been a lawyer in private practice. Born on Puerto Rico, Tristani is a graduate of Barnard College of Columbia University, with a law degree from the University of New Mexico School of Law.

Kathleen Q. Abernathy, Commissioner

Abernathy was nominated by President Bush on May 1, 2001 and confirmed May 25, 2001. Before appointment to the FCC, she was director for government affairs at BroadBand Office, Inc; a partner in a Washington, DC, law firm; vice president for regulatory affairs at U.S. West (now Qwest Communications); and vice president for federal regulatory affairs at AirTouch Communications. She also served as advisor to past Commissioners Sherrie Marshall and James Quello. Abernathy has a degree from Marquette University and a J.D. from Columbus School of Law at Catholic University of America.

Michael Copps, Commissioner

Copps was nominated by President Bush on May 1, 2001 and confirmed May 25, 2001. Copps has served as Assistant Secretary of Commerce for Trade Development and was previously Deputy Assistant Secretary of Commerce for Basic Industries. He has been Chief of Staff for Senator Ernest Hollings (D-SC) and was a professor of U.S. history at Loyola University of the South. Copps has a degree from Wofford College and earned a Ph.D. from the University of North Carolina at Chapel Hill.

Recent FCC activity

The fiscal 2002 budget for the FCC proposed by the President is $248,545,000. This budget represents an increase of $18,545,000 over the FY 2001 appropriation of $230,000,000. Full time equivalent staffing is proposed to be 1,975. Forty percent of the increase will cover mandatory increases in salaries and benefits, plus inflationary increases for contracts. The balance of the increase includes funds to replace outmoded computer equipment and make other improvements to the Commission's information technology infrastructure.

In the wireless arena, the Commission has released a staff report, "Spectrum Study of 2500-2690 MHz Band: the Potential for Accommodating Third Generation Mobile Systems." This report is a companion to a study done by the National Telecommunications and Information Administration (NTIA) on the 1755 to 1850 MHz band, "Federal Operations in the 1755-1850 MHz Band: The Potential for Accommodating Third Generation Mobile Systems," and the NTIA *Final Report*, "The Potential for Accommodating Third Generation Mobile Systems in the 1710-1850 MHz Band: Federal Operations, Relocation Costs, and Operational Impacts." A January 2001 Notice of Proposed Rulemaking (NPRM) was issued that will examine and propose spectrum for allocation to 3G fixed and mobile wireless services. Comments on these reports and the NPRM were due by April 16 (Docket No. 00-258). No action has yet been taken.