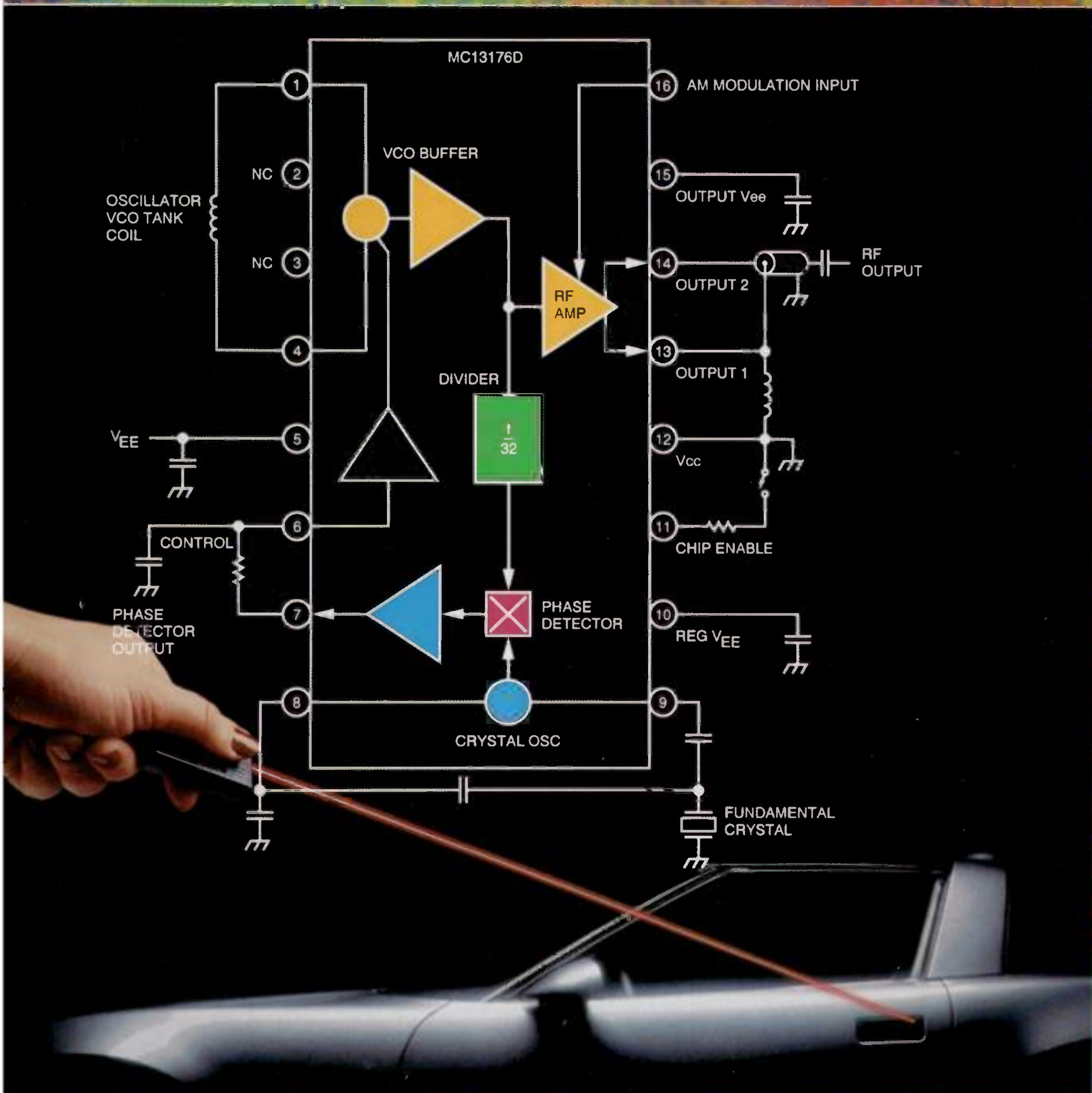
RF design

engineering principles and practices

April 1992



Cover Story
A New UHF Transmitter IC

Featured Technology
Personal Communications

Special Catalog Section — *p. 55*

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P35-4226-0	SPDT-RT	6	1.7	30	Chip	
P35-4230-0	SPST-R	12	2.2	23	Chip	
P35-4245-0	DPDT-R	6	0.8	32	Chip	
P35-4250-0	SP4T-R	4	[illegible]	28	Chip	0.67mm Squared
P35-4252-0	SP4T-T	3	[illegible]	[illegible]	Chip	

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P35-4101-0	0.5-3.5	9	4.5	22	Chip	Self-Biased
P35-4104-0	0.05-3.0	18	6.0	13	Chip	Low VSWRs
P35-4105-0	0.8-1.8	21	3.5	8	Chip	
P35-4110-0	1-6	7.5	4.6	20	Chip	
P35-4140-0	[illegible]	[illegible]	5.5	15	Chip	Pos. Gain Slope
P35-4150-0	2-18	6.0	7.5	15	Chip	AGC
P35-4160-0	[illegible]	20	2.8	14	Chip	Low VSWR

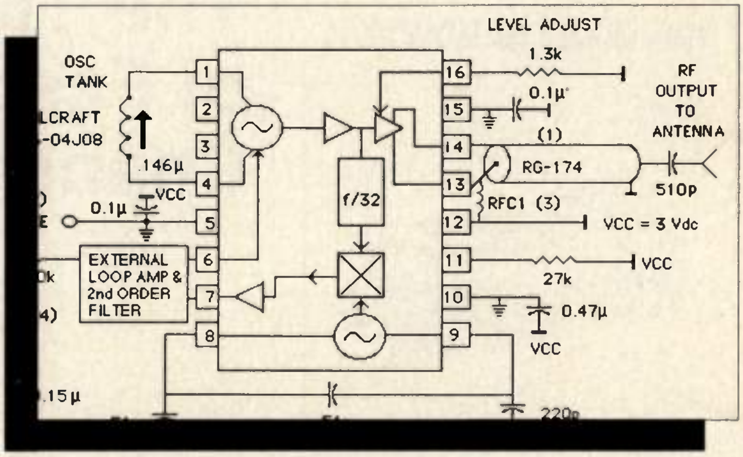
This product is manufactured by GEC-Marconi Materials, UK and distributed by Daico Industries Inc.

INFO/CARD 3

RF design

contents

April 1992



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The Trials of Fast-Paced Change

By Gary Breed
Editor

Personal Communications is our featured technology this month; easily the hottest subject in the world of RF. Voice, video, audio and data are all part of this current boom in our industry.

We have come a long way since the early radio-controlled garage door openers! Other remote controls, cordless phones, and cellular mobile phones started an avalanche that has become very difficult to manage. The problems in managing new wireless technology have been both technical and administrative. Engineers have been forced to develop new skills in a very short time, while regulatory bodies around the world struggle to allocate spectrum space and establish the appropriate technical standards for the right types of services.

Technically, the most difficult problems have been those of engineers in non-RF disciplines, who are familiar with data transmission, interface protocols and network structures. Suddenly, they have been called on to develop a wireless system and need new expertise in RF circuit design, modulation and demodulation, propagation, antennas and EMI, on top of adding to their digital repertoire with error detection, correction and encryption schemes.

Traditional RF engineers have had to take a big step ahead in digital interfaces, modulation techniques, spread spectrum, indoor propagation and all the individual circuit elements that are needed to achieve the desired performance. RF engineers also have had to reduce cost and complexity for circuits operating up to 2500 MHz.

All technical problems have possible solutions, which is the definition of engineering. Hopefully, we at *RF Design* have helped by making information available that helps creative engineers develop this new generation of products.

The regulatory side of new technology is another story, but with some promising recent developments. Congress has pending legislation that would require establishment of spectrum especially for development of new technology. Although there is little chance of passage, the bill puts pressure on the NTIA and FCC to deal with frequency allocations in a more timely manner.

The current World Administrative Radio Conference (WARC 92) is considering worldwide allocations for low earth orbit (LEO) radio services, aircraft telephone services, and future land mobile services. This month's News section has a summary of the final actions of the conference.

Technical standards have been difficult to develop, as proponents of different modulation techniques and advocates of different frequency allocations fight to establish their systems as the "standard." Data rates, error-correction and other digital protocols are following the same road. There is a huge need for reasoned discussion of these issues. Such discussion is taking place, but is proceeding shakily.

Many of these new services will end up as products, providing markets for RF companies and jobs for RF engineers. Not every company will benefit, nor will every engineer. But, with other electronic disciplines stagnant, personal convenience and communications products using RF as the medium of transmission are becoming one of the bright spots in U.S. business.

RF design

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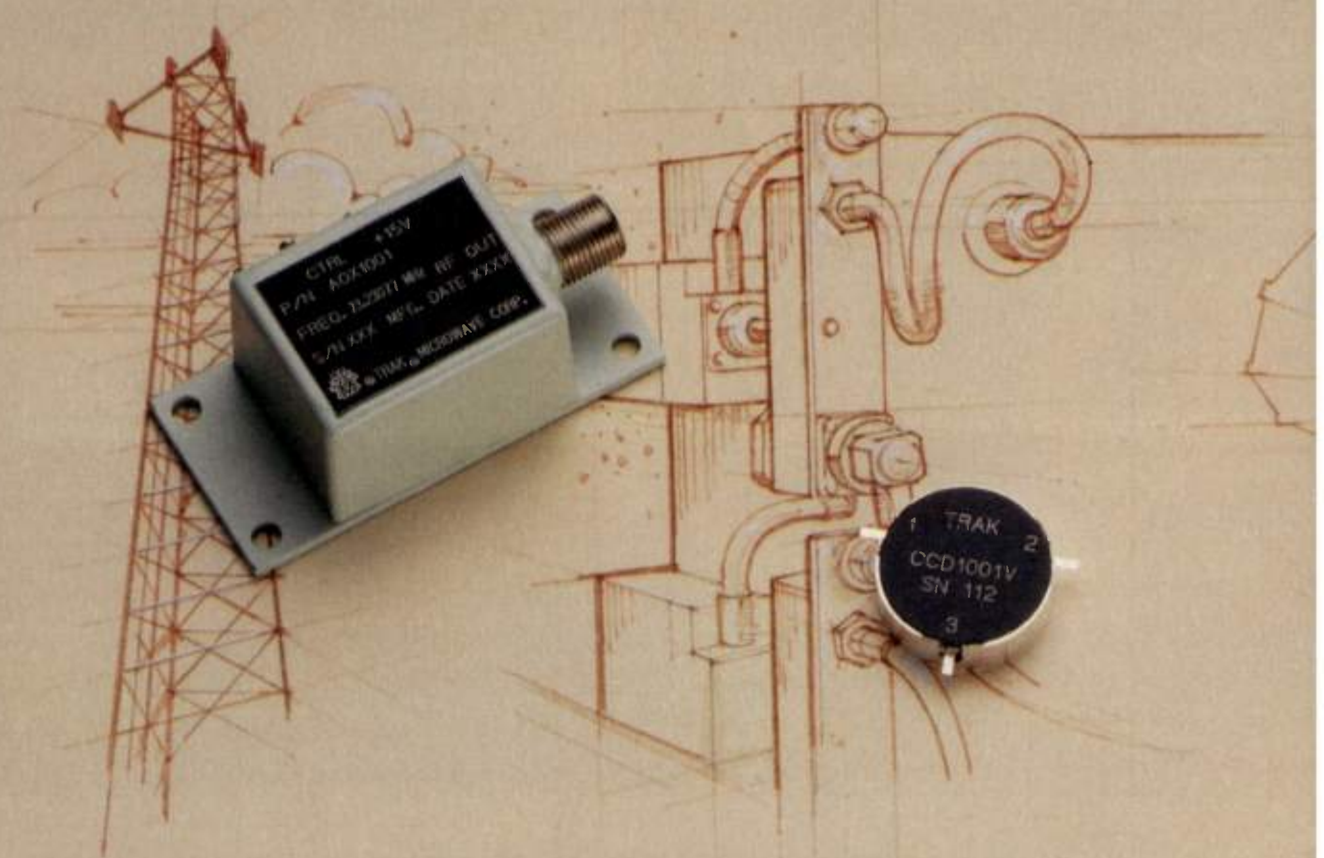

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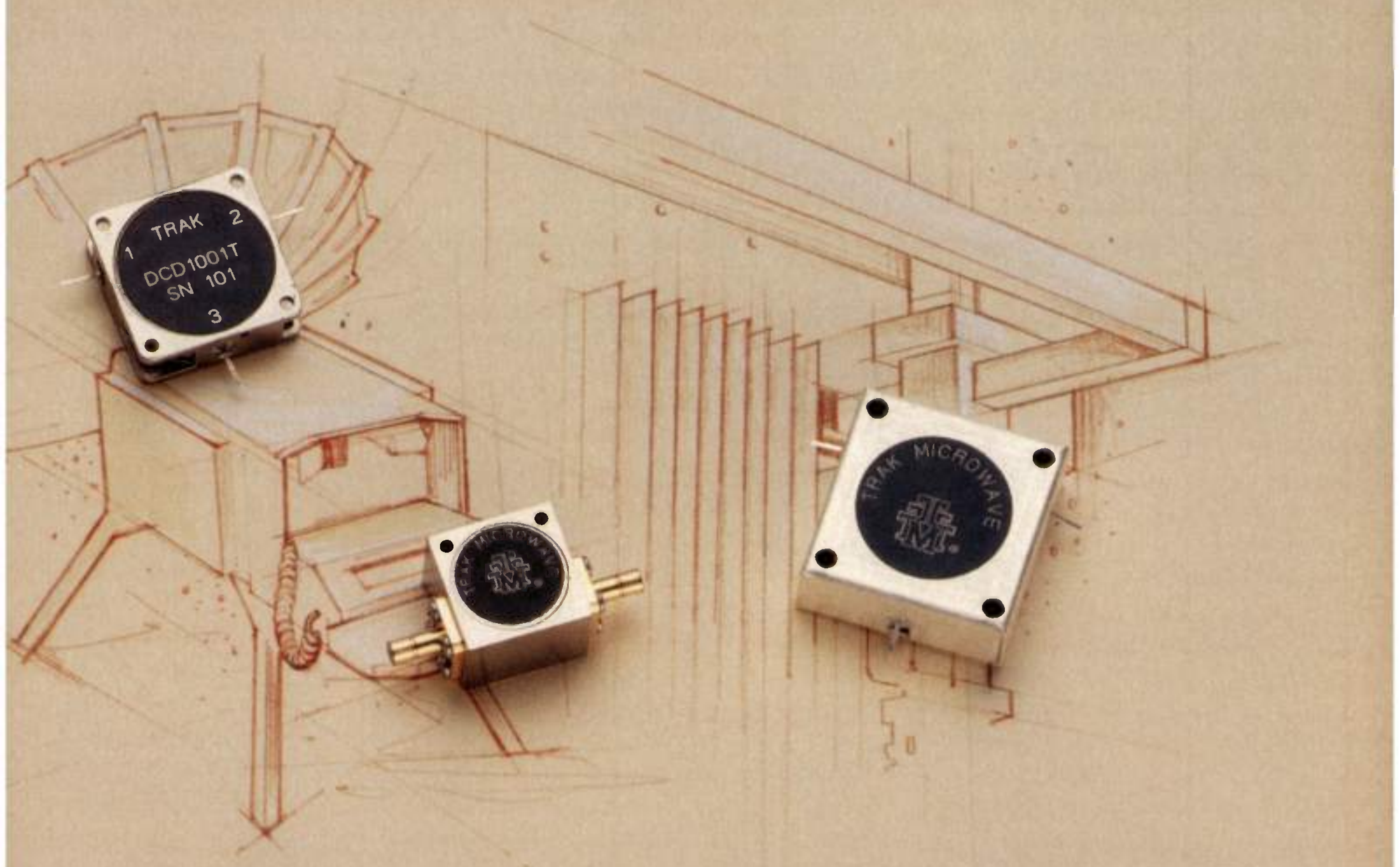

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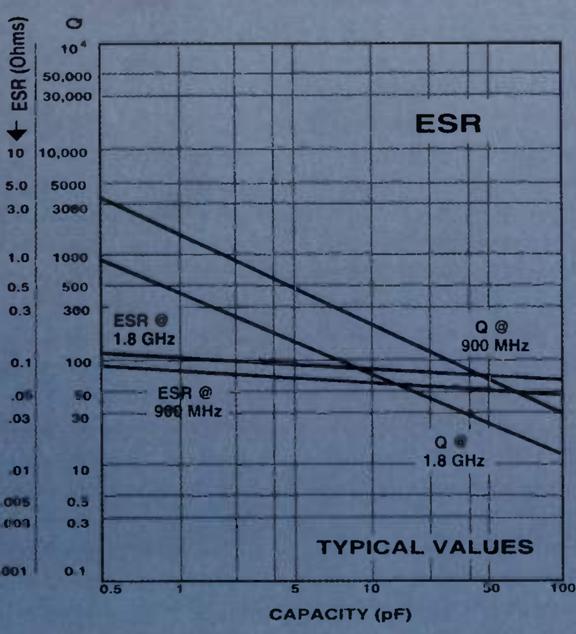

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INFO/CARD 85

Letters should be addressed to Editor, *RF Design*, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111.

Locating Interference

Editor:

James Harris of Trilithic, Inc. presented helpful facts in his article, "Locating Power Line RF Interference," in the February 1992 issue of *RF Design*. My experience, however, does not entirely jibe with his. Here in southwestern Connecticut, overhead high-tension lines with about 13,000 volts run throughout residential areas. The lines are constructed of aluminum wire joined with compression slices. With age, the splices loosen, corrode, and oxides form. Microsparking within these semiconductor boundaries gives rise to a noise spectrum that peaks at approximately 20 MHz. Energy rolls off with frequency and becomes negligible at 150 MHz, which is the operating frequency of the Trilithic Interference Locator System. TV channel 2 (54-60 MHz) suffers the most interference, by channel 5 (76-82 MHz) the interference can hardly be seen, and channel 7 (174-180 MHz) has no visible interference. Radio reception across the HF band is especially noisy.

Splice sparking is a current-related phenomenon that peaks with power demand in the early evening. Harris describes voltage phenomena such as corona discharge and microgap discharge in nearby hardware. These peak when power demand is low and the line voltage is high.

I suggest that power line interference could be more effectively located at 50 MHz. Granted that the directional Yagi antenna would triple in size, but such an antenna isn't necessary at all. I use a short dipole to locate the poles in question and power company technicians have no trouble pinpointing and correcting the problem.

Abraham Albert Goldberg, P.E.
Stamford, CT

Mr. Goldberg is correct in noting that there are interference mechanisms that peak at lower frequencies. The Trilithic unit was designed primarily for television applications, which explains the choice of operating frequency. The disadvantage of locating interference at lower frequencies is less precision. At 50 MHz or at HF, a suspect pole is about the best that can be done. If enough energy is present for detection at VHF, a particular hardware group can usually be determined. — Editor

Attenuator Correction

We made an error in the equations for Pi attenuators in the "Attenuator Basics" tutorial (February 1992 *RF Design*, page 77). Equations (4), (5) and (6) are all presented in the form of admittance instead of impedance. Robert Reyers at the FAA Technical Center in Atlantic City was the first of many readers to notice the mistake.

To obtain resistor values for Pi attenuators, the equations should be:

$$\frac{1}{Z3} = \frac{2}{A-1}\sqrt{\frac{A}{Z_{in} \cdot Z_{out}}} \qquad (4)$$

$$\frac{1}{Z1} = \frac{1}{Z_{in}}\left(\frac{A+1}{A-1}\right) - \frac{1}{Z3} \qquad (5)$$

$$\frac{1}{Z2} = \frac{1}{Z_{out}}\left(\frac{A+1}{A-1}\right) - \frac{1}{Z3} \qquad (6)$$

RF calendar

April

12-16 **NAB '92**
Las Vegas, NV
Information: NAB, 1771 N Street, NW, Washington, DC. Tel: (202) 429-5350. Fax: (202) 429-5406.

21-24 **1992 Conference on GaAs Manufacturing Technology**
San Antonio, TX
Information: Mr. Larry Varnerin, Publicity Chairman. Tel: (215) 758-4061.

22-24 **EMC/ESD International**
Denver, CO
Information: Kristin Hohn, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Tel: (800) 525-9154. Fax: (303) 770-0253.

27-29 **40th International Relay Conference**
Chicago, IL
Information: International Relay Conference, Engineering Extension, 512 E.N., Oklahoma State University, Stillwater, OK 74078-0532. Tel: (405) 744-5714. Fax: (405) 744-5033.

May

12-14 **IEEE Instrumentation and Measurement Technology Conference**
Meadowlands Hilton, NJ
Information: Robert Myers, 3685 Motor Avenue, Ste. 240, Los Angeles, CA 90034. Tel: (310) 287-1463. Fax: (310) 287-1851.

18-20 **42nd Electronic Components and Technology Conference**
San Diego, CA
Information: EIA, 2001 Pennsylvania Avenue, NW, Washington, DC 20006-1813. Tel: (202) 457-4900. Fax: (202) 457-4985.

25-27 **International Symposium on EMC**
Beijing, China
Information: Professor Zhang Linchang, Northern Jiaotong University, Beijing 100044.

27-29 **46th Annual Symposium on Frequency Control**
Hershey, Pennsylvania
Information: Mr. Michael Mirarchi or Ms. Barbara McGivney, Synergistic Management Inc., 3100 Route 138, Wall Township, NJ 07719. Tel: (908) 280-2024.

June

2-4 **MTTS**
Albuquerque, NM
Information: Joyce Long, Horizon House. Tel: (617) 769-9750.

10-13 **NAB/Montreux International Radio Symposium and Exhibition**
Montreux, Switzerland
Information: NAB, 1771 N Street, N.W., Washington, DC 20036-2891. Tel: (202) 429-5350.

RF courses

Advanced Communication Systems using Digital Signal Processing
May 4-8, 1992, Los Angeles, CA
Microwave/Millimeter Wave Monolithic Integrated Circuits
June 8-11, 1992, Los Angeles, CA
Radiation Hardening of Electronic Systems
June 8-12, 1992, Los Angeles, CA
Information: UCLA Short Course Program Office. Tel: (213) 825-3344. Fax: (213) 206-2815.

Infrared/Visible Signature Suppression
April 28-May 1, 1992, Atlanta, GA
Information: Education Extension, Georgia Institute of Technology. Tel: (404) 894-2547.

EMC Solutions by Design and Case Studies
April 22-24, 1992, Pontypridd, UK
Information: IEE, Savoy Place, London WC2R 0BL, United Kingdom.

Analog/RF Fiber-Optic Communications
April 22-24, 1992, Washington, DC
Advanced Signal Processing
April 27-May 1, 1992, Washington, DC
Frequency Hopping Signals and Systems
May 18-20, 1992, Washington, DC
Introduction to Modern Radar Technology
May 27-29, 1992, Washington, DC
Electromagnetic Interference and Control
June 1-5, 1992, Washington, DC
Spread Spectrum Communications Systems
June 15-19, 1992, Washington, DC
Radio Frequency Spectrum Management
June 15-19, 1992, Washington, DC
Information: The George Washington University, Continuing Engineering Education, Merril A. Ferber. Tel: (202) 994-8522 or (800) 424-9773.

Fundamentals of Radar Cross Section: Principles, Prediction and Computation
April 28-May 2, 1992, St. Cloud, FL
Information: Kelly Brown, Southeastern Center for Electrical Engineering Education. Tel: (407) 892-6146.

Modern Microwave Techniques
May 11-14, 1992, Bethesda, MD
Antenna Design
June 9-12, 1992, Silver Spring, MD
Radomes
June 9-12, 1992, Bethesda, MD
Antenna Measurement Techniques
June 16-19, 1992, Rockville, MD
Near-Field Antenna Measurement Techniques
July 7-10, 1992, Boulder, CO
Modern Antennas
July 14-17, 1992, Boulder, CO
Information: Technology Service Corporation, Lynda S. Epstein, Training Coordinator. Tel: (301) 565-2970. Fax: (301) 565-0673.

The EC Directive on EMC
April 21, 1992, Denver, CO
May 15, 1992, Boston, MA
June 4, 1992, Washington, DC
Information: Technology International, Inc. Tel: (804) 644-7735 or (800) 242-8399.

RF and Microwave Circuit Design: Linear and Non-Linear
May 18-22, 1992 Garmisch-Partenkirchen, Germany
RF and Microwave Component Modeling
May 20-22, 1992, Garmisch-Partenkirchen, Germany
Modern Microwave Techniques: Measurements, Signal and Network Analysis, Microwave Products and Systems Characterization
July 13-17, 1992, Singapore
Aspects of Modern Military and Commercial Radar
July 13-17, 1992, Singapore
Maintaining Signal Quality in High-Speed Digital Systems
July 13-17, 1992, Singapore
Information: CEI-Europe/Elsevier, Mrs. Tina Persson. Tel: (46) 122-175-70. Fax: (46) 122-143-47.

EMC 1992: Symposium on EC Requirements
April 27-28, 1992, Boston, MA
April 30-May 1, 1992, Dallas, TX
May 4-5, 1992, Chicago, IL
May 7-8, 1992, Anaheim, CA
ISO 9000 Introduction and Company Registration
April 21-22, 1992, Austin, TX
June 2-3, 1992, Danbury, CT
ISO 9000 Internal Auditor Course
April 23-24, 1992, Austin, TX
June 4-5, 1992, Danbury, CT
Information: TUV Rheinland. Tel: (313) 464-8881.

Introduction to ISO 9000/Q90
April 20-21, 1992, Columbus, OH
April 27-28, 1992, Woburn, MA
May 4-5, 1992, Greenville, SC
Information: AIQR Seminars, Inc. Tel: (800) 274-4220. Fax: (408) 275-9399.

Electronic Design Techniques and Analysis Required to Meet Electromagnetic Compatibility Requirements
May 6-7, 1992, Farmington Hills, MI
Advanced EMC Printed Circuit Board Design
May 8, 1992, Farmington Hills, MI
Information: JASTECH. Tel: (313) 553-4734.

Impulse Radar
April 29-May 1, 1992, Washington, DC
ELINT Analysis
April 29-May 1, 1992, Washington, DC
ELINT/EW Applications of Digital Signal Processing
April 29-May 1, 1992, Washington, DC
Information: Research Associates of Syracuse, John Eckmair. Tel: (315) 455-7157.

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Global Allocations for LEOs and PCs Created at WARC-92

Representatives of 127 nations comprising the 166 member International Telecommunications Union met in Malaga-Torremolinos, Spain from February 3 to March 3 for the World Administrative Radio Conference (WARC-92). WARC-92 was the first major frequency allocation conference held since 1979 when the entire Radio Regulations were reviewed. This Conference sought to locate allocations for low-Earth orbiting (LEO) satellites for data and voice communications, digital audio broadcasting (DAB), High Frequency broadcasting, and future public land mobile telecommunications systems (FPLMTS), including personal communications services (PCS). Even though WARC-92 had just ended at our deadline, final decisions had become available.

LEO satellites below 1 GHz would be used primarily for data transmission and radiolocation. Primary allocations were made In the bands 137-137.025 MHz, 137.175-137.825 MHz, 148-149.9 MHz, and 400.14-401 MHz. Secondary allocations were agreed upon for the 137.025-137.175 MHz and 137.825-138 MHz. Additionally, an agreement on sharing criteria between LEO mobile satellites and geostationary orbit satellites and among LEO mobile satellites was completed.

Global allocations for LEO systems above 1 GHz were not approved until the waning hours of the Conference. These "big LEOs" would permit worldwide voice communications via satellite on systems such as those proposed by Motorola, Ellipsat, Qualcomm, TRW, and Constellation. One roadblock to obtaining a global LEO allocation was the need to prevent interference to the Russian satellite navigational system Glonass and the U.S. Global Positioning System. The primary allocation was made in the bands 1610-1626.5 MHz (earth-to-space) and 2483.5-2520 MHz (space-to-earth).

A global allocation for DAB emerged in the bands 1452-1492 MHz, but the U.S., seeking an S-band allocation (2.3 GHz), sought an exception to the rule in order to reserve the S-band for domestic DAB. Terrestrial-based DAB will be discussed at a future WARC.

In the area of HF, or shortwave broadcasting, it was recommended that single-side band (SSB) techniques be placed on the agenda of the next WARC by the ITU Administrative Council. SSB would enable the use of approximately 1.5 channels more than the current double-side band method, thus, significantly increasing spectrum efficiency. The representatives requested that SSB be generally introduced and double-side band use be ceased by December 31, 2015. Some countries requested that that date be advanced by up to 10 years.

By upgrading to primary status the mobile service in some bands in Region 1, a worldwide primary allocation to the mobile service in the band 1700-2690 MHz was created for FPLMTS. The sub-bands 1885-2025 MHz and 2110-2200 MHz have been designated for the implementation of terrestrial FPLMTS (expected to be realized by the year 2010) and the sub-bands 2010-2025 MHz and 2185-2200 MHz for a combination of terrestrial and space FPLMTS components. — *Lou Manuta*

Superconducting Wires Consortium — American Superconductor Corporation has announced the formation of the Wire Development Group, comprising industry, government and academic representatives to develop high temperature superconducting wires for electric energy applications. In addition to American Superconductor, the group consists of three of the U.S. Department of Energy's National Laboratories — Los Alamos, Oak Ridge and Argonne, and the University of Wisconsin's Applied Superconductivity Center. The group has focused on making fully superconducting flexible wires that can be manufactured in lengths sufficiently long to be used by industry in programs underway to develop commercial products.

Measurement Service for CW Wattmeters — NIST expects to establish a measurement service for high power, continuous wave wattmeters in the near future. Measurements will be available at several points from 2 to 30 MHz (1 to 1,000 W) and 30 to 400 MHz (1 to 5,000 W). Wattmeters must be controllable via an IEEE-488 bus, have a type N male input connector, and either have a type N female output connector or be supplied with a load. For more information, contact Gregorio Rebuldela or Jeffrey Jargon, Div. 813.01, NIST, Boulder, CO 80303. Tel: (303) 497-3561.

Personal Communications Service to be Tested — Bell Atlantic Mobile Systems and Motorola have announced that they will perform a joint trial of a cellular-based personal communications service in Pittsburgh, Pennsylvania later this year. The service will provide users with a single personal telephone number that will make them reachable at home, in the office and on the road. The service will employ the Narrowband Advanced Mobile Phone Service, a portable handset and charge, personal base station, and the Advanced Intelligent Network for routing calls. The service will also use traditional cellular service and the new microcell technologies.

Radio Waves Used to Find Buried Land Mines — NIST recently completed a six year project to help the U.S. Army detect buried land mines using electromagnetic technology. The method involves sending radio waves into the soil and analyzing the reflections received. A new report, *Qualifying Standard Performance of Electromagnetic-Based Mine Detectors* (NISTR 3982), covers theoretical relationships between EM fields and matter; critical EM performance factors for portable mine detectors; measuring EM properties of materials relevant to EM mine detection; EM properties of soils and recommendations for simulated soil standards; and desired properties and recommendations for simulated mine standards. Copies of NISTR 3982 are available from the National Technical Information Service, Springfield, VA 22161. Order by PB 92-116292. The price is $26.

Antenna Gain Improvement Using Superconductors — Ball Corporation recently demonstrated improvements in antenna gain by using a superconducting thin film in planar microstrip antenna feed networks. Ball demonstrated a 64-element superconducting array operating at 30 GHz with a 2 dB higher gain than an identical antenna patterned in gold and measured at the same cryogenic temperature of 77 degrees Kelvin. In comparison with a room temperature measurement, the gain increase was 4 dB.

IC Comparator Developed by NIST — Researchers have created an integrated circuit comparator for sampling electrical signals that is faster and less error-prone than existing devices. The new design eliminates thermal effects common in other devices that can cause errors and effect voltage settling time. Exhibiting a bandwidth greater than 2 GHz, the NIST circuit is over twice as fast as most other available comparators. It can make decisions with 0.1 percent accuracy within 2 nanoseconds following an abrupt input change. The IC was fabricated using a commercial silicon bipolar process. For more information contact Michael Souders, B162 Metrology Bldg., NIST, Gaithersburg, MD 20899. Tel: (301) 975-2406.

Low Cost All-Diamond Ceramic — Crystallume has developed a new synthetic diamond material composite which can be produced for less than $5/gram as opposed to the current $500/gram. The new composite materials are made using commonly available diamond particles cemented together with diamond "glue" created by chemical vapor deposition techniques. Testing of initial samples has shown a thermal conductivity of nearly 6 watts/cm/degree C. It is also possible to consolidate the diamond composite in net shape form, reducing or eliminating expensive polishing and fabrication steps.

EF Johnson and Racotek Enter Into License Agreement — Racotek and E.F. Johnson recently announced the signing of a technology licensing agreement. The agreement calls for E.F. Johnson Company to share technology with Racotek relating to the implementation of RacoNet wireless data communications service over E.F. Johnson specialized mobile radio equipment.

DB Products Acquires Carl E. Holmes Company — DB Products recently announced the acquisition of the Carl E. Holmes Company (CEHCO). CEHCO will operate as a division of DB Products. Terms of the acquisition were not announced.

Microwave Power Devices Awarded Contract — Microwave Power Devices, Inc. has been awarded a $5.8 million contract by the U.S. Air Force for wide band, high power amplifiers in support of airborne platforms.

Charterhouse Buys Amplica — Charterhouse Group International has announced the acquisition of the assets and business of Amplica, Inc., formerly a subsidiary of Triax, Inc. Amplica designs and manufactures advanced solid state microwave amplifiers and subassemblies for military and commercial applications.

Sierra Aerospace Technology Acquired by Maxwell Laboratories — Maxwell Laboratories has announced the acquisition of Sierra Aerospace Technology, a developer and manufacturer of high-reliability EMI filter and multilayer ceramic capacitors for medical, geophysical, geothermal, aerospace and military markets. The acquisition was an asset purchase for cash. No other terms were announced.

Calibration Services Users' Guide — A newly revised *NIST Calibration Services User's Guide* lists more than 500 different calibration services, special test services, and measurement assurance programs available for industry from NIST. The guide lists available calibration services, such as: dimensional; mechanical, thermodynamic quantities, optical radiation, ionizing radiation, electromagnetic, and time and frequency measurements. Copies are available from the Calibration Program, Room A104, Bldg. 411, Gaithersburg, MD 20899. Tel: (301) 975-2002.

Milliwave Technologies to Purchase SMT Division — Sierra Microwave Technology and Milliwave Technologies Corp. have reached an agreement in principal for Milliwave to purchase the technology, assets and liabilities of SMT's Amplifier Division. The entire operation, including equipment and personnel will be transferred to Milliwave's facility. Milliwave has agreed to honor and meet all prior commitments of the division including pricing and deliveries of existing orders as well as existing quotations and warranty repairs.

Lorch Electronics Receives Contract — Lorch Electronics has received a purchase order valued at \$0.7 million from Paramax Systems Corporation. Lorch will design and manufacture high performance phase comparators for the NEXRAD Program. NEXRAD (Next Generation Weather Radar) is an advanced weather detection system designed to replace present weather detection equipment at sites throughout the world. Various options for additional units and field support could increase the award by an addition \$0.1 million.

New Company Formed — Eastern Multiplexers, Inc. has announced its formation. The company designs and manufactures microwave and RF components for the defense electronics industry. Products include suspended substrate broadband filters, multiplexers and switched filter banks. They are located at 7836-E Airpark Road, Gaithersburg, MD 20879. Tel: (301) 990-8336.

Cubic Defense Receives Joint STARS Contract — Cubic Corporation has been awarded a \$26 million contract from Grumman Melbourne Systems Division to continue work on Joint STARS, a battlefield surveillance and target acquisition system. Cubic will continue to refine and enhance the datalink it designed and built for the Joint Surveillance Target Radar Attack System.

Broadcast Applications Drive RF and Video Technology

By Gary A. Breed
Editor

One of the first RF industries, broadcasting, remains a major factor in RF and video electronics. This industry is experiencing continued development of new technologies like single sideband (SSB) shortwave broadcasting, digital FM broadcasting, high definition television (HDTV), wide range paging service on broadcast subcarriers, and several new satellite services for video and audio programming.

In the studio, advanced video system development using ever-wider bandwidths, with complex analog and digital signal processing, is pushing high speed circuit design. Other convenience products like wireless microphones, short-range microwave links for portable cameras, and mobile satellite uplinks continue to add to broadcasting's use of RF technology.

Traditional RF Transmission

RF power components, vacuum tubes, klystron-family devices and transistors continue to see development. High-efficiency thermionic devices for UHF television broadcasting are still drawing interest, as are better transistors for high power applications, especially for television transmitters. For medium wave (AM band) transmitters, switching-mode amplification using power MOSFETs remains the method of choice, with power levels now reaching 100 kW. AM transmitter designers have developed novel methods for combining and modulation; solid-state television transmitters may need similar breakthroughs to become reliable and relatively inexpensive.

Studio-transmitter links and satellite uplinks are markets for microwave equipment. In the interest of quality and reliability, the industry has seen an increase in upgraded studio-transmitter links. More television stations are utilizing mobile satellite uplinks, as well, providing a market for satellite systems.

Short-range wireless links for microphones and cameras have been in use for some time, but the convenience and flexibility of wireless interconnection is getting renewed attention. High performance wireless microphones are being developed which allow many more performers to use them at one time. New technology, including very high performance receivers and spread spectrum transmission, are being utilized to avoid interference. Portable cameras are being outfitted with short-range microwave links to get rid of the "umbilical cord" of control and video cables.

Video Circuitry

There has been no letup in the extremely rapid development of video processing equipment. Competition in both technical capabilities and style have kept video effects designers busy. High speed digital signal processing is used for video image manipulation, along with wideband, high isolation switching and distribution circuitry. With bandwidths up to 50 MHz, these circuits closely parallel digital signal processing for other baseband and IF applications.

More flexible signal routing and switching to reduce the expense of cabling is another area of development activity. A few fiber optic installations have been made for video distribution, and systems for directing the desired audio and video programming are undergoing continued improvement.

New Applications

Single sideband (SSB) transmission for international shortwave broadcasting will be phased into operation by the end of 2015. This broadcasting medium is growing rapidly, and the spectrum savings of narrowband modulation is a necessity. Planning for this major shift from amplitude modulation will involve new transmitter construction or major retrofitting of existing equipment. For consumer electronics manufacturers, economical SSB receivers must be designed and distributed to all corners of the world.

HDTV has passed the point where it is new and speculative. Limited broadcasting is underway in Japan, and plans are firmly in place for program broadcasting by satellite. HDTV using terrestrial transmission appears to be nearing a resolution with field trials beginning soon that are supposed to result in a selection of a technical standard. Once the regulatory hurdles are crossed, most analysts predict a slow initial growth, but with a rapid upward swing after three to five years.

Another new, and very rapidly developing broadcast mode is digital audio broadcasting (DAB), transmitting compact disc (CD) quality audio. Initial broadcast via satellite will be almost immediate, and proposals for digital FM broadcasting are being evaluated. Although DAB was proposed after HDTV was conceived, it is likely to be implemented long before HDTV sees its first regular programming. Digital modulation will require changes in FM transmission equipment, and add-on equipment for existing receivers must be developed quickly to take advantage of the marketing opportunity that superior quality sound offers broadcasters.

Summary

Although broadcasting has seen slow development of some new technologies like HDTV and stereo AM broadcasting, there have been other areas with substantial growth. Television stereo and second-audio program channels, extensive use of subcarriers on TV and FM signals for auxiliary services, and the use of satellite communications systems are some of the most visibly active areas in broadcast technology. New services like SSB international broadcasting, DAB and HDTV are providing the next challenges for broadcast equipment designers.

Sophisticated video systems and RF equipment for operational support demonstrate that broadcasting is a significant market for more than just high power transmitting equipment. Like many so-called "old" RF technologies, broadcasting continues to be an active and innovative technological force. **RF**

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Statistical Design Improves Reliability and Manufacturing Yields of RF Circuits

By Keith Cobler
EEsof Inc.

Computer simulation is a well established method for investigating typical or optimum circuit performance. But simulation fails to adequately address the issues important to product success, including: maximum statistical (6-sigma) yield, improved quality, and faster time-to-market. Unavoidable variations in component values due to component tolerances, environmental effects, or process variations cause a design to vary within a given lot or production run. CAE programs usually only consider a single set of component values that calculate a nominal response thus failing to recognize the response of manufactured circuits. Engineers can optimize a nominal response for performance, but to increase the manufacturing yield the engineer must intuitively replace parts or change component tolerances.

By analyzing a design in terms of its component's statistical variations, designs can be produced with higher manufacturing yields, and higher quality, and ultimately more cost-effectively. In fact, it is the statistical response, and not the nominal response, that determines the final success of a design since it represents the actual manufactured performance. In the commercial sector where time-to-market is crucial and a six-month delay may cost as much as a third of the profit, statistical analysis is critical for maximizing yield before a design is committed to production. Today's software programs can not only analyze manufactured responses but can also optimize manufacturing yield by selecting the correct nominal component values such that the high-yield design is obtained. This type of analysis is virtually impossible without the aid of software.

In this article, some of the concepts that are fundamental to the understanding of statistical design will be explained. The use of histograms in interpreting statistical data as well as the ability to automatically improve yield through design centering are described. New features that give designers the ability to utilize statistical design techniques are now available in programs such as EEsof's Libra and jOMEGA circuit simulators. In this paper, a low-pass filter example will be used to demonstrate how to use statistical design software to maximize yield while considering part selection and cost.

	Part	Value
Single-point design values:	L1	168.7 nH
	C2	94.6 pF
	L3	236.3 nH
	C4	67.6 pF

Table 1. Values determined from single-point optimization.

Analyzing the Nominal and Statistical Responses

Designers have had to rely on different methods in an attempt to control the response of manufactured circuits. Many incorrectly believe that the nominal response is the geometric mean of the statistical response. Consequently, designers often try to meet specifications by using small tolerance components such that the manufactured responses fall symmetrically about the nominal design. In this way the true statistics of the problem are ignored, and the resulting design may not be cost effective. Software tools are now available that can analyze and optimize the statistical response of a circuit, based on variations in component values, tolerances, or other types of statistical variations.

In circuit simulation it is important to make the distinction between single-point and statistical analysis. A single-point analysis only considers the nominal component values within a circuit. It does not take into account any type of variation or uncertainty within component values. This, in turn, leads to a single or nominal response that is only good for one specific set of component values as shown by the single response of an active low-pass filter shown in Figure 1a. With statistical analysis, the variations in component values are taken into account by the Monte Carlo algorithm which varies every statistical component randomly such that a family of responses exists as shown in Figure 1b. The nominal response is contained somewhere within the statistical response. In the same way that the single nominal response is optimized for peak performance, so the

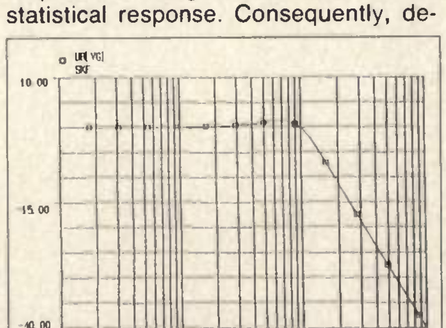

Figure 1a. Nominal response of active low-pass filter.

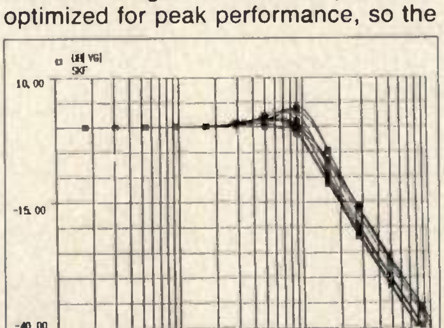

Figure 1b. Statistical response of active low-pass filter.

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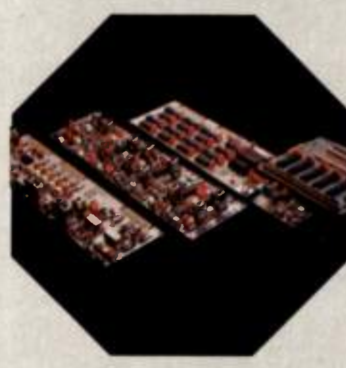

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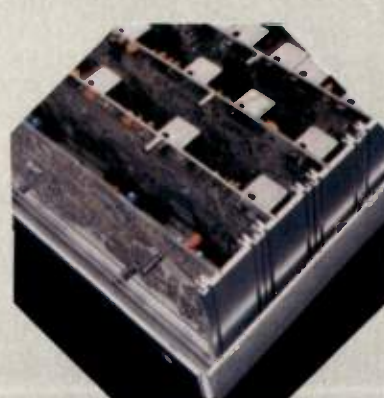

Part	Value	Tol.
L1	180 nH	10%
C2	100 pF	10%
L3	220 nH	10%
C4	68 pF	10%

Table 2. Using discrete part values (based on actual selection).

statistical response can be optimized for optimum statistical or manufactured performance. By controlling and optimizing a circuit's statistical performance the reliability and manufacturing yield can be maximized by decreasing the sensitivity of circuit performance to changes in its component values.

In order to justify the use of statistical design, it is beneficial to first understand the basic principals and concepts. To begin, Monte Carlo analysis, which forms the basis for most statistical design software programs, will be reviewed. The concept of component space will then be used to introduce some statistical design features. Statistical design software's greatest benefit,

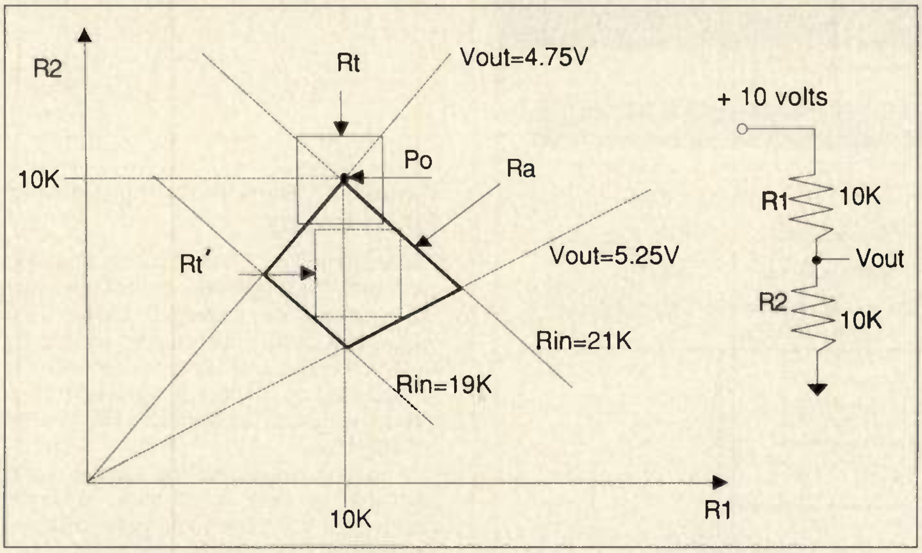

Figure 2. Two-dimensional component space for a voltage divider.

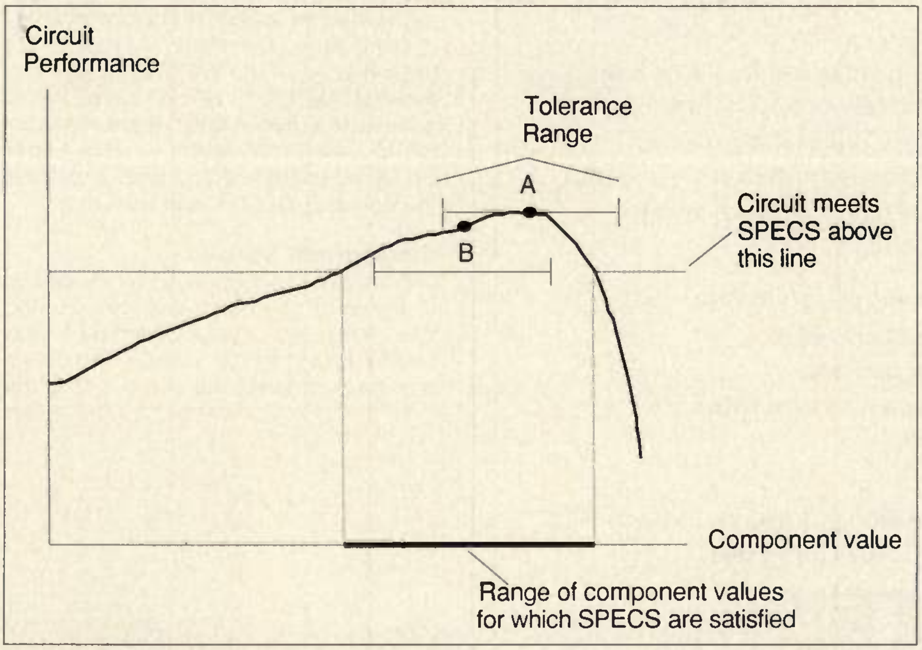

Figure 3. Graph of circuit performance versus component value for a typical circuit.

design centering, will be explained. Design centering automatically adjusts the nominal components of a design such that the highest yield possible is obtained. The use of histograms, which serve as a useful tool to interpret statistical data, will then be described.

Monte Carlo Analysis

The fundamental method of statistical analysis is based on Monte Carlo. Monte Carlo works by randomly varying each component's value within its specified tolerance according to the probability distribution function of each component. Monte Carlo analysis has been found to be the most practical and accurate method for estimating yield. One of the major advantages of Monte Carlo is that it does not suffer from the "curse of

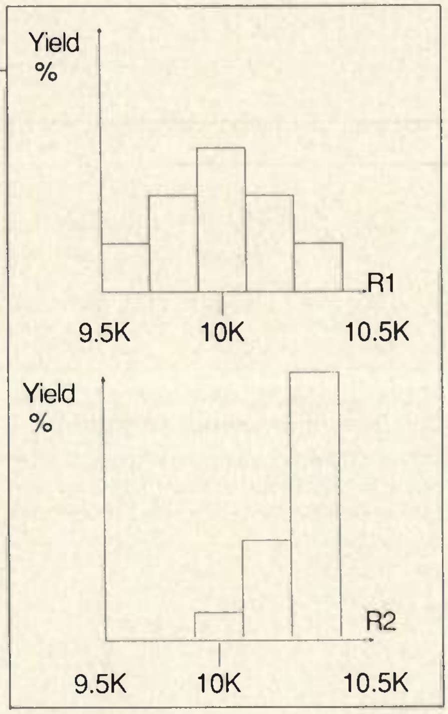

Figure 4. Sensitivity histograms for R1 and R2.

dimensionality." This means that the analysis is completely independent of the number of statistical parameters within the circuit. Therefore, according to Monte Carlo, the same amount of time is required to estimate the yield of a circuit with five statistical components as with fifty.

A major draw-back to Monte Carlo analysis is that it requires a large number of samples for a given degree of confidence in the estimate. The variance in the estimate is proportional to the inverse square root of the number of trials used. Therefore, in order to cut the variance of the estimate in half, the number of trials would have to be quadrupled. Fortunately, there are techniques available (such as the EEsof Shadow Model) which greatly increases the speed of Monte Carlo analysis.

Component Space

Statistical concepts can be visualized in terms of geometric descriptions and one particularly useful definition is that of component space. Component space is a multi-dimensional space where the

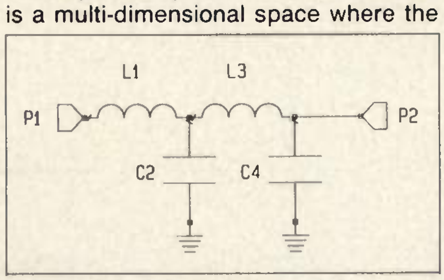

Figure 5. Schematic for a two section low-pass filter.

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Wide Band / Low Noise Amplifiers										
	W40C	1MHz—40MHz	42	±.5	1.0 Typ 1.2 Max	+5	2:1	+15	20	C/SMA
	W50ETC	10KHz—50MHz	24	±.5	5.3 Typ 6.0 Max	+23	2:1	+15	125	E-75/BNC
	W50ATC	10KHz—50MHz	50	±.5	1.3 Typ 1.5 Max	+5	2:1	+15	25	C-75/BNC
	W110F	5MHz—110Mhz	55	±.5	1.1 Typ 1.2 Max	+15	2:1	+15	80	C/SMA
	W110H	5MHz—110MHz	30	±.5	1.2 Typ 1.4 Max	+5	2:1	+15	30	C/SMA
	W500K	1KHz—500MHz	30	±1	1.7 Typ 2.2 Max	+3	2:1	+15	25	C-75/BNC
	W500C	5MHz—500MHz	40	±.5	1.4 Typ 1.6 Max	+10	2:1	+15	50	C/SMA
	W500EF	5MHz—500MHz	60	±.5	1.3 Typ 1.4 Max	+20	2:1	+15	190	A/SMA
	W500H	5MHz—500MHz	33	±.5	1.2 Typ 1.4 Max	+5	2:1	+15	25	C/SMA
	W1G2M	10KHz—1000MHz	30	±1	2.0 Typ 3.0 Max	+5	2:1	+15	35	C-75/SMA
	W1G2H	5MHz—1000MHz	30	±.5	1.3 Typ 1.5 Max	+5	2:1	+15	40	C/SMA
	W2GH	500MHz—2000MHz	22	±1	4.0 Typ 4.5 Max	+5	2:1	+15	30	C/SMA
	WFR1-4GA-14	100MHz—4000MHz	28	±1	3.5 Typ 4.0 Max	+14	2:1	+15	100	A-75/SMA
Medium Power Amplifiers										
	P150D	35KHz—150MHz	27	±.5	5.0 Typ	+30	2:1	+24	400	H/SMA
	P150M	500KHz—150MHz	26	±.5	5.0 Typ	+30	2:1	+24	600	H/BNC
	P150ML	400KHz—150MHz	24	±1	11 Typ	+29.5	2:1	±24	600	H/BNC
	P500A	2MHz—500MHz	37	±.5	4.5 Typ	+30	2:1	+24	500	H/SMA
	P500L	5MHz—500MHz	17	±.7	10 Typ	+30	2:1	+24	420	H/BNC
	P500ML	2MHz—500MHz	16	±1	11 Typ	+28	2:1	+24	600	H/BNC
	P1GB	50MHz—1000MHz	30	±1	5.5 Typ	+30	2:1	+20	800	A-S/SMA
	P1000M	5MHz—1000MHz	20	±.5	6 Typ	+21	2:1	+20	200	H/SMA
	P2GF-2	10MHz—2000MHz	32	±1	7.5 Typ	+30	2:1	+15	1000	FW1/SMA
	P42GA-29	.5GHz—4.2GHz	30	±1.5	6.5 Typ	+29	2:1	+20	1200	FW75/SMA

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dimension is equal to the number of components within a circuit. For example, consider the voltage divider shown in Figure 2. For a circuit with two statistical parameters a two-dimensional component space is defined. The two resistors R1 and R2 each have a nominal value of 10K which may vary ±500 ohms. The two resistors define a tolerance region, R_t, whose limits are constrained by the tolerances assigned to each part. When R1 and R2 are equal to 10K, a nominal response will result and is shown at P_o. The circuit specifications may be applied to the component space by defining the region of acceptability, R_a. This is the region in which the circuit performance meets specifications as shown in the figure. For the voltage divider, there are two specifications: (1) the input resistance R_{in} falls within the range $19K < R_{in} < 21K$ and (2) V_{out} falls within $4.75\ V < V_{out} < 5.25\ V$. The amount of overlap between R_a and R_t determines the manufacturing yield of the circuit. The nominal component values of the circuit give an estimate of manufacturing yield to be about 25 percent.

Part	Value	Tol.
L1	180 nH	10%
C2	91 pF	5%
L3	220 nH	10%
C4	68 pF	5%

Table 3. Using tighter tolerance parts (based on actual selection).

Design Centering

Design centering is the process of choosing the correct nominal component values of a design such that the number of manufactured responses meeting specifications are maximized. Consider a typical circuit whose performance, as a function of component value, is shown in Figure 3. All points which fall above the horizontal dashed line represent circuits which meet specifications. Typically, a designer will optimize or tune the circuit such that it achieves peak performance. For this example, peak performance is found at point A. Inevitably, the circuit's performance will change as a result of the unavoidable variations associated with each component. The magnitude of this change is defined by the tolerance region. If the nominal or peak operating point is chosen close to a "performance cliff", the overall circuit performance may fall out of specification. In a manufacturing environment this is a major contributor to low manufacturing yield. Even for the case where only a single circuit is to be built, this type of behavior may lead to a design with unreliable performance. A design with higher yield and greater reliability may be achieved by moving the nominal value response to point B on the response such that the tolerance region falls well within the acceptable range and away from the performance cliff. This type of "centered design" can automatically be achieved by using a statistical optimizer.

Another way to describe design centering is in terms of component space. In Figure 2, the manufacturing yield of a design may be increased by moving the tolerance region R_t to R_t' such that the volume is now contained primarily within the region of acceptability, R_a. In other words, if the circuit's components vary about some new nominal value with

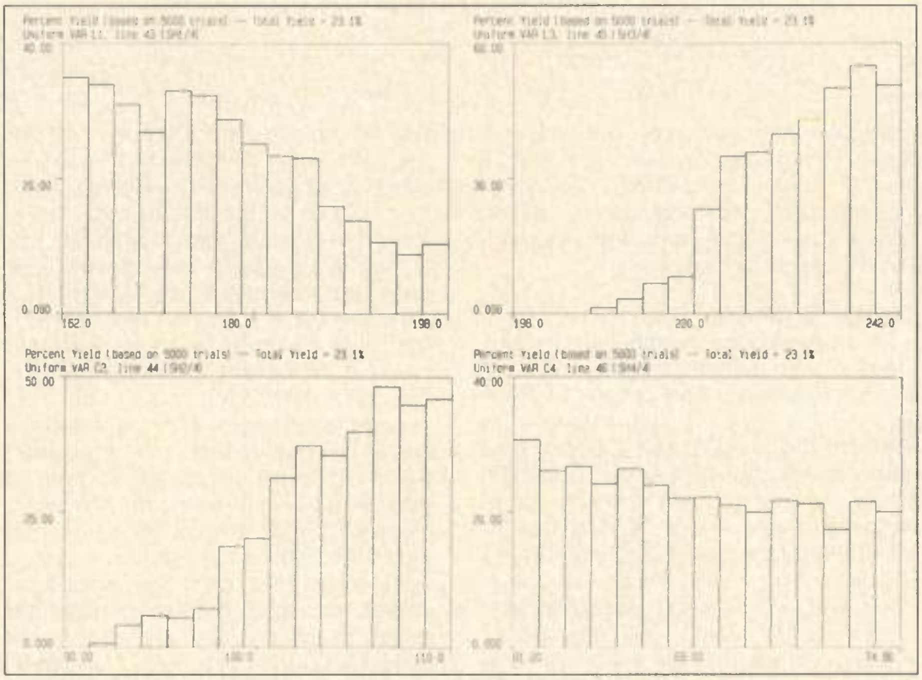


Figure 6. Sensitivity histograms before design centering.

their same associated tolerances, all of the circuits will meet specifications. This is the process of design centering. Design centering works by recalculating the nominal values of the circuit components with their associated tolerances such that the overall circuit variance falls within the specification. Design centering not only improves the manufacturing yield, but it also improves the circuit's reliability by desensitizing the response and minimizing the probability that the circuits performance will fall outside of the region of acceptability.

Interpreting Data With Histograms

One method for interpreting statistical data generated by a Monte Carlo analysis is through the use of histograms. The sensitivity histograms in Figure 4 present a plot of percent yield as a function of parameter value. This information is displayed in bins where the magnitude of each bin corresponds to the relative yield achieved if that particular component value is used. Two essential pieces of information are obtained from sensitivity histograms. The first is whether or not the nominal value for a given component is centered so the highest yield for the design occurs at the nominal value of the component. Once our design is centered, the second piece of information indicates the relative tolerance we can use for a given component value.

In the case of the voltage divider, notice that the original nominal value for R2 was selected too low, as shown in Figure 4. If a new nominal value is selected, the yield should improve. Once the component value is centered, decisions can then be made on the tolerances to use. For the case of R1, which is already centered, a tighter tolerance part may be used such that the variation about the nominal value is minimized. Note that if the histogram is flat over the entire tolerance range an expensive tight-tolerance part may be unnecessary. To investigate this, it is only a simple matter of changing the tolerances on selected components, running Monte Carlo again, and then interpreting the resulting histograms.

Design Example

A simple design example will now be used to demonstrate the capabilities of statistical design. The schematic for a two-section low-pass filter is shown in Figure 5. The initial circuit specifications are a bandwidth of 50 MHz, pass-band ripple less than 1 dB, an input return loss less than −14 dB, and an out-of-band attenuation of −24 dB one octave above cut-off. The circuit has been optimized using a single-point optimizer to achieve the initial single-point specifications. Notice that the values used in the single-point design, as listed in Table 1, are not discrete off-the-shelf parts. In addition, no consideration has been given to the component's tolerances at this time. The next step in the design is to see what values of off-the-shelf parts are available. To begin, a relatively moderate tolerance of 10 percent for each component is used. In general, the tolerance of a given part is inversely proportional to its cost. Therefore, it is always best to start off with loose tolerance parts. The closest off-the-shelf part values that are available are shown in Table 2. Using these values in the yield estimate leads to a relative yield of 23 percent. For the designer using a single-point optimizer the easiest method to improve the yield is to use tighter tolerance parts. In this example the next tighter tolerance off-the-shelf parts available are 5 percent silver-mica capacitors with the same 10 percent inductors. Generally, when using a tighter tolerance part, the number of values available increases, thus the actual value selected is closer to the initial single-point values. The tighter tolerance off-the-shelf parts values are listed in Table 3. Notice that for C2 a 91 pF capacitor is now used as opposed to the 100 pF capacitor used before. This is because the 91 pF capacitor is closer to the value determined in the single-point optimization. After applying the

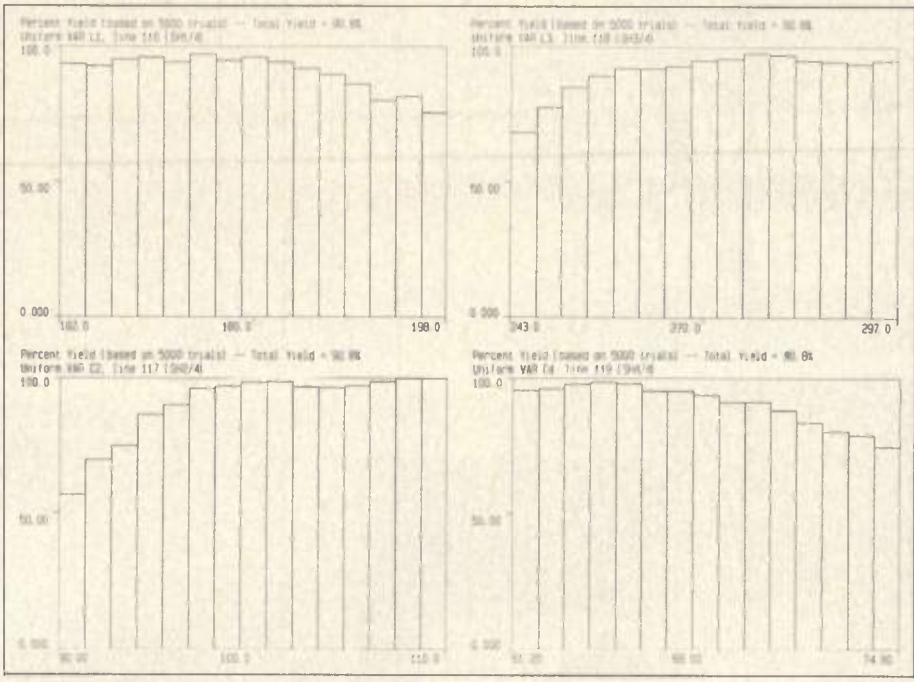


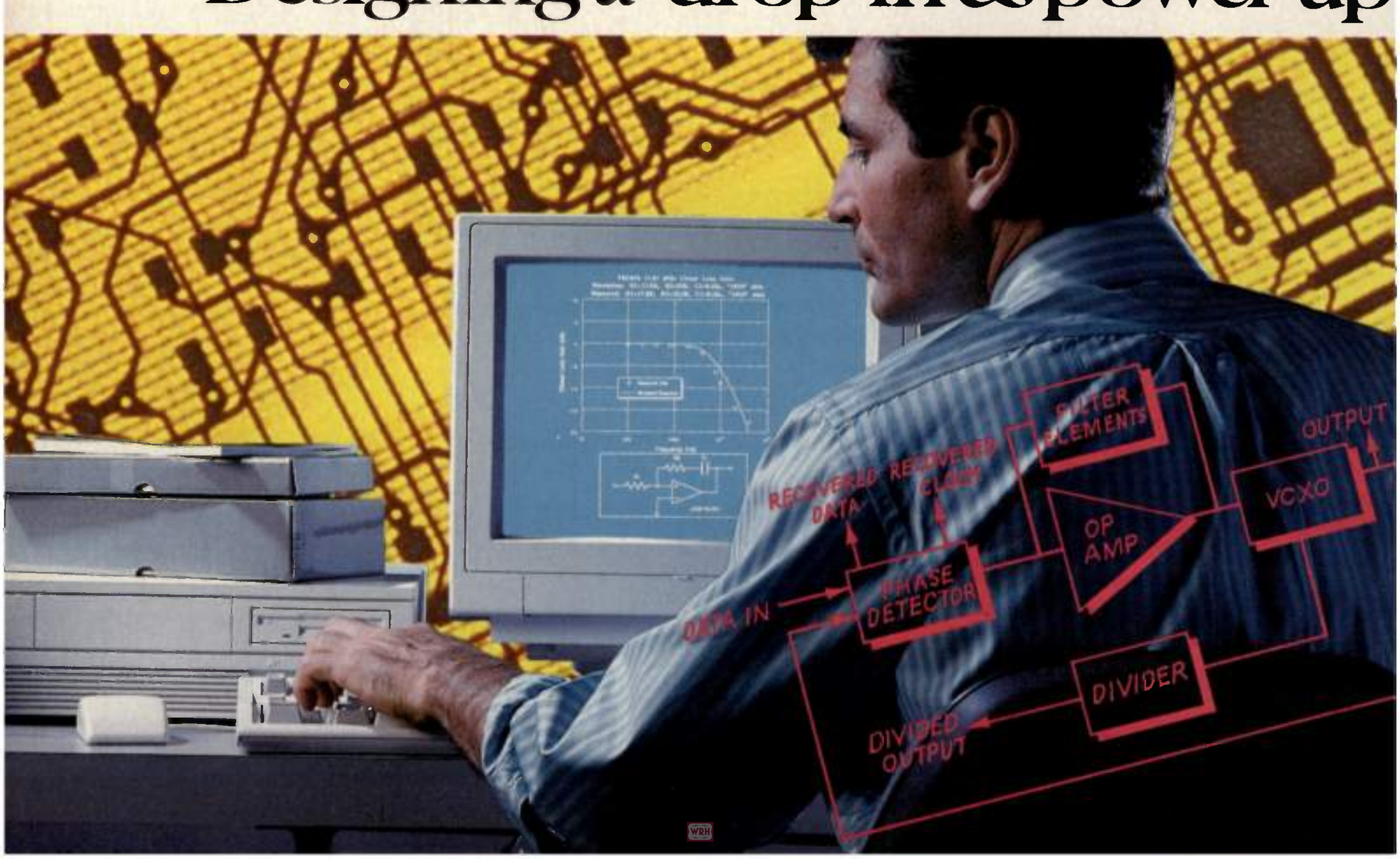
Figure 7. Sensitivity histograms after design centering.

tighter tolerance parts, the yield actually gets worse and goes down to 4 percent. The reason for this is that the original design was not design centered such that when tighter tolerance parts were applied to the sloping yield functions, the sample size was decreased resulting in a lower yield.

It is evident that single-point optimizers do not offer the complete solution. The correct methodology for the design should have included a statistical analysis, especially before any design decisions such as the selection of component tolerances were made. In this example, the sensitivity histograms for the loose tolerance case are shown in Figure 6. Notice that the nominal component values are not centered and that the nominal component values need to be adjusted slightly in value. In order to improve the current design, design centering is applied and then the closest discrete part values available are selected. After centering, the most appropriate option is to change L3 from 220 nH to 270 nH. By doing this, the manufacturing yield increases to 90 percent without having to use tighter tolerance parts. Now the sensitivity histograms after design centering, as shown in Figure 7, have a relatively more flat, uniform response for each component over their corresponding tolerance ranges.

Cost Analysis

In today's highly competitive global



market the success of a product is largely dependent on its cost to manufacture. Over the last few years, assembly line processes and labor have become so efficient that the only variables left in the cost equation are the parts that make up the design. If 5 percent capacitors instead of 10 percent capacitors are used on the centered low-pass filter design the relative manufacturing yield is 99 percent. Depending on the circumstances, the tighter tolerance parts may or may not be desirable. The trade-off between having a cheaper circuit with a lower manufacturing yield, or a more expensive, yet higher yield circuit must be made.

For the filter example, assume a total manufacturing cost of $.50/circuit. The only variable cost lies in the selection of component tolerances. If 500 circuits are manufactured, the difference between using 10 percent ceramic disc capacitors and 5 percent silver mica capacitors, is $.13/part. For the first case with a single-point optimized design and 10 percent parts, the relative yield was 28 percent. This results in a cost per working unit of $2.40. In the second case, the single-point design is used except with 5 percent capacitors instead of 10 percent capacitors. This leads to a yield of 4 percent at a cost of $19.00 per working unit. In the third case, the design is centered and uses 10 percent parts giving a resulting yield of 90 percent. The cost in this case is $0.56 per working unit. For the last case, the circuit uses design centered values with the tighter tolerance 5 percent parts. In this case, the cost is $0.77 per working unit. This shows that it is not always best to use tighter tolerance parts, it depends on the specific design situation. Through the application of statistical design software, designers now have the ability to consider factors which affect the economic reality of their designs.

Conclusion

Statistical design reveals that the nominal response is a benchmark and manufactured designs should be based on the statistical response. In addition, it has been shown that the process of design centering provides an automated method with which to improve manufacturing yields. Design centering allows for optimization of manufacturing yield before production begins and promotes the most cost-effective design. ***RF***

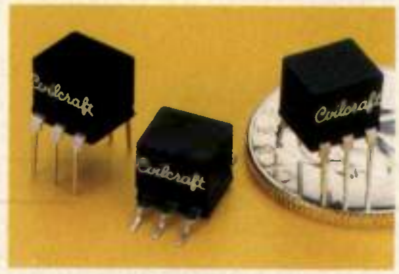
References

1. J.M. Hammersley, D.C. Handscomb, *Monte Carlo Methods*, Metheun and Co. Ltd., New York, 1964.

2. John Purviance, Mike Meehan, "CAD for Statistical Analysis and Design of Microwave Circuits," *International Journal of Microwave and Millimeter-Wave CAE*, Vol. 1, No. 1, 1991, pp. 59 - 76.

About the Author

Mr. Cobler is a product marketing engineer with EEsof, Inc. His area of specialization is in Statistical Design. Before joining EEsof, Mr. Cobler worked at Hughes Aircraft in the Advanced Communications and Receiver Department. He may be contacted at EEsof, Inc., 5601 Lindero Canyon Rd., Westlake Village, CA 91362, phone (818) 991-7530.



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INFO/CARD 95

User Friendly Error Curves for Digital Radios

By Glen A. Myers
Naval Postgraduate School

As digital communications applications continue to grow, more designers must understand the factors affecting system performance. The simple procedure here helps an engineer determine the required signal levels for the desired system bit error rate (BER).

The noise performance of digital communication systems is presented as a curve of probability, P, of error (or BER) versus usually E_b/N_o or sometimes S/N_i where

E_b = average energy per bit
N_o = value of the noise power spectral density function
S = average input signal power
N_i = average in-band noise power

Such a presentation does not explicitly account for the bit rate, r_b, of the system. The bit rate (or bit duration $T_b = 1/r_b$ sec) is used to calculate either E_b as $(S)(T_b)$ or N_i as $(N_o)(B)$ where B is the bandwidth of the IF amplifier of the superheterodyne radio receiver and where N_o is assumed to be a constant.

So, the system designer or user has to have available the value of N_o and then calculate E_b or N_i before entering the curves. This note develops a new presentation which directly relates P to S in dBm. A simple calculation accounts for the system bit rate. Since S must be known in any case and is available from link calculations in many cases, it is felt that the use of S directly as a variable is a convenience.

We begin by observing that in thermal noise limited receivers,

$$N_o = (k)(T_e) \tag{1}$$

where

$k = 1.38 \times 10^{-38}$ = Boltzmann's constant
T_e = temperature of the receiver front end = 290 degrees Kelvin at room (earth) temperature.

So, at room temperature (17 degrees Centigrade),

$$N_o = 4 \times 10^{-21} \text{ watts per Hertz} \tag{2}$$

The noise power in a one Hz bandwidth B is:

$$N_1 = 4 \times 10^{-21} \text{ watts} = -174 \text{ dBm} \tag{3}$$

In the ratio E_b/N_o, we interpret N_o as having a value equal to the power level of −174 dBm.

Now, the value of E_b is $(S)(T_b) = S/r_b$. The ratio $E_b/N_o = E_b/N_1$ when expressed in dB becomes

$$10\log S - 10\log r_b - 10\log N_1 = S - 10\log r_b + 174 \text{ dBm} \tag{4}$$

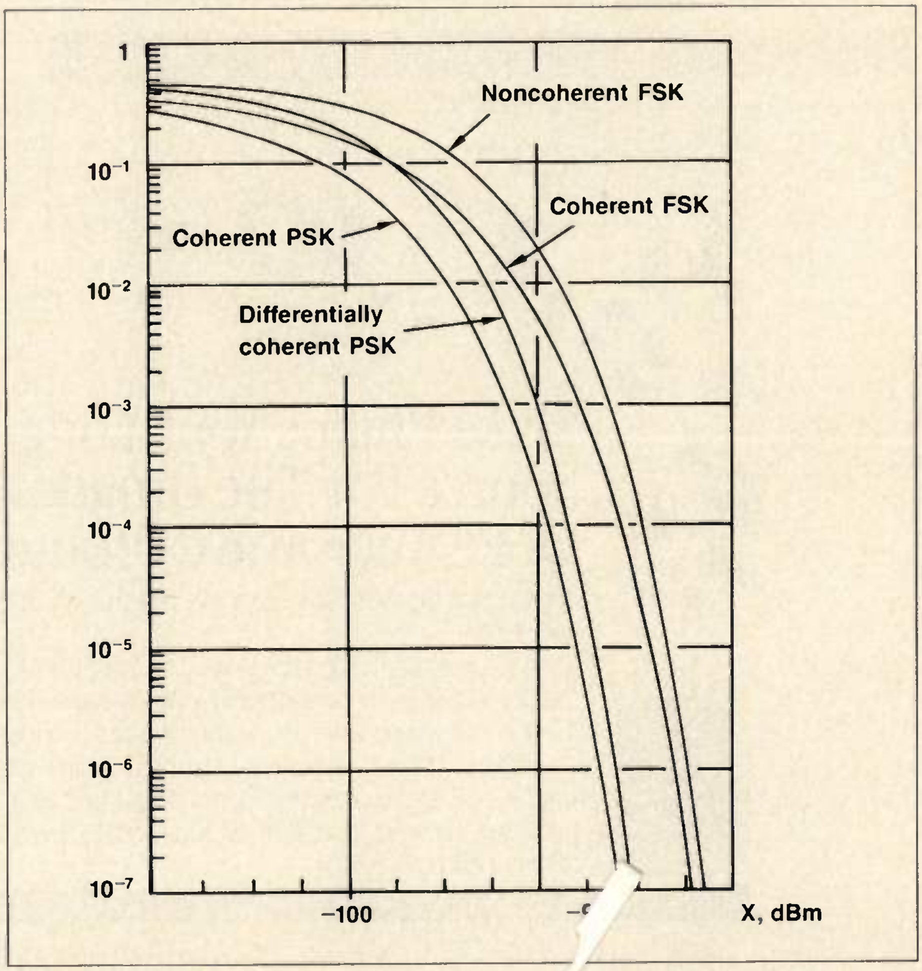

Figure 1. P vs. X.

If we let r_b = 25 Mbs, then

$$\frac{E_b}{N_o}\text{, dB} = \frac{E_b}{N_1}\text{, dBm} = S + 100 \text{ dBm} \qquad (5)$$

Or, S = (E_b/N_o dB) − 100 dBm. So, we have converted the abscissa of the usual presentation to signal power in dBm by subtracting 100 from the given values. Instead of ranging from about 0 to 20 dB, the abscissa now ranges from −100 to −80 dBm.

To this point, the curve is only valid for a 25 Mbs link. Other rates are accommodated directly by defining a ratio R = $10\log[(25 \times 10^6)/(r_b)]$ dB. Now, plot P vs. S + R dBm.

Finally, another parameter affecting receiver performance is the noise figure F dB, of the front end. Although the noise figure is a measure of the relative noise added by circuitry, by working with a ratio of signal power to noise power, we can realize this effect by subtracting F in dB from S in dBm. (If the circuit

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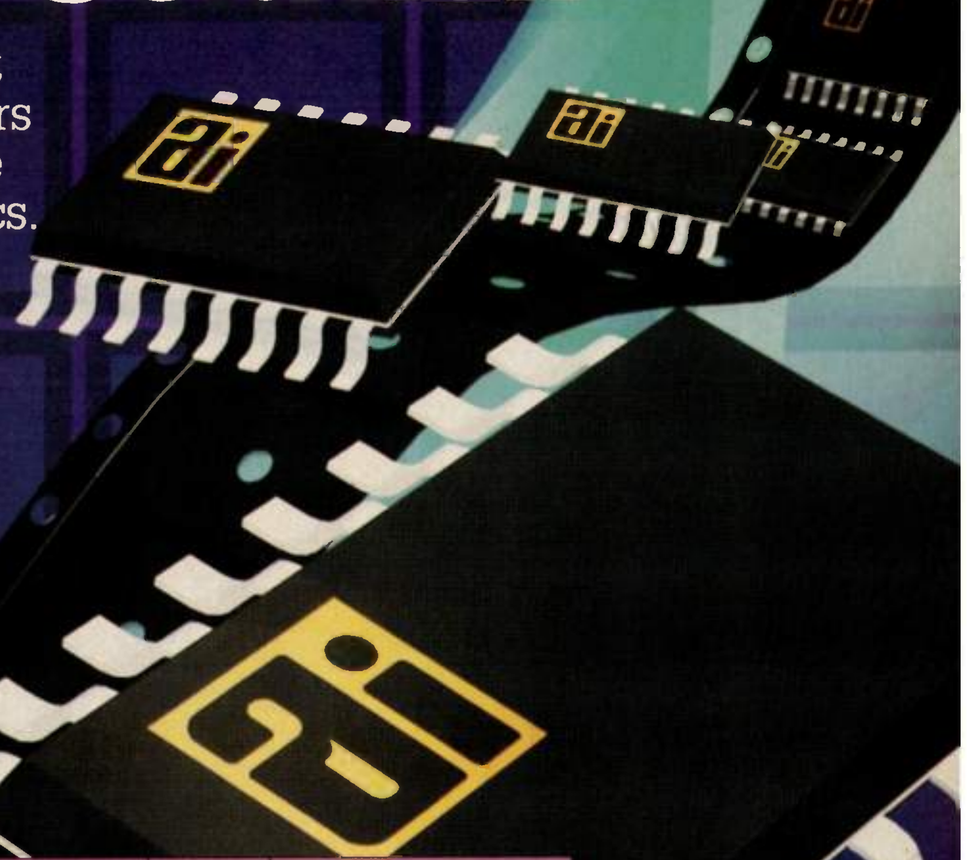

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ADCO2D2-12*	Diversity TX RX	1.2/20 dB 2.0/30 dB	SOIC 8	Polarization Switching
AF001C1-39**	Switching FET	0.5/15 dB	SOT 23	Matrix Switching
AF002N2-32**	Attenuator (VVA) Single Bias	3.1/15 dB	SOT 143	AGC Control
AT002S3-12	Attenuator (VVA) Single Bias	1.5/35 dB	SOIC 8	Fiber Optic AGC (Sonet) AGC Control
AT001D4-25	Digital Attenuator	2,4,8,16 dB Bits	SOIC 16	Level Set
AK001D4-24	Digital Attenuator w/Driver	1,2,4,8 dB Bits	SOIC 14	Level Set
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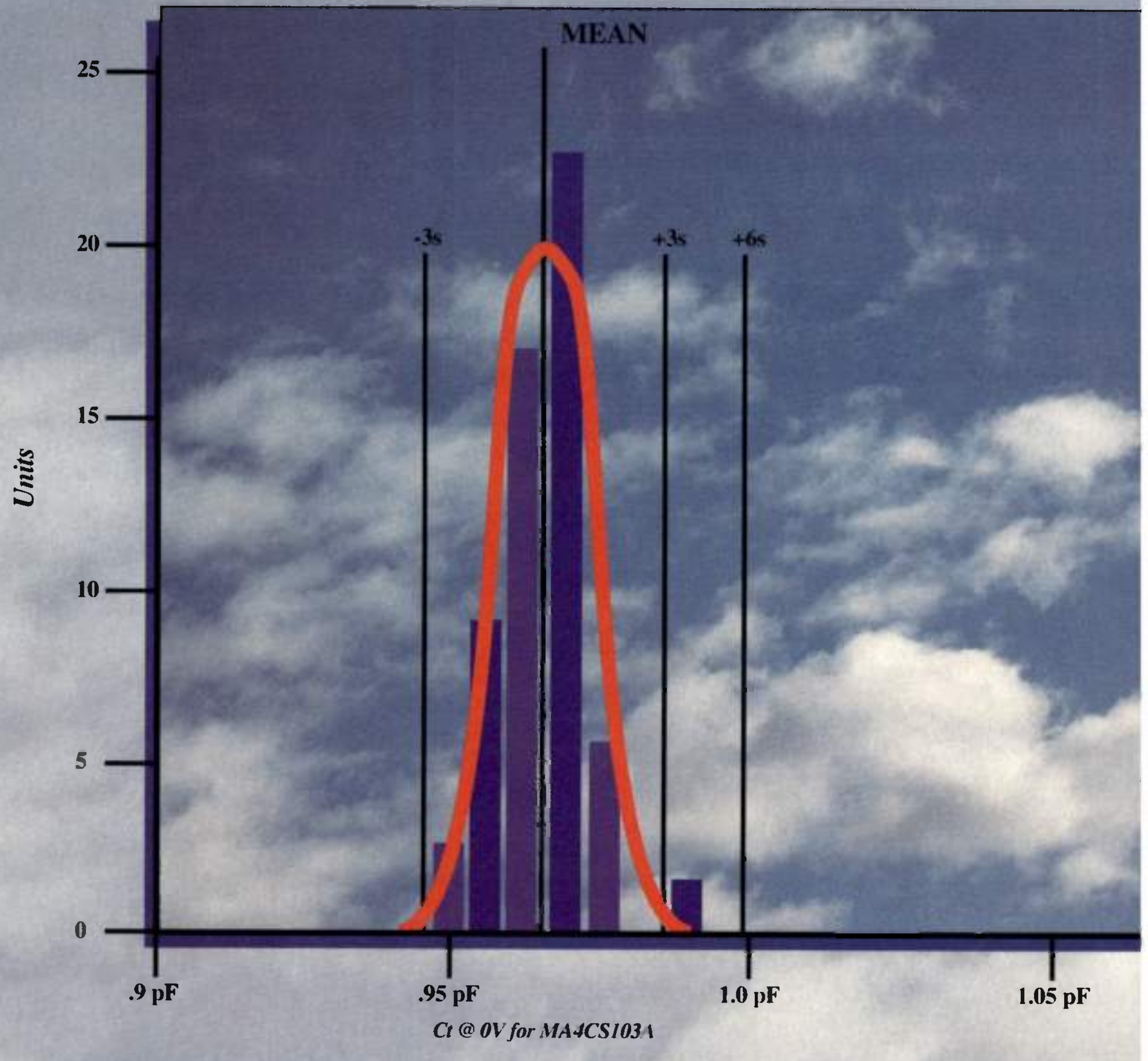

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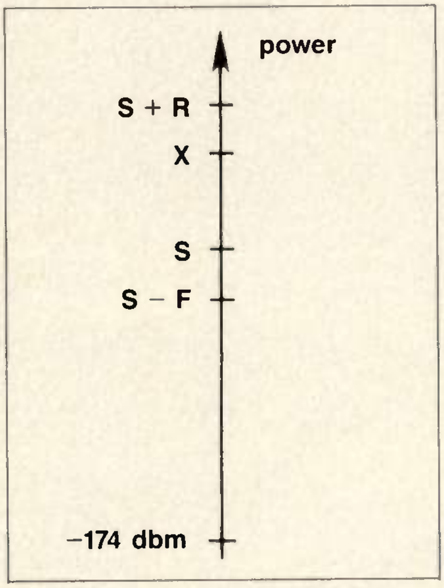

Figure 2. An example of power levels.

noise is characterized by an effective input noise temperature T_e, convert this to $F = 10\log[1 + (T_e/290)]$.)

The result is a curve of P vs X = (S + R − F) dBm, as shown in Figure 1. Figure 2 shows the various (power) levels.

An example of the use of Figure 1 is the following. Given the value of S of interest and known value of F, calculate R for the bit rate specified. For X = S + R − F. If $X < -100$, the system is unusable (usually). If $X > -80$, there exists a power margin (usually). For that value of X, enter the curve for the carrier modulation and demodulator used (BPSK, non-coherent FSK, etc.) and read P.

In m-ary systems, many available curves substitute symbol rate for bit rate and give probability of symbol error for P. Further generalization of this procedure for other system temperatures, T_s, (space receivers) can be obtained by defining $T = 10\log(290/T_s)$ and redefining X = S + R + T − F. *RF*

About the Author

Glen A. Myers is an associate professor at the Department of Electrical and Computer Engineering for the Department of the Navy, Naval Postgraduate School, Monterey, CA 93943-5100.

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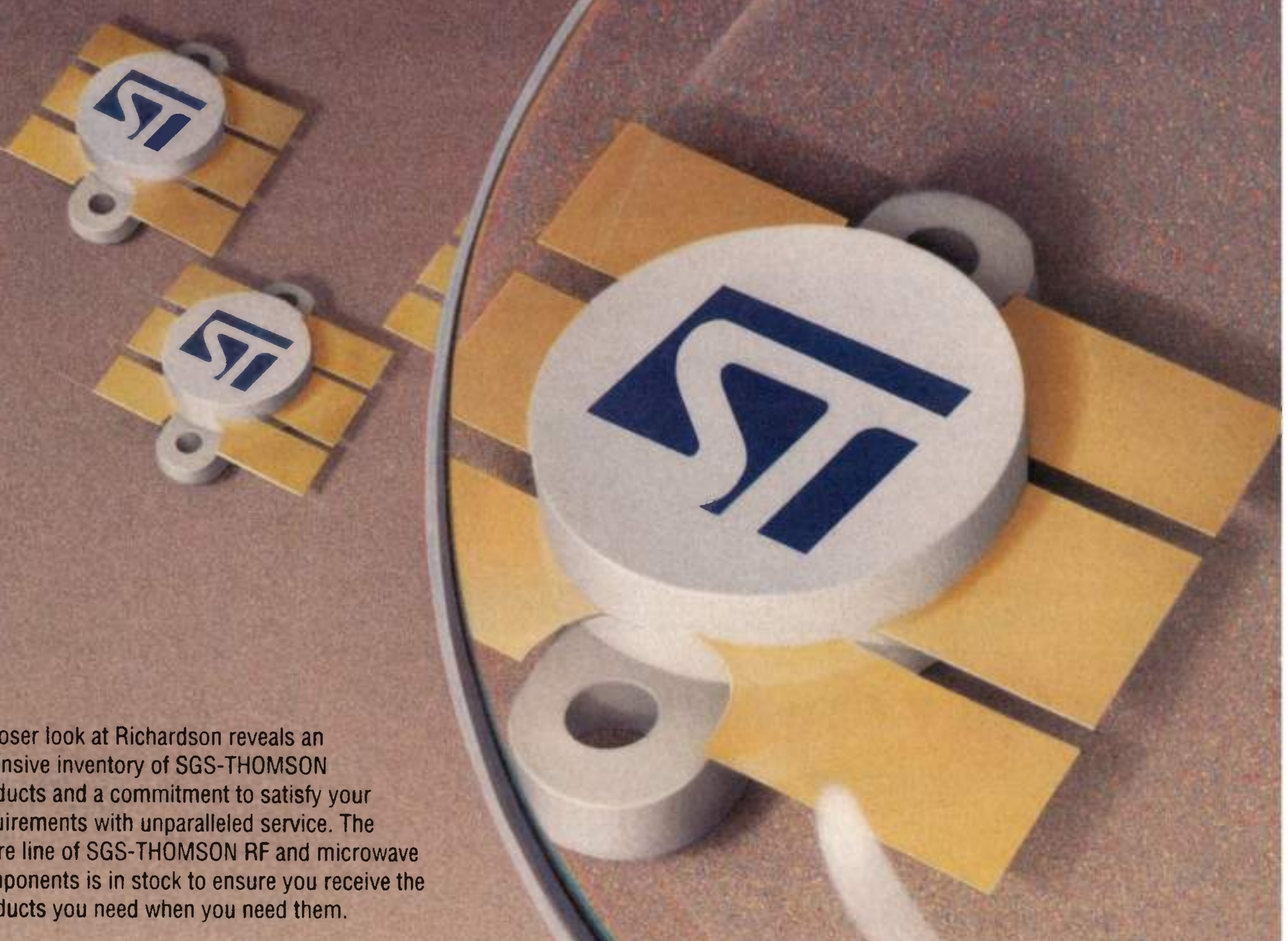

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INFO/CARD 36

A Simple Algebraic and Analogical Approach to A Scrambler/ Descrambler

By Jaouhar Mouine
University of Sherbrooke

In data communication systems, scrambler/descrambler devices are widely used. The analysis of their operation is commonly done with a numerical approach since we deal with binary waveforms. Here, we will present the classic numerical approach and another one which is analogical, leading to the same results by representing the binary waveforms as NRZ signals. The use of this second method may be of great interest when additive analogical signals are present with the input data signal. Spectral analysis of the output signals can be performed directly without need of representing the output binary sequence by an NRZ signal since it has already been done. To support the mathematical explanations, an example will also be presented.

The scrambler is a machine that converts a data sequence into a channel sequence. It achieves two basic goals, both of which improve the distribution of the output signal. It increases the number of transitions in the channel sequence and expands the period of the input signals.

The basic scrambler/descrambler consists of a linear sequential filter with feedback/feed-forward paths. Figure 1 depicts their different elements. Constants in that figure are binary, that means, the tap is present when b_k takes a value of "1". These constants are chosen such that the scrambler increases the period of the signal in the desired way. It has been shown (1) that the period of the output signal, when the input signal is of period s, is the least common multiple (LCM) of s and 2^m-1; m being the number of delay elements. This is always true except for one initial state of the scrambler where the signal period remains unchanged. Monitoring logic allows us to avoid this last case.

The self-synchronizing properties of these devices are easily determined by inspecting their block diagrams in Figure 1. The scrambler is said to be synchronized with the descrambler if its register contents are the same as those of the descrambler. Note that the same scrambler output which passes through its shift registers will pass through the descrambler registers, and synchronization is automatically achieved.

Numerical Analysis

A well known mathematical representation of the basic scrambler/descrambler takes a polynomial form (1). If we represent the delay caused by one shift register as an x, an m delay elements scrambler is characterized by:

$$h(x) = 1 - \sum_{k=1}^{m} b_k x^k \tag{1}$$

This is called the characteristic polynomial of the scrambler/descrambler (or the tap polynomial). Similarly, a binary sequence can be expressed mathematically in a polynomial form. A sequence $\{C\}$ can be denoted:

$$C(x) = \sum_{i=0}^{\infty} c_i x^i \tag{2}$$

Where x is the delay of one bit and i is its order. Now, we can easily deduce from Figure 1a that the scrambler divides the input sequence $I_s(x)$ by its characteristic polynomial.

$$O_s(x) = I_s(x) + [O_s(x)b_m x^m + O_s(x)b_{m-1}x^{m-1} + \ldots + O_s(x)b_1 x^1] \tag{3}$$

$$= I_s(x) + \left[O_s(x) \sum_{k=1}^{m} b_k x^k\right]$$

$$\leftrightarrow I_s(x) = O_s(x)\left(1 - \sum_{k=1}^{m} b_k x^k\right) \tag{4}$$

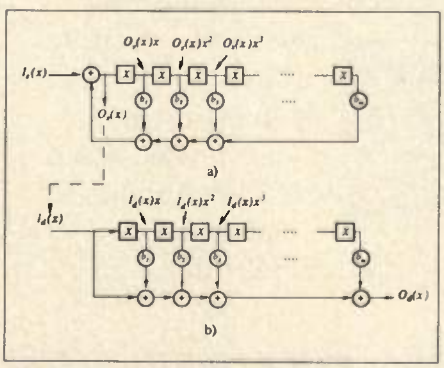

Figure 1. a) basic scrambler, b) basic descrambler.

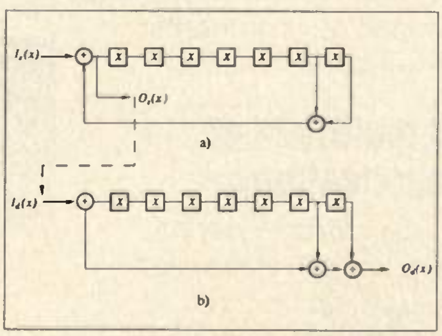

Figure 2. a) 7-stage shift register scrambler, b) 7-stage shift register descrambler.

f \ g	0	1
0	0	1
1	1	0

f(t) \ g(t)	∓1	±1
∓1	∓1	±1
±1	±1	∓1

$f \oplus g \xleftrightarrow{\text{isomorphism}} \mp[f(t) \times g(t)]$

Figure 3. Isomorphism between modulo two addition and multiplication.

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$$\leftrightarrow O_s(x) = \frac{I_s(x)}{1 - \sum_{k=1}^{m} b_k x^k} \tag{5}$$

We can verify in the same manner, in Figure 1b that the descrambler multiplies the received sequence, called $O_s(x)$ or $I_d(x)$, by its tap polynomial.

$$O_d(x) = I_d(x) b_m x^m + I_d(x) b_{m-1} x^{m-1} + \ldots + I_d(x) b_1 x^1 + I_d(x)$$
$$= I_d(x) \left[1 + \sum_{k=1}^{m} b_k x^k \right] \tag{6}$$

It's worth remembering that all operations are made in modulo two arithmetic, therefore, the addition operation is equivalent to the subtraction operation.

The operation of the scrambler consists of the division of two polynomials. To perform this division, polynomials should be ordered, starting with the smallest degree term. This division is of the infinite kind, as opposed to the division made by a "divider by a polynomial" (2) that keeps the remainder at its registers.

Analogical Analysis

The analogical approach to digital scrambler/descrambler operations can be performed by substituting NRZ signals for the binary sequences. One only has to represent symbols 1 and 0 by normalized values −1 and +1 (or +1 and −1) respectively. Also the modulo two adders should be replaced by multipliers, owing to the isomorphism existing between modulo two addition and real multiplication (Figure 2). Assuming these conditions, one can express scrambler operation as follows:

Let $I_s(x)$ and $O_s(x)$ be represented by the NRZ signals $i_s(t)$ and $o_s(t)$ respectively, hence:

$$o_s(t) = (\pm 1)^{\sum_{k=1}^{m} b_k} i_s(t) \prod_{k=1}^{m} \left[(-1)^{b_k} + b_k \left(1 + o_s \left(t - \frac{k}{f_s} \right) \right) \right] \tag{7}$$

where the decision on the first term sign depends on the convention taken to represent the binary sequences by NRZ signals and f_s is the sampling frequency that matches the shifting one.

In the same manner, the descrambler operation can be expressed as follows: Let $i_d(t)$ and $o_d(t)$ denote respective NRZ signals which correspond to $I_d(x)$ and $O_d(x)$ sequences:

$$o_d(t) = (\pm 1)^{\sum_{k=1}^{m} b_k} i_d(t) \prod_{k=1}^{m} \left[(-1)^{b_k} + b_k \left(1 + i_d \left(t - \frac{k}{f_s} \right) \right) \right] \tag{8}$$

When replacing $i_d(t)$, which is the same as $o_s(t)$ by equation 7, we obtain:

$$o_d(t) = i_s(t) \tag{9}$$

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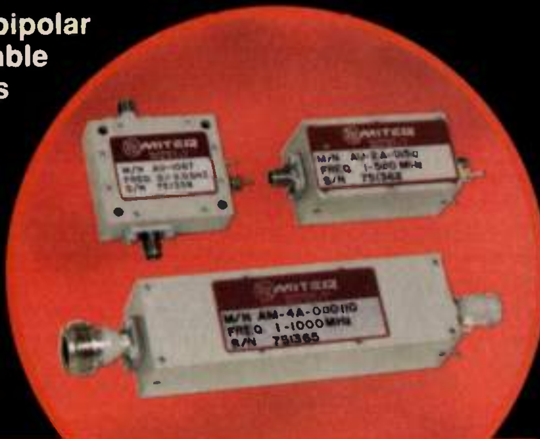

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AU-1310	.01 – 500	30	0.50	1.3	1.4	1.5	2:1	8	15	50
AM-1300	.01 – 1000	25	0.75	1.4	1.6	1.8	2:1	6	15	50
AU-1378*	1 – 300	17	0.50	1.9	1.9	1.9	2:1	–2	6	10
AU-1379*	1 – 500	13	0.50	2.2	2.3	2.4	2:1	–2	6	10
AU-2A-0150	1 – 500	30	0.50	1.3	1.4	1.5	2:1	8	15	50
AU-3A-0150	1 – 500	45	0.50	1.3	1.4	1.5	2:1	10	15	75
AM-2A-000110	1 – 1000	25	0.75	1.4	1.6	1.8	2:1	8	15	50
AM-3A-000110	1 – 1000	37	0.75	1.4	1.6	1.8	2:1	9	15	75
AU-1021	5 – 300	24	0.50	2.2	2.4	2.6	2:1	20	15	175
AU-1158	20 – 200	30	0.50	2.7	2.7	2.7	2:1	17	15	125
AMMIC-1318	100 – 2000	6	1.00	4.5	4.0	4.0	2:1	12	15	35
AMMIC-1348	100 – 2000	14	1.00	5.0	5.0	5.0	2:1	14	15	150
AM-2A-0510	500 – 1000	24	0.50	1.4	1.5	1.6	2:1	0	15	50
AM-3A-0510	500 – 1000	38	0.50	1.4	1.5	1.6	2:1	10	15	75
AM-3A-1020	1000 – 2000	30	0.50	1.8	2.1	2.4	2:1	10	15	75

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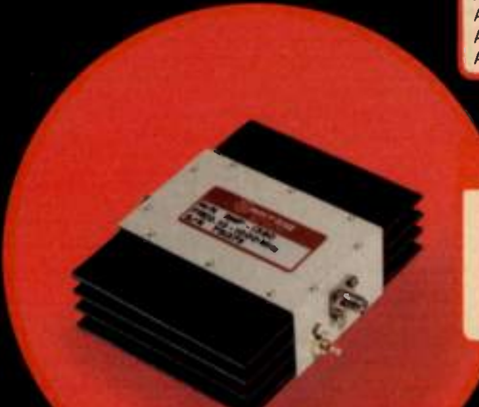

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AUP-1374	10 – 500	30	1.50	4.5	5.0	5.5	2:1	29	21	550
AUP-1383	20 – 300	35	1.50	2.4	2.5	2.6	2:1	29	21	650
AUP-1382	20 – 300	40	1.50	2.4	2.5	2.6	2:1	29	21	630
AMP-1380	10 – 1000	20	1.50	6.0	6.5	7.0	2:1	29	21	590
AMP-1381	20 – 1000	30	1.50	4.2	3.6	3.8	2:1	29	21	670
AMP-1389	10 – 1000	12	1.00	10.0	10.0	10.0	2:1	29	21	500

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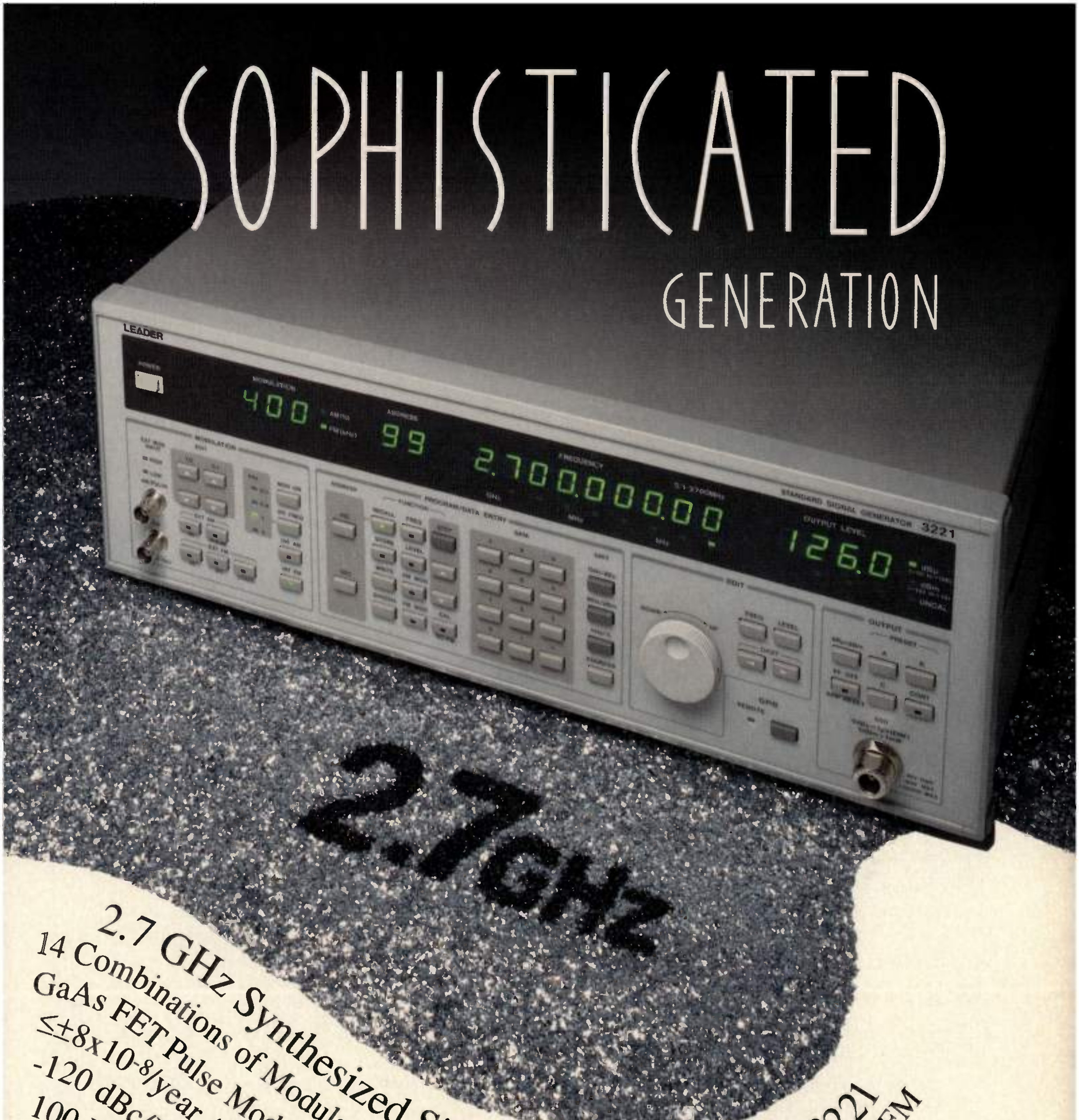

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$$\left\{ (\pm 1)^{\sum_{k=1}^{m} b_k} i_d(t) \prod_{k=1}^{m} \left[(-1)^{b_k} + b_k \left(1 + i_d \left(t - \frac{k}{f_s} \right) \right) \right] \right\}^2 = 1 \quad (10)$$

The two basic equations presented above lead to the same results as in a numerical approach. To help fix this last approach in one's memory, we present an example using the two approaches.

Example

Consider a scrambler/descrambler device of 7-stage shift register described by the tap polynomial (Figure 3):

$$h(x) = 1 + x^6 + x^7 \quad (11)$$

On the other hand, consider a scrambler input sequence called $\{I_s\}$. Assuming that this binary sequence is:

$$\{I_s\} = 1,0,1,1,0,0,1,0,1, \ldots \quad (12)$$

it can be expressed in the form of a polynomial as:

$$I_s(x) = 1 + x^2 + x^3 + x^6 + x^8 + \ldots \quad (13)$$

According to equation 3, the output of the scrambler will be:

$$O_s(x) = \frac{I_s(x)}{h(x)} = \frac{1 + x^2 + x^3 + x^6 + x^8 + \ldots}{1 + x^6 + x^7} \quad (14)$$

This division can be carried out as shown in Equation 15.

$$\begin{array}{l|l}
\oplus\ 1 + x^2 + x^3 + x^6 + x^8 & 1 + x^6 + x^7 \\
\quad 1 + x^6 + x^7 & \\
\hline
\oplus\ x^2 + x^3 + x^7 + x^8 & 1 + x^2 + x^3 + x^7 + \ldots \\
\quad x^2 + x^8 + x^9 & \\
\hline
\oplus\ x^2 + x^3 + x^7 + x^9 & \\
\quad x^3 + x^9 + x^{10} & \\
\hline
\oplus\ x^7 + x^{10} & \\
\quad x^7 + x^{13} + x^{14} & \\
\hline
\quad x^{10} + x^{13} + x^{14} & \\
\quad \vdots &
\end{array} \quad (15)$$

Hence,

$$O_s(x) = 1 + x^2 + x^3 + x^7 + \ldots \quad (16)$$

and the descrambler operation may be described similarly

$$O_d(x) = I_d(x)h(x) = (1 + x^2 + x^3 + x^7 + \ldots)(1 + x^6 + x^7)$$

$$= 1 + x^2 + x^3 + x^6 + x^8 + \ldots \quad (17)$$

Which corresponds to the scrambler input $I_s(x)$ described in equation 13.

Now let $i_s(t)$, $o_s(t)$, $i_d(t)$ and $o_d(t)$ be the NRZ signals corresponding respectively to sequences $I_s(x)$, $O_s(x)$, $I_d(x)$ and $O_d(x)$. Assuming the convention (+1 —> 1, −1 —> 0), one can find, according to equation 7:

$$o_s(t) = -i_s(t) o_s \left(t - \frac{6}{f_s} \right) o_s \left(t - \frac{7}{f_s} \right) \quad (18)$$

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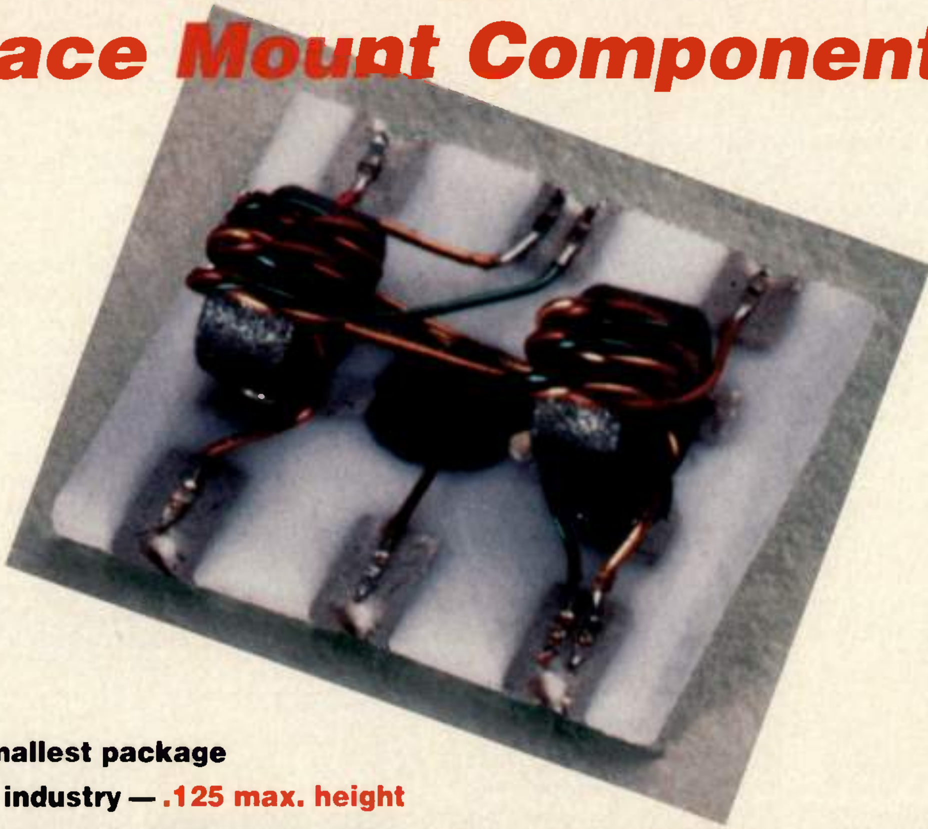

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RFMS-2-10	5-1000	DC-1000	+10	9.0	7.95
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RFMS-5-13	10-1500	DC-1000	+13	9.5	10.95
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In the same manner, applying equation 8 leads to

$$o_d(t) = -i_d(t) i_d \left(t - \frac{6}{f_s}\right) i_d \left(t - \frac{7}{f_s}\right) \tag{19}$$

By substituting $i_d(t)$ by $o_s(t)$ in equation 19

$$o_d(t) = -o_s(t) o_s \left(t - \frac{6}{f_s}\right) o_s \left(t - \frac{7}{f_3}\right) \tag{20}$$

But $o_s(t)$ is expressed by equation 18, hence:

$$o_d(t) = -\left[\left[-i_s(t) o_s \left(t - \frac{6}{f_s}\right) o_s \left(t - \frac{7}{f_s}\right)\right] o_s \left(t - \frac{6}{f_s}\right) o_s \left(t - \frac{7}{f_s}\right)\right] = i_s(t) \tag{21}$$

since

$$o_s \left(t - \frac{6}{f_s}\right) o_s \left(t - \frac{6}{f_s}\right) = 1 \tag{22}$$

and

$$o_s \left(t - \frac{7}{f_s}\right) o_s \left(t - \frac{7}{f_s}\right) = 1 \tag{23}$$

Conclusion

We have presented here the basic scrambler/descrambler operations, describing general equations in both approaches, numerical and analogical. These equations can be effectively used to build up subroutines to simulate a scrambler/descrambler device under any circumstances. ***RF***

Acknowledgement

The author would like to express his deep appreciation to Sana Majdoub for her support.

References

1. J.E. Savage, "Some Simple Self-Synchronizing Digital Data Scrambler," B.S.T.J., vol. 46, pp. 449-487, February 1967.
2. Al. Spataru, "Theorie de al Transmission de l'Information 2, Codes et Descisions Statistiques," Editura Tehnica, Bucarest, Roumanie, 1973.
3. L.S. Lyons, "Scrambler Theory in Data Communications," *Electronic Engineering*, pp. 35-38, July 1977.

About the Author

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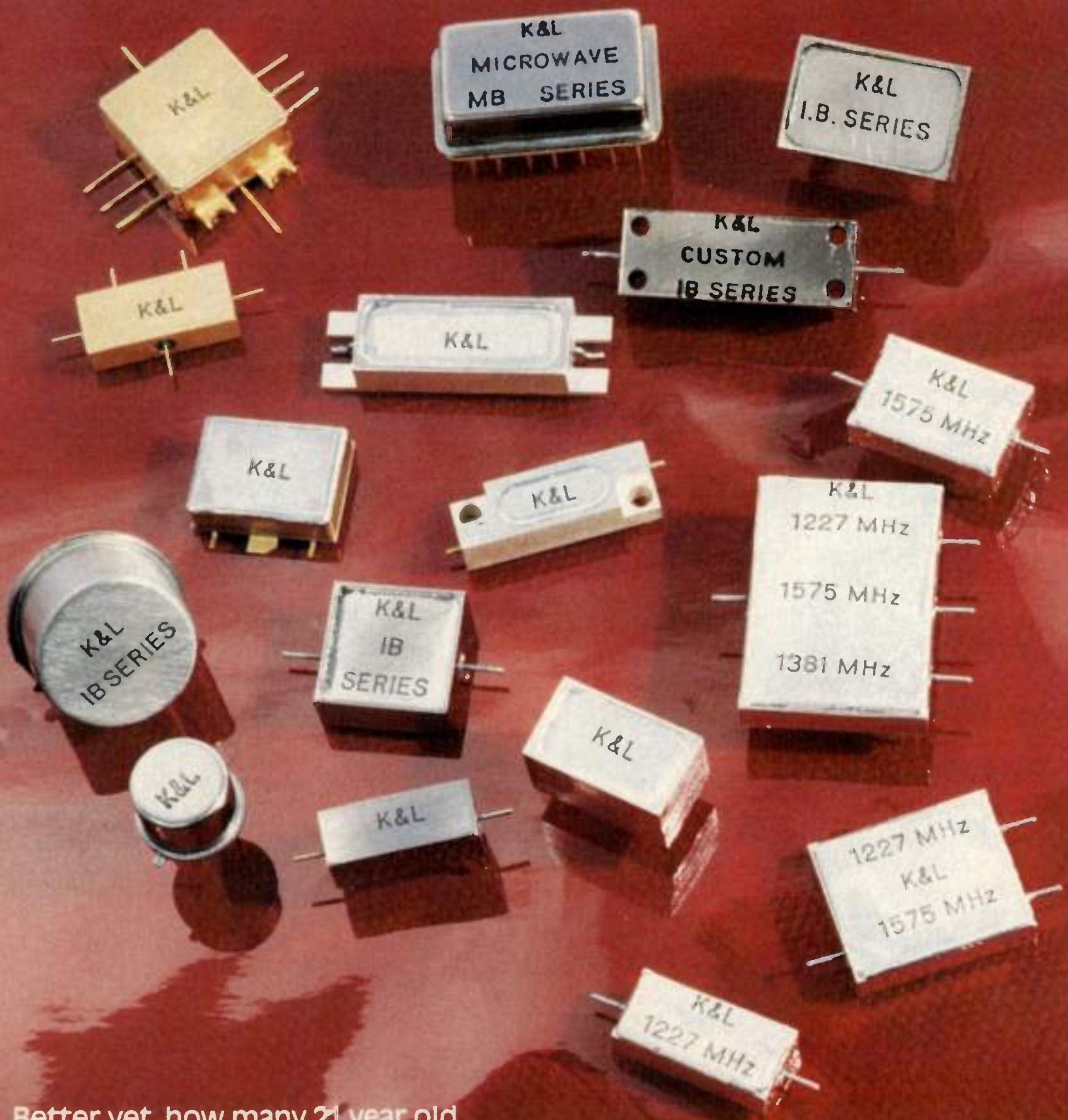

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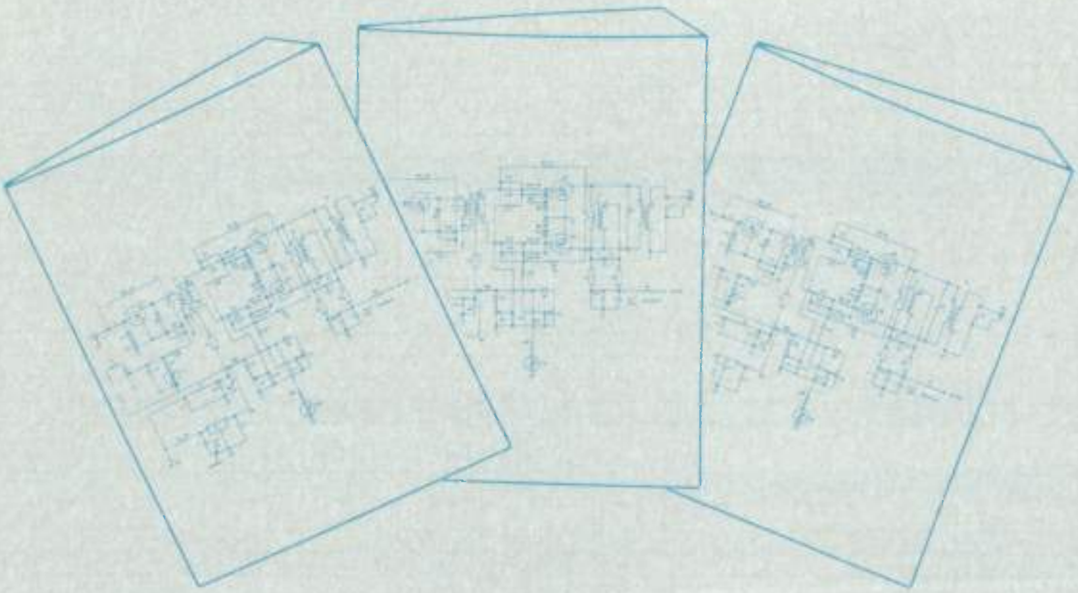

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L9*6001	4-8	10	18	0.6	1.30	-54° to +95°	50	25	+50	.62 x	.500 x	.24
L9*9001	8-12	5	20	0.45	1.20	-54° to +95°	50	25	+50	.50 x	.350 x	.14
L9*9001	8-12	10	18	0.55	1.30	-54° to +95°	50	25	+50	.50 x	.350 x	.14
L9*2001	12-18	5	18	0.6	1.30	-54° to +95°	50	25	+50	.50 x	.350 x	.14
L9*2001	12-18	10	17	0.7	1.35	-54° to +95°	50	25	+50	.50 x	.350 x	.14

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M9*6001	4-8	10	18	0.6	1.30	-54° to +95°	50	0.7	+95	.62 x	.500 x	.24
M9*9001	8-12	5	20	0.45	1.20	-54° to +95°	50	0.7	+95	.50 x	.350 x	.14
M9*9001	8-12	10	18	0.55	1.30	-54° to +95°	50	0.7	+95	.50 x	.350 x	.14
M9*2001	12-18	5	18	0.6	1.30	-54° to +95°	50	0.7	+95	.50 x	.350 x	.14
M9*2001	12-18	10	17	0.7	1.35	-54° to +95°	50	0.7	+95	.50 x	.350 x	.14

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F9*6101	4-8	10	20	0.5	1.25	-54° to +95°	50	.7	95	.62 x	.375 x	.21
F9*9001	8-12	10	20	0.4	1.25	-54° to +95°	50	.5	95	.50 x	.25 x	.18
F9*2001	12-18	10	17	0.5	1.35	-54° to +95°	50	.5	95	.50 x	.25 x	.18
F9A6141	3.7-4.3	FULLBAND	15	0.6	1.45	-30° to +70°	50	.7	70	.62 x	.375 x	.21
F9A9101**	8-12	FULLBAND	16	0.7	1.45	-54° to +95°	50	.7	95	.62 x	.375 x	.21
F9A2201**	12-18	FULLBAND	17	0.7	1.50	-55° to +100°	50	.5	95	.50 x	.25 x	.18

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G9*6101	4-8	10	20	.5	1.25	-54° to +95°	50	25	50	.375 x	.375 x	.21
G9*9001	8-12	10	20	.4	1.25	-54° to +95°	50	29	50	.25 x	.25 x	.18
G9*2001	12-18	10	17	.5	1.35	-54° to +95°	50	20	50	.25 x	.25 x	.18
G9A9101**	8-12	FULLBAND	16	.7	1.45	-54° to +95°	50	20	50	.375 x	.375 x	.21

Flangeless Micropuck® Isolators

MODEL NUMBER	FREQUENCY RANGE (GHz)	BANDWIDTH %	ISOLATION dB min.	INSERTION LOSS dB max.	VSWR max.	OPERATING TEMP °C	PEAK POWER WATTS	AVG. POWER WATTS	HEAT SINK TEMP	SIZE (INCHES NOMINAL) L	W	H
H9*6101	4-8	10	20	.5	1.25	-54° to +95°	50	.5	50	.375 x	.375 x	.21
H9*9001	8-12	10	20	.4	1.25	-54° to+ 95°	50	.7	50	.25 x	.25 x	.18
H9*2001	12-18	10	17	.5	1.35	-54° to +95°	50	.5	50	.25 x	.25 x	.18
H9A9101**	8-12	FULLBAND	16	.7	1.45	-54° to +95°	50	.7	50	.25 x	.25 x	.18
H9A2201	12-18	FULLBAND	17	.7	1.50	-55° to +100°	50	.5	50	.375 x	.375 x	.21

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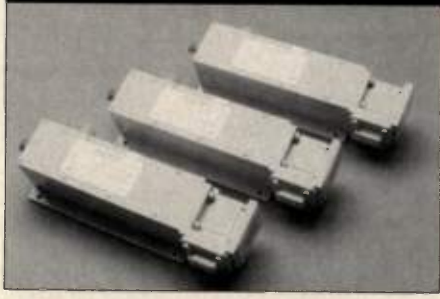

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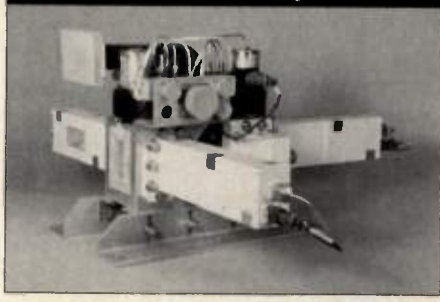

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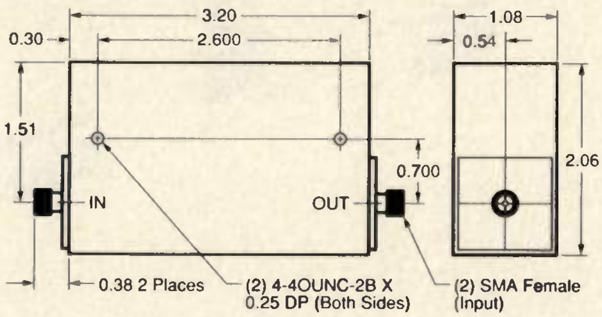

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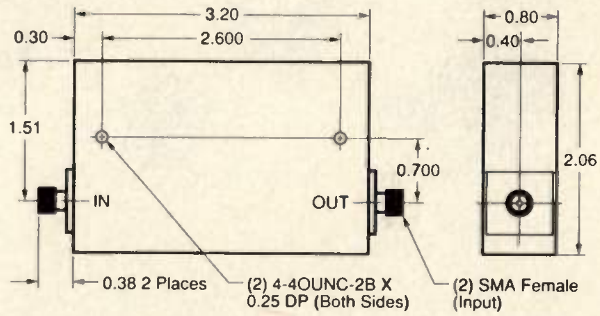

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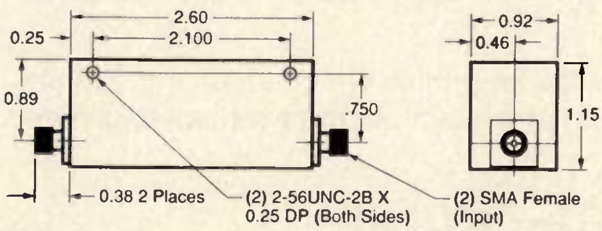

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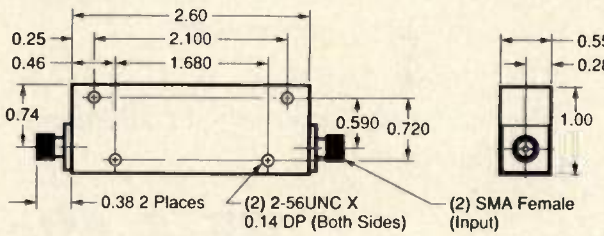

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2 - 8	T-2S123T-2	21	1.0*	1.35:1	10 W	B
2 - 18	T-2S163T-1	11	2.5	2.00:1	10 W	A
2 - 18	T-2S163T-2	10	3.5	1.90:1	10 W	A
4 - 18	T-4S123T-1	16	1.5	1.45:1	10 W	C
6 - 18	T-6S103T-11	16	1.3	1.35:1	10 W	D
3 - 20	T-3S143T-1	16	2.5**	1.45:1	10 W	D

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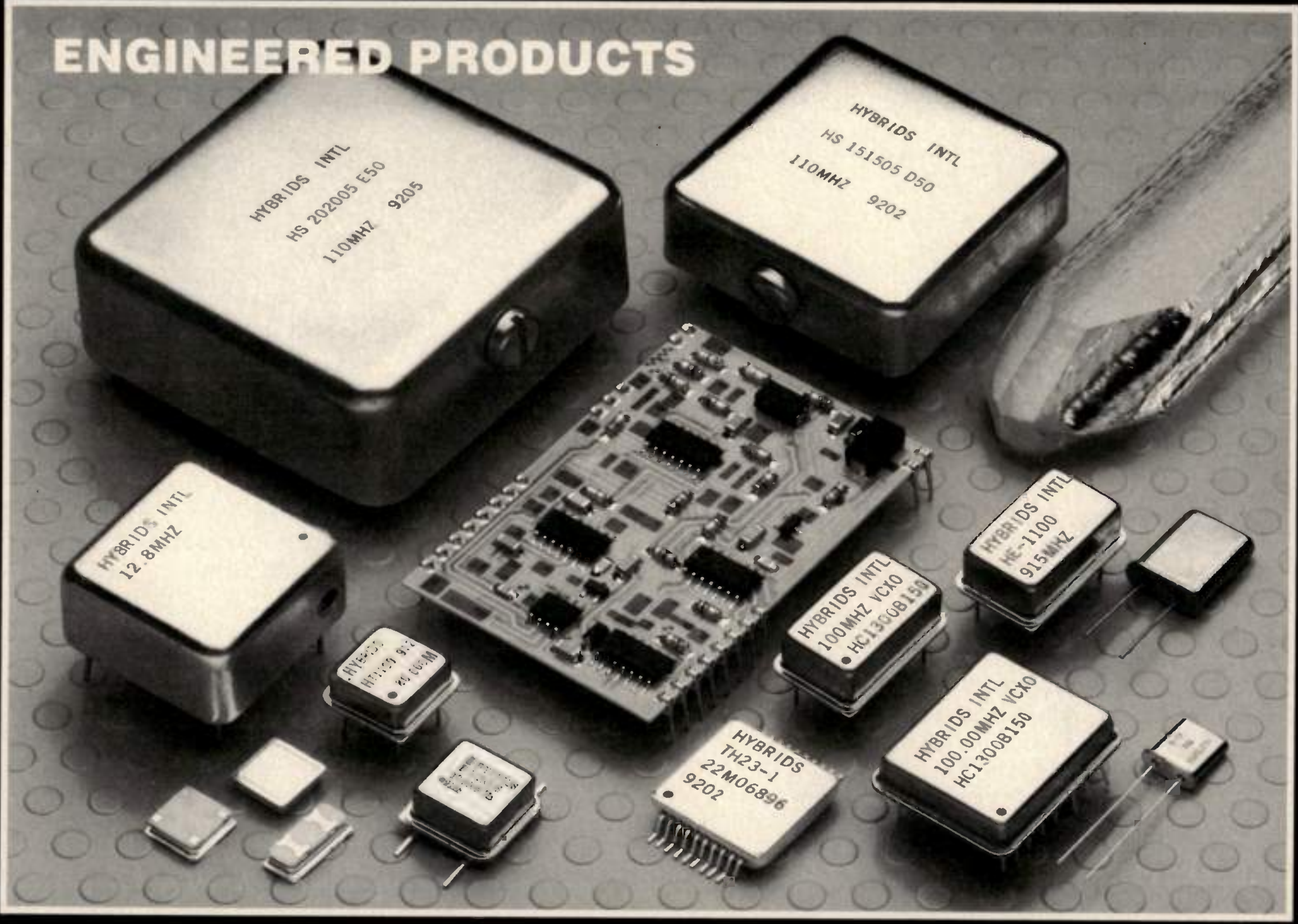

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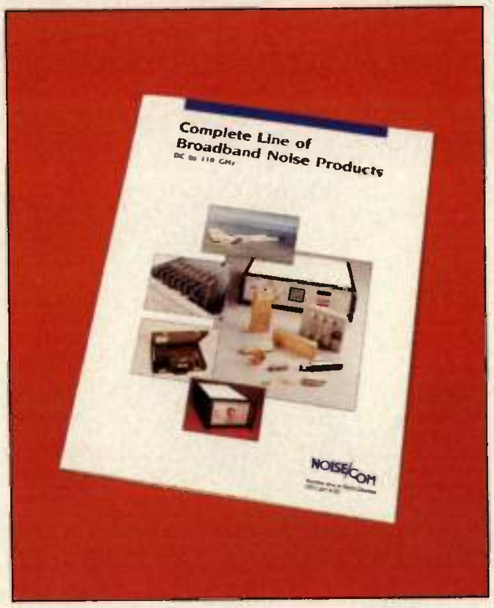

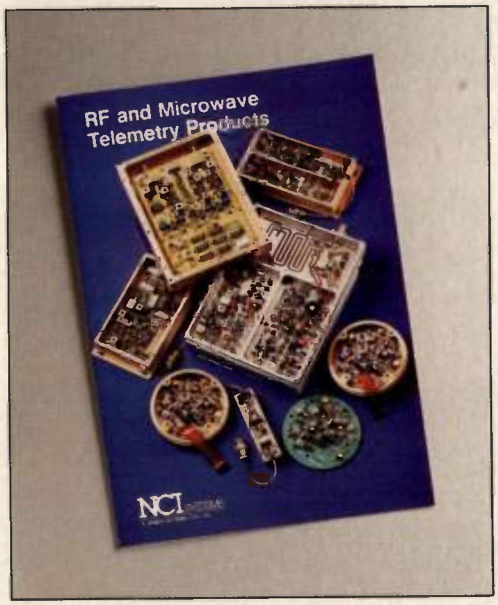

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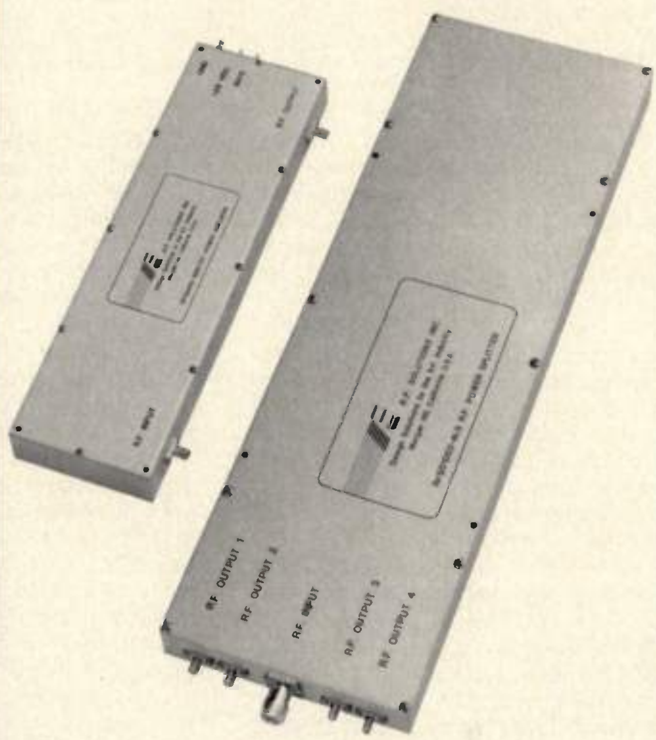

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Versatile UHF Data/Telemetry Transmitter

By Harry J. Swanson
Motorola Semiconductor Products Sector

RF communication in the UHF and 900 MHz bands constitute a new and growing industry covered by the FCC regulations Title 47; Part 15. This section covers unlicensed security systems, keyless entry, and RF local area networks (LANs) in the 260 to 470 MHz band. The 902 to 928 MHz band is also covered by Part 15 where frequency hopping and direct digital sequence spread spectrum techniques are employed to increase frequency spectrum capability and to provide secured communications. Discretes and some IC components are available to the system designer but until now there have been very few system components that offer a low cost, sophisticated solution.

Data transmission systems used in consumer applications are simple, inexpensive and often mediocre in performance. Two common circuit designs that are currently used are a frequency multiplier system where a reference crystal is used with cascaded multiplier stages to achieve the desired carrier frequency or a SAW resonator plus a simple Colpitts oscillator network is used in amplitude shift key (ASK) applications where on-off keying is required.

The shortcomings of the current systems include:

- Expensive 5th or 7th overtone crystals
- High manufacturing cost due to sophisticated alignment procedures
- Lack of frequency stability
- High current consumption in receiver to provide needed IF bandwidth
- Compromised reliability due to large number of critically tuned components
- Little or no FM possibilities.

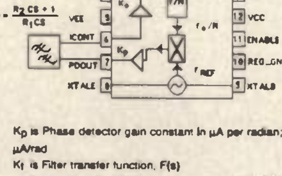
Many more complex applications including cellular, CT2 and SMR can also benefit from a fully integrated system that employs a PLL structure. This paper demonstrates a complete system with functional performance suitable for a low cost solution to data/telemetry and voice applications. Cost and size restraints are met by the simplicity of the supporting circuitry. Total system reliability and performance are vastly improved with a single chip PLL approach. The MC13175 and MC13176 offer the following features:

- UHF oscillator current controlled
- Uses easily available 3rd overtone or fundamental crystals
- Output frequency set by 8x reference frequency for MC13175 and 32x reference frequency for MC13176
- Low number of external parts required
- Low operating supply voltage (1.8-5.0 VDC)
- Low supply drain currents
- Power output adjustable (up to +10 dBm)
- Differential output for loop antenna or balun transformer networks
- Power down feature
- ASK modulated by switching output on and off
- Easily FM voice or FSK modulated
- Surface mount 16 pin SOIC

PLL System Description

The MC13175 and MC13176 are one-chip FM/AM transmitter subsystems designed for AM/FM communication systems operating in VHF, UHF or 900 MHz bands. The system consists of a Colpitts reference crystal oscillator, UHF oscillator, divide by 8 (MC13175) or divide by 32 (MC13176) prescalar, and phase detector forming a versatile, fully integrated PLL system.

Figure 1 is the component block diagram of the MC1317XD PLL system in which the loop characteristics are described by the gain constants. Access to individual components of this PLL system is limited, inasmuch as the loop is only pinned out at the phase detector output and the frequency control input for the CCO. However, this allows for characterization of the gain constants of these loop components. The gain



where

K_p is Phase detector gain constant in μA per radian; K_p = 30 μA/rad

K_f is Filter transfer function, F(s)

K_n is 1/N; N= 8 for MC13175 and N = 32 for the MC13176

K_o is CCO gain constant in radians per second per μA; $K_o = 9.1 \times 10^5$ radians/sec/μA.

Figure 1. MC1317XD PLL block diagram.

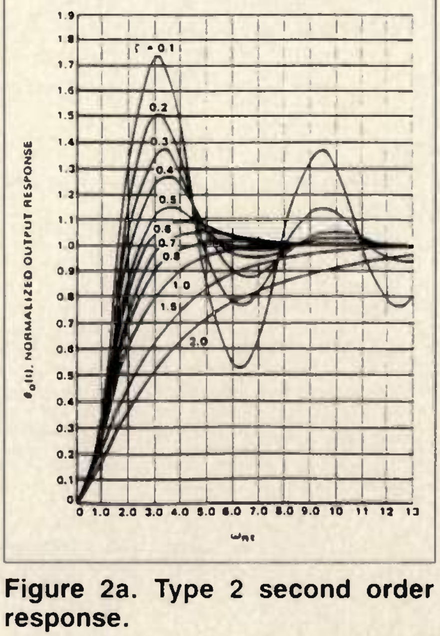


Figure 2a. Type 2 second order response.

Bandwidth as a Function of Damping Range

ζ	ω_{-3dB}
0.5	$1.82\omega_n$
0.7	$2.06\omega_n$
1.0	$2.48\omega_n$

Figure 2b. Loop bandwidth.

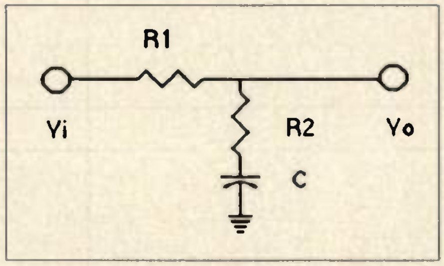


Figure 3. Lag-lead low pass filter.

constants K_p, K_o and K_n are derived and specified in the MC13176 data sheet. A detailed discussion of the characteristics of the IC with a pin by pin description and a discussion of the PLL fundamentals and how they apply to this PLL system component is also included in the data sheet (1).

Loop Filtering

The fundamental loop characteristics, such as capture range, loop bandwidth, lock-up time and transient response are controlled externally by loop filtering. The loop filter may take the form of a simple low pass filter or a lag-lead filter which creates an additional pole at origin in the loop transfer function. This additional pole along with that of the CCO provides two pure integrators ($1/s^2$). With two poles at the origin, a type 2 second order response yields a zero phase error to a step input of phase or frequency. The natural frequency, ω_n and damping factor, δ, are important in the transient response to a step input of phase or frequency. For a given δ and lock time, ω_n can be determined from the output response of a type 2 second order system shown in Figure 2a (2).

In the lag-lead low pass network shown in Figure 3, the values of the low pass filtering parameters R_1, R_2 and C determine the loop constants ω_n and δ. The following equations show this relationship (2,3,4):

$$\omega_n^2 = \frac{K_pK_oK_n}{R_1C} = \frac{K_pK_o}{R_1CN} \qquad (1)$$

$$\delta = \frac{K_pK_oK_nR_2}{2\omega_nR_1} = \frac{K_pK_oR_2}{2\omega_nR_1N} \qquad (2)$$

Rewriting in terms of R_2 and R_1C:

$$R_1C = \frac{K_pK_o}{\omega_n^2N} \qquad (3)$$

$$R_2 = \frac{2\delta\omega_nR_1N}{K_pK_o} = \frac{2\delta}{C\omega_n} \qquad (4)$$

Demonstration Transmitter

The demonstration transmitter is discussed in the following sections and is

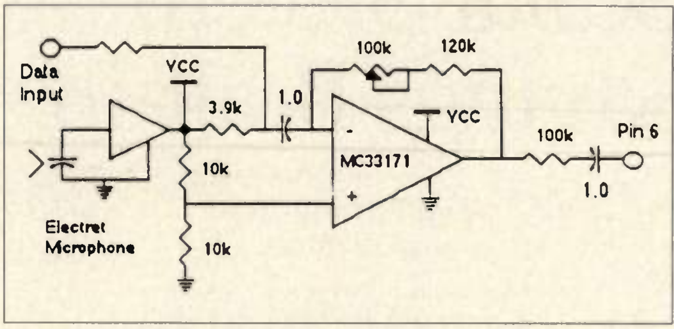


Figure 4. Microphone/data amplifier.

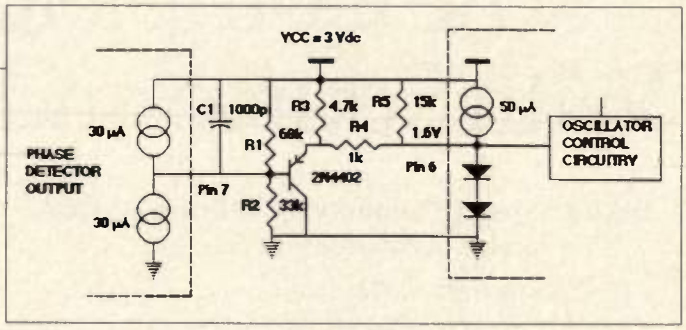


Figure 6. External loop amplifier.

built on a double sided PCB defined in the data sheet and shown in Figure 9.

The center section of the board provides an area for attaching all SMT components to the circuit side and radial leaded components to the component ground side of the PCB. Additionally, the peripheral area surrounding the RF core provides pads to add supporting and interface circuitry.

FM Modulation

The demonstration transmitter is FM modulated with voice and data via a summing amplifier to pin 6 as shown in Figure 4. In FM voice and low data rate applications, the loop bandwidth must be narrow enough so that the loop will not cancel out the modulation frequency components. The loop bandwidth is related to the natural frequency, ω_n as shown in the table in Figure 2b. For a loop bandwidth of 1 kHz, the natural frequency, ω_n is 3.05 krad/sec for a damping factor, δ of 0.707 (3).

In the example below, R_1, R_2, and C are calculated for the second order, type 2 system described above.

$$K_pK_oK_n = (30)(0.91 \times 10^6)(1/32)$$

$$= 0.853 \times 10^6 \quad (5)$$

$$R_1 = \frac{K_pK_oK_n}{\omega_n{}^2C} = \frac{0.853 \times 10^6}{9.30 \times 10^6}\,(C) \quad (6)$$

$$R_2 = \frac{2\delta}{\omega_nC} = \frac{(2)(.707)}{3.05 \times 10^3}\,(C) \quad (7)$$

For $C = 1.0\mu$; then

$$R_1 = 91.6k \text{ and } R_2 = 464 \quad (8)$$

In the above example the following standard value components are used:

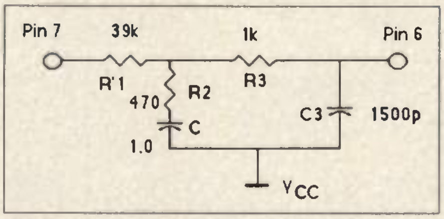


Figure 5. Modified low pass loop filter.

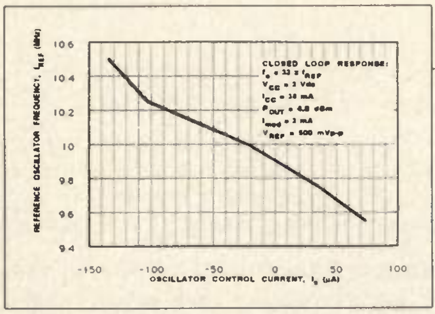


Figure 7. MC13176D reference oscillator frequency versus oscillator control current.

$$C = 1.0\mu;\ R_2 = 470 \text{ and}$$
$$R'_1 = 91.7k - 53k \sim 39k \qquad (9)$$

(R'_1 is defined as R_1 − 53k, the output impedance of the phase detector)

Since the output of the phase detector is high impedance and serves as a current source, and the input to the frequency control, pin 6, is low impedance (impedance of the two diode to ground is approximately 500 ohms), it is imperative that the second order low pass filter design above be modified. In order to minimize loading of the R_2C shunt network, a higher impedance must be established to pin 6. A simple solution is achieved by adding a low pass network between the passive second order network and the input to pin 6 (see Figure 5). This helps to minimize the loading effects on the second order low pass while further suppressing the sideband spurs of the crystal oscillator. A low pass filter with R_3=1k and C_2=1500p has a corner frequency, f_c of 106 kHz; the reference sideband spurs are down greater than −60 dBc.

Hold-In Range

The hold-in range, also called the lock range, tracking range and synchronization range, is the ability of the CCO frequency, fo, to track the input signal, $f_{REF} \times N$, as it gradually shifts away from the free running frequency, f_f. Assuming that the CCO is capable of sufficient frequency deviation and that the internal loop amplifier and filter are not overdriven, the CCO will track until the phase error, θ_e approaches $\pm\pi/2$ radians. Since sin θ_e cannot exceed ±1, as θ_e approaches $\pm\pi/2$ the hold-in range is equal to the DC loop gain, Kv × N.

$$\pm\Delta\omega_H = \pm K_v \times N \qquad (10)$$

where

$$K_v = K_p K_o K_n \qquad (11)$$

In the above example,

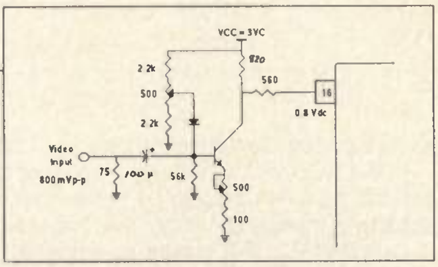


Figure 8. NTSC video modulator.

$$\pm\Delta\omega_H = \pm 27.6 \text{ Mradians/sec;}$$
$$\pm\Delta f_H = \pm 4.40 \text{ MHz} \qquad (12)$$

Extended Hold-In Range

The hold-in range of about 3.0 percent could cause problems over temperature in cases where the free running oscillator drifts more than 2 to 3 percent because of relatively high temperature coefficients of the ferrite tuned CCO inductor. This problem might be worse for lower frequency applications where the external tuning coil is large compared to internal capacitance at pins 1 and 4. The hold-in range can be increased to approximately 10 percent by addition of an external loop amplifier with an external current source at pin 6 that extends the operating range of the CCO (1).

In the demo transmitter, the external loop amplifier in Figure 6 is used. An external resistor (R5) of 15k to V_{CC} (3 VDC) provides approximately 100 uA boost to supplement the existing 50 uA internal source current. R_4 (1k) is selected for approximately 0.1 VDC across it with 100 uA. R_1, R_2 and R_3 are selected to set the potential at pin 7 and the base of 2N4402 at approximately 0.9 VDC and the emitter at 1.55 VDC when the error current to pin 6 is approximately zero uA. C_1 is chosen to reduce the level of the crystal sidebands. The impedance at this node now is the parallel resistances of 68k and 33k with (HFE + 1)(RE) which is >150k; the equivalent impedance seen by pin 7 is approximately 20k. The lead-lag loop filter described in Figure 3 is added to provide zero phase and frequency errors to transient inputs.

Figure 7 shows the improved hold-in range of the loop. The Δf_{REF} is moved 950 kHz with over 200 uA swing of control current for an improved hold-in range of ±15.2 MHz or ±95.46 Mradians/sec.

Video Modulator

The demo transmitter is also capable of AM modulation. Analog AM bandwidth using a sinusoidal waveform is typically 25 MHz. Figure 8 is the circuit used to amplitude modulate with a NTSC composite video signal. It is necessary to invert the negative going sync of composite video before applying the signal to pin 16 of the IC. As in the analog AM example in the data sheet, the modulating signal rides on a positive DC offset; however, in this case the video sync is clamped by the diode, MPN3401 or MBD101. The gain in the amplifier and the linearity of the AM modulation is adjusted by the 500 ohm pot in the emitter of the 2N4401.

PCB Layout Considerations

In the PCB layout, the V_{CC} trace must be kept as wide as possible to minimize inductive reactance along the trace; it is best that V_{CC} (RF ground) completely fills around the surface mounted components and interconnect traces on the circuit side of the board. This technique is demonstrated in the demo transmitter PC board.

The ground pins (also applies to pins 10 & 15) are connected directly to chassis ground. Decoupling capacitors to V_{CC} are placed directly at the ground returns.

Battery Selection - Lithium Types

The operating supply voltage range is from 1.8 VDC to 5.0 VDC. The demo transmitter is operated from a 3 volt lithium battery. Selection of a suitable battery is important. Because one of the major problems for long life battery powered equipment is oxidation of the battery terminals, a battery mounted in a clip-in socket is not advised. The battery leads or contact post should be isolated from the air to eliminate oxide build-up. The battery should have PC board mounting tabs which can be soldered to the PCB. Consideration should be given for the peak current capability of the battery. Lithium batteries have current handling capabilities based on the composition of the lithium compound, construction and the battery size. A 1300 mAhr rating can be achieved in the cylindrical cell battery. The Rayovac CR2/3A Lithium-Manganese Dioxide battery is a crimp sealed, spiral wound 3 volt 1300 mAhr cylindrical cell with PC board mounting tabs. It is an excellent choice based on capacity and size (1.358 inches long by .665 inches in diameter).

Differential Output (Pins 13 & 14)

The availability of micro-coaxial cable and small baluns in surface mount and radial-leaded components allows for simple interface to the output ports. A loop antenna may be directly connected with bias via RFC or 50 ohm resistors. Antenna configuration will vary depending on the space available and the frequency.

Matching to Antenna

When using an antenna having 50 ohms impedance, a quarter wave balun with a Z_o = 50 ohms would present a 50 ohm load to the IC. However, if the antenna is not actually 50 ohms, then the complex impedance presented to the device would be transformed by the balun as shown in the following formula:

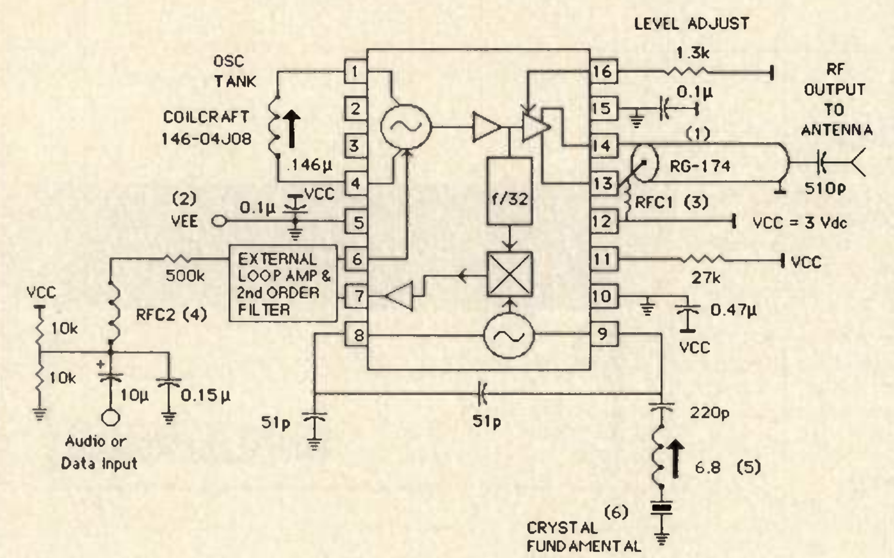
$$Z_s = \frac{Z_o^2}{Z_{load}} \qquad (13)$$

where

Z_{load} is the complex impedance of the antenna

Z_s is the load presented to the device

Z_o is 50 ohms



NOTES:

(1) 50Ω COAXIAL BALUN, 2 INCH LONG.

(2) PINS 5, 10 & 15 ARE GROUNDS AND CONNECTED TO VEE WHICH IS THE COMPONENS SIDE GROUND PLANE. THESE PINS MUST BE DECOUPLED TO VCC; DECOUPLING CAPACITATORS SHOULD BE PLACED AS CLOSE AS POSSIBLE TO THE PINS.

(3) RFC1 IS 180 nH COILCRAFT SURFACE MOUNT INDUCTOR OR 190 nH COILCRAFT 146-05J08.

(4) RFC2 IS HIGH IMPEDANCE TO 2X CRYSTAL FREQUENCY OF 10 MHz; 8.2 μh MOLDED INDUCTOR GIVES XL > 1000 OHMS.

(5) RECOMMENDED SOURCE IS A COILCRAFT "SLOT SEVEN" 7 MM TUNEABLE INDUCTOR, PART #7M3-682.

(6) THE CRYSTAL IS A PARALLEL RESONANT, FUNDAMENTAL MODE CALIBRATED WITH 32 PF LOAD CAPACITANCE.

Figure 9. Example circuit: MC13176D FM transmitter at 320 MHz.

For instance, if the antenna radiation resistance is low (when its electrical length is less than 1/10 wavelength), Z_s would be transformed to a relatively high impedance. Thus, the energy delivered to the antenna is reduced because of a severe mismatch of the antenna to the IC. Therefore, the 1/4 wavelength balun is intended in systems where the load impedance is near 50 ohms.

Size and Type Antenna

The size and type of antenna is an important consideration. At 320 MHz, a quarter wavelength antenna is 0.234 meters or 9.2 inches. This is likely to be too long for practical systems. However, when the antenna is on the order of 1/25 wavelength, the radiation efficiency of the antenna is very low (less than 1 percent). The radiation and loss resistances of an antenna determine the radiation efficiency. The loss resistance of a short loop is generally much larger than its radiation resistance. To increase the radiation efficiency (increased radiation resistance), multiturn loops are often employed, but the spacing between loops must be maintained. For close spacing between turns, the contribution to the loss resistance due to proximity effects can be larger than that due to the skin effect. In other words, a multiturn loop antenna which has the turns touching or with spacing between turns less than 3 times the wire diameter will increase the ohmic resistance exponentially with decreasing distance between turns. Therefore, a multiturn loop antenna requires adequate space for proper distance between the turns and for the necessary ratio of loop circumference to the wavelength, λ.

Radiation resistance equation can be written as

$$R_r = 20\pi^2(C/\lambda)^4 \qquad (14)$$

where $C = 2\pi a$ is the circumference of the loop (5). At 320 MHz, if the radius of a single turn loop in free space equals 1/10 wavelength or approximately 3.6 inches, then the radiation resistance is 29.4 ohms. For a loop with a radius of 1/25 wavelength or 1.5 inches, the radiation resistance falls to less than one ohm. To accommodate the size constraints placed on a system, resonant loops and folded monopoles are sometimes employed. A resonant loop may be configured as a parallel resonant circuit of a single turn loop and small series loop radiation resistance with a shunt capacitor in which high loop energy is developed at the carrier frequency. This loop should be printed on the PCB as an airline (i.e. no ground plane on either side of the board under or around the loop). In a hand held portable transmitter the coupling effects of the hand must be considered.

In most cases these designs are a compromise in which either the receiver is counted on to have excellent sensitivity or the transmitter requires relatively excessive power to make up for the lack of efficiency in the antenna. The size and design of the antenna system is important to its radiation capability; this area should not be overlooked in terms of the total transmitter system. It is not the scope of this paper to propose the ultimate solution or profess that one exists.

Conclusions

This paper has detailed the design of a monolithic UHF transmitter IC and its interface circuitry. The demonstration transmitter shows the versatile aspects of this basic PLL building block in both AM and FM applications. It offers the following advantages: it uses low cost surface mounted and low profile insertion mounted components, on a double sided PCB a finished product takes up little space, and with the extended hold-in range circuitry, the transmitter functions from −40 degrees C to +85 degrees C. In addition it has excellent frequency stability, and low manufacturing cost due to simple tuning procedures.

The issues left open by this paper and the data sheet, such as temperature characterization are important and will likely be addressed as the product matures. The benefits of using this single chip PLL in other more complex applications are yet to be realized. Being the first of its kind opens the way to scrutiny on one hand, but paves the way to new horizons on the other hand. ***RF***

References

1. MC13175D and MC13176D Technical Data Sheet, Motorola, Inc., 1991.
2. AN553, A New Generation of Integrated Avionics Synthesizers, Motorola, Inc., 1971, p. 6.
3. AN535, Phase-Locked Loop Design Fundamentals, Motorola, Inc.
4. Herbert L. Krauss, Charles W. Bostian, and Frederick H. Raab, *Solid State Radio Engineering*, Wiley, New York, 1980, pp. 164-185.
5. Constantine A. Balanis, *Antenna Theory: Analysis and Design*, Wiley, New York, 1982, pp. 169-184.

About the Author

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Class A Linear Amplifier

A new 20 Watt, class A linear amplifier is available from Trontech. The amplifier, part number P2450M-46-PS, features a frequency range of 2445-2455 MHz; S.S. gain of 36 dB minimum and a VSWR of 2.0:1 maximum. The third order intercept is +53 dBm minimum and +55 dBm typical. P_{out} at 1 dBc is +46 dBm. These low cost, 19 inch rack amplifiers are available in both broadband and narrowband frequency bandwidths. The present frequency coverage is 500-4000 MHz. Units are available for both domestic (110 VAC) and European (220 VAC) applications. Part number P1GA-33 is a 2 Watt, class A linear amplifier covering the 10-1000 MHz range. It features 30 dB of gain, and power output at the 1 dB compression point is 33 dBm.

Trontech Inc.
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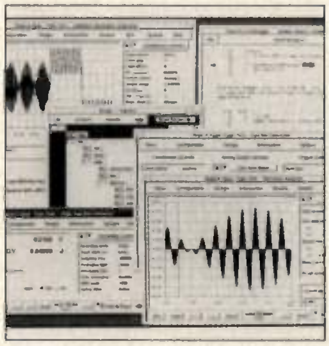
VXI Test System

A new series of VXI products is now available from Bruel & Kjaer. The test system includes both hardware and software introductions to reduce test time. New hardware products include A/D and D/A converters which sample at 100 kHz. Using DSP, a dynamic range of over 100 dB is possible with signal levels down to 1 uV. In addition, the virtual



instruments are software packages running on an embedded VXI computer. In conjunction with the A/D converter, D/A converter and Digital Signal Processor, the software package covers the majority of analog measurement functions. Virtual instruments include a multi-function voltmeter, arbitrary waveform generator, multichannel event recorder, function generator, waveform analyzer and spectrum and signal analyzer. The VXI modules include: a configurable switch, user module, 30 kHz input, 30 kHz output, 5-channel charge amplifier, and 5-channel microphone/AC amplifier. All of the products run within the Modular Test System architecture, with a choice of LAN-based or IEEE-488 based configurations.

Bruel & Kjaer
INFO/CARD #249

Low Noise PLL Oscillator

A miniature low noise, phase lock loop oscillator with applications as a frequency source for low noise, highly stabilized communications systems has been developed by Servo Corporation. The PLL source is comprised of three hybrids, an oscillator, frequency divider and charge pump/loop filter. The unit operates from −55 degrees C to +71 degrees C and features dual filtered coherent outputs, low phase noise and wide loop bandwidth for minimizing vibration sensitivity. Coherent 1300 and 2600 MHz frequency outputs are derived from a fundamental 2600 MHz oscillator which is stabilized by a cavity resonator and then phase locked to an external 10.156 MHz reference. The oscillator measures 0.75" × 3" × 4". Additional fundamental frequencies in the range of 1.8 to 4.5 GHz are also available. Delivery for standard unit is four months.

Servo Corporation of America
INFO/CARD #248

Continuously Variable Attenuators

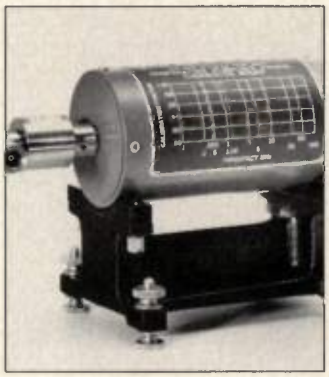
Now available from Alan Industries are continuously variable attenuators operating up to 800 MHz. Peak power is 100 Watts with an average power of 0.5 Watts. The devices have an attenuation range of 0-25 dB and feature screwdriver slot adjustment. Mounting configurations include: PC board mount, surface mount and panel mount configurations. Connector choices include BNC, SMA or F. 50 and 75 ohm models are available.

Alan Industries, Inc.
INFO/CARD #247

Coaxial Power Standards

Two models of a stabilized coaxial power standard are available for precise measurement of microwave power in the 0.1 to 100 MHz frequency range. Features include 10 uW to 25 mW range, thermally stabilized, precision matched thermistor elements and high stability. Calibration factor stability is less than 0.5 percent per year and thermistor bias power is 30 ±0.7 milliwatt with temperature control. RF impedance is 50 ohms normal. Connectors are Type N per MIL-STD-348 interface dimensions mate non-destructively with MIL-STD-39012 connectors. Mount outputs are Binding Post, standard 0.75" spacing for Banana plugs. Both the model 1116 and 1111 are designed for use with DC self balancing bridges or controllers. The model 1111 is a terminating power standard capable of calibration directly by NIST. The model 1116 is a thermistor mount/power splitter combination used as a feedthrough standard for the calibration of terminating power sensors.

Lucas Aerospace
INFO/CARD #246



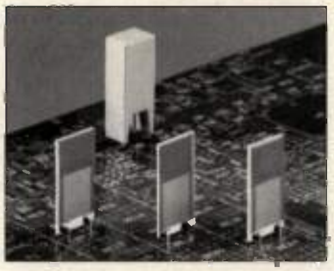
DISCRETE COMPONENTS

Mica Capacitors

Type CD17 and CD18 RF mica capacitors are now available in addition to type CD4 capacitors. The devices feature capacitances from 1 pF to 0.0082 uF and voltages up to 500 VDC with stable high frequency impedance. Insertion loss in a 50 or 75 ohm system is flat ±0.25 dB from 200 MHz to 1.2 GHz. Delivery is stock to 8 weeks and pricing is from $.19 each in OEM quantities.
Cornell Dubilier
INFO/CARD #245

Non-Inductive Resistors

Alumina substrate thick film resistors are now available. The products in the "Power Chip" line can dissipate up to five Watts of power and are offered in values from 1 ohm to 1 Mohm with a



standard tolerance of ±1 percent. The resistors measure .125"H × 1"L × .5"W and are designed for plug-in circuit boards with 0.10" centers. Availability is six to eight weeks.
Ohmite
INFO/CARD #244

Surface Mount Inductors

The RL2515 series of miniature inductors, for use in automatic surface mount assembly are available in 35 standard values from 0.15 uH to 100 uH with DC current ratings of 70 mA to 610 mA. The operating temperature range is −25 degrees C to +80 degrees C. They are available in tape and reel or in bulk quantities.
Renco Electronics, Inc.
INFO/CARD #243

Low Cost Inductors

Low cost molded and conformal coated inductors are available for as little as $0.15 each in quantity. The series 9130 molded inductors are available from 0.10 uH through 1000 uH. Series 77F and 78F conformal coated inductors are available from 0.10 uH through 1000 uH as well.
J.W. Miller
INFO/CARD #242

Low Cost Reed Relays

The COTO 8200 series SIP reed relays feature 0.3" × 0.4" × 0.3" or 0.2" × 0.4" × 0.2" pin spacing and come in four standard models with a 5 V or 12 V coil and 10 W or 50 W switching options. Their dielectric strength is 2000 V contact-to-contact and contact-to-coil, if supplied with optional high voltage isolation. The relays are priced from $0.70 each to $1.49 each, depending on the model, in production volume.
Coto Wabash
INFO/CARD #241

TEST EQUIPMENT

Mixer Measurement System

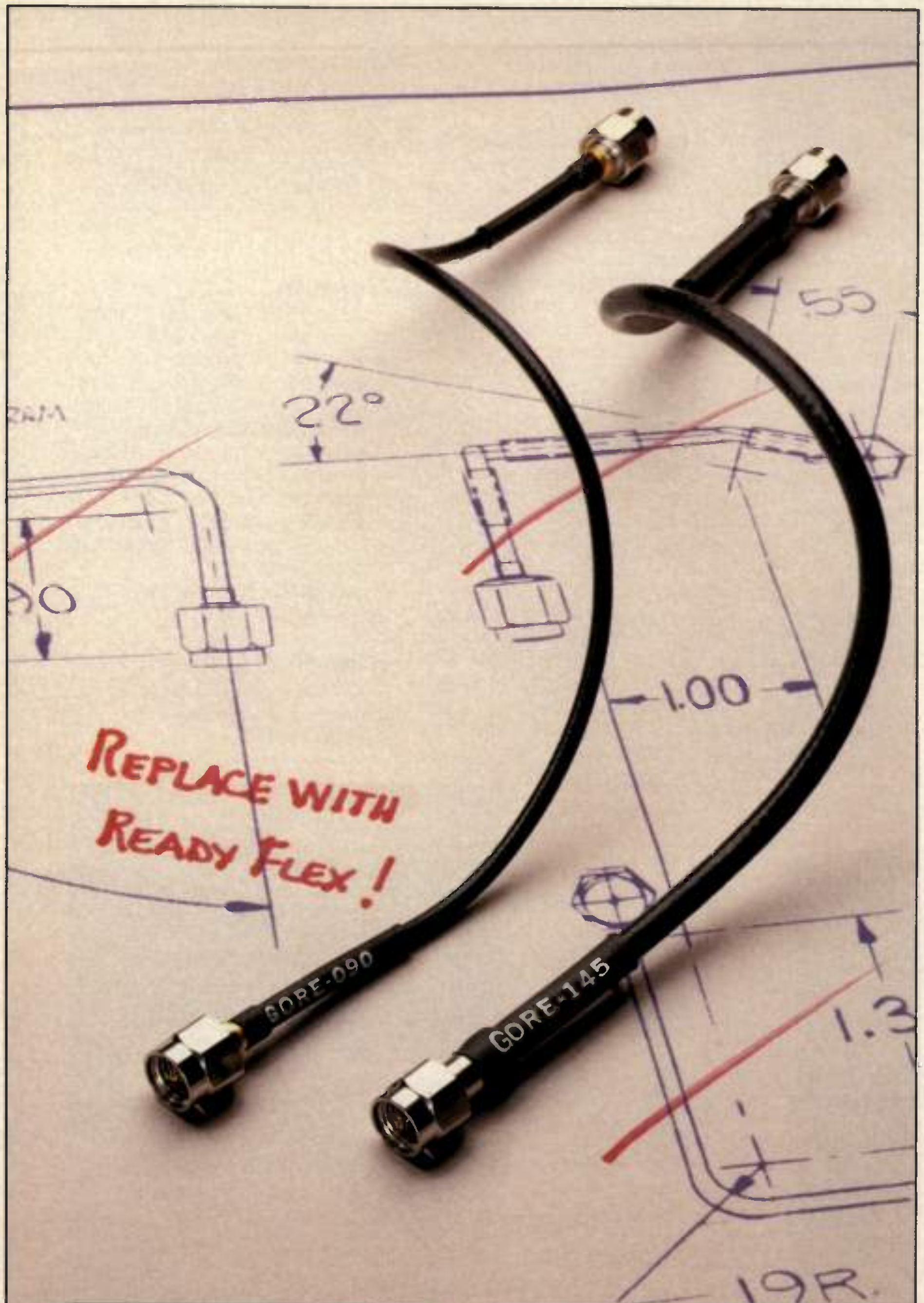
The HP 8753MX is an automated mixer measurement system which characterizes frequency-translation devices with a single connection, eliminating system configuration changes between tests. The system measures: conversion loss, compression, RF and IF port SWR, LO feedthrough, isolation, group delay, output power and amplitude and phase tracking.
Hewlett-Packard Company
INFO/CARD #240

Standard Mismatches

Precision, standard mismatches are available calibrated over the range from 2 to 26.5 GHz

Flexible, Reliable, and only $68*!

Introducing ReadyFlex™ microwave assemblies from Gore



Guaranteed Insertion Loss (dB)				
.090" Assemblies				
Length (In.)	6"	12"	24"	36"
Freq. (GHz)				
2	.31	.48	.84	1.19
4	.40	.66	1.16	1.66
8	.56	.92	1.64	2.36
12	.69	1.14	2.03	2.92
18	.87	1.42	2.52	3.62
.145" Assemblies				
2	.22	.32	.51	.71
4	.29	.43	.70	.98
8	.40	.60	.99	1.39
12	.49	.74	1.23	1.73
18	.62	.93	1.54	2.16

Specifications	
Cable O.D.:	.090", .145"
Frequency Range:	D.C. to 18 GHz
VSWR:	1.35:1 up to 18 GHz
Shielding:	>90dB up to 18 GHz
Impedance:	50 Ohm +/- 1 Ohm
Velocity of propagation:	85%
Bend Radius (static):	.090" - 0.25" .145" - 0.5"
Temp. Range:	-55°C to 125°C
Cable MIL SPEC:	MIL-C-17
Connectors:	Straight SMA to SMA Males
Interface:	Per MIL-C-39012

A cost-effective, high performance alternative to RG & semi-rigid assemblies

A truly flexible, easy to install microwave cable assembly for use to 18 GHz is now available directly from stock.

New ReadyFlex microwave assemblies, in a choice of .090" and .145" O.D.'s, replace hard to work with semi-rigid tubing with an easy to handle high performance package. Designed with a pre-determined feature set, these highly reliable assemblies are offered at an extremely cost effective price.

ReadyFlex assemblies offer short & long term savings

ReadyFlex assemblies not only reduce costly installation time and failures typical of stiffer semi-rigid and less durable RG assemblies, they also eliminate expensive and time consuming 3-D drawings. This results in immediate cost savings. A single ReadyFlex assembly also replaces multiple semi-rigid configurations and lengths, further saving on inventory and paperwork.

ReadyFlex assemblies offer SMA male connectors with unique pin captivation. Bend radii as tight as 1/4", reinforced strain reliefs, operating temperatures from -55°C to 125°C, and other features have also been added to ensure long term reliability. And because they're flexible, vibration stresses don't get transferred to the connector/cable interface, further eliminating in-use failure.

Direct from stock

ReadyFlex assemblies are stocked in lengths of 4, 6, 9, 12, 15, 18, 24, 30, and 36 inches. Normally, within 24 hours of an easy toll free call you can have these high performing, off-the-shelf, flexible microwave assemblies on the way to your door. For as little as $68! Call now to order.

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INFO/CARD 98

(usable from DC to 34 GHz) using precision 3.5 mm connectors. The 8033 mismatches are available individually, with either male or female connects, at six specific mismatch values ranging from 1.10 to 2.00. The mismatches are also available as the Model 8033K mismatch set which consists of all twelve units supplied in a wooden instrument case with a calibration report.
Maury Microwave Corporation
INFO/CARD #239

LCZ Meter

The model 3330 meter has the ability to make small, incremental changes in the frequency and signal levels which allow users to select test parameters that more closely match in-circuit conditions. The 3330 offers 0.1 percent basic accuracy, 4-1/2 digit resolution, 201 frequencies from 40 Hz to 100 kHz, finely adjustable signal levels from 10 mV to 1.100 V, determines L, C, R, |Z|, Q, D, ESR, G, X, Θ, V or I in as little as 64 ms, and is programmable via GPIB interface or front panel controls.
Keithley Instruments, Inc.
INFO/CARD #238

Low Cost Spectrum Analyzer

A 1 GHz bench model spectrum analyzer with cursor and 6" CRT readout display is now available. Specifications include: 1 to 1000 Mhz frequency bandwidth; ±1 percent accuracy and 1 MHz resolution for center frequency display; 0.1 to 100 MHz, 10 step scanning band at 3 dB per band; scanning band accuracy is ±6 percent below 100 MHz center frequency and ±10 percent above 100 MHz at approximately 5 msec/div. Amplitude measuring range is rated at 15 to 129 dBuV.

Dynamic range is 70 dB and input impedance is 50 ohms (1.5 VSWR max) with maximum input level at 130 dBuV.
Protek
INFO/CARD #237

Digital Power Meters

The 8540 series power meters are designed for fast power measurements in ATE systems. The meters can provide at reading speed of >200 triggered readings per second in CW mode and >1000 readings per second in a new burst mode. Three triggered modes are available: fast free-run CW mode, fast bus triggered CW mode and fast TTL triggered CW mode.
Wavetek
INFO/CARD #236

Portable Spectrum Analyzers

Two new portable synthesized spectrum analyzers covering 100 Hz to 2.2 GHz are now available from Anritsu Europe. Both the MS2601B (50 ohm) and MS2601K (75 ohm) feature an overall level of accuracy of 1 dB and a minimum dynamic range of 75 dB. The analyzers feature single level soft keys and an optional GPIB controller. Other optional accessories include a tracking generator, a programmable pre-selector for pre-compliance EMI measurements and a battery pack for DC operation.
Anritsu Europe Limited
INFO/CARD #235

Compact Level Meter

A new level meter (voltmeter and power meter in one unit), model URV35, measures voltage and power over the frequency

range from DC to 26.5 GHz. Operation is from a conventional AC source or from an optional battery supply. It can be operated via front panel controls or over an RS-232 bus interface. Measurements are absolute in dBm, V or W, or relative, in dB referred to a stored reference value. Cost is $2310.00.
Rohde & Schwarz
INFO/CARD #234

SIGNAL SOURCES

Ovenized Crystal Source

The 2000 series of ovenized crystal source features low phase noise and compact size. The unit is available at frequencies between 40 and 125 MHz, meeting frequency stabilities up to $\pm 1 \times 10^{-7}$. The oscillator has a phase noise level of −148 dBc at 1 kHz and a floor of −170 dBc at 100 kHz offset. The harmonics are down −26 dBc and spurious are down −70 dBc.
Techtrol Cyclonetics, Inc.
INFO/CARD #233

Microwave Oscillator

The MOMO is a miniature ovenized microwave oscillator design to supply a 10 dBm signal into 50 ohms (13 dBm typical) with center frequencies to 1.3 GHz. It measures 1.35" square by 0.58" high and requires less than 3 Watts steady state power. The phase noise, based on 1.0 GHz, is typically −136 dBc at 10 kHz, −120 dBc at 1 kHz and −94 dBc at 100 Hz.
Greenray Industries, Inc.
INFO/CARD #232

Low Cost VCOs

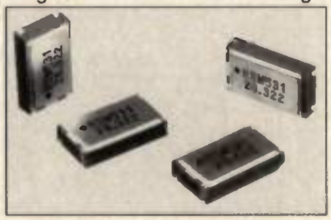
The series 180 oscillators are pin compatible with TO-8 type oscillators. Specifications include: +13 dBm typical power output, frequency stability of 150 ppm/degree C, harmonics of greater than 15 dBc, spurious of >70 dBc and input power of +15 VDC at 50 mA.
EMF Systems Inc.
INFO/CARD #231

INFO/CARD 71

INFO/CARD 96

Surface Mount Oscillator

A reduced size, surface mount, HCMOS compatible crystal oscillator is available from Connor-Winfield. The HSM531/536 is available with a frequency range of 1.8432 MHz through



70.000 MHz. Stabilities are either ±50 ppm or ±100 ppm, over a temperature range of 0 to +70 degrees C. Pricing for prototype quantities of 25 pieces at 50 MHz is $11.25 each.
Connor-Winfield Corp.
INFO/CARD #230

AMPLIFIERS

Ultra-Broadband RF Amplifier

The model 603L RF power amplifier produces up to 3 Watts of linear Class A output over the frequency range of 0.8 to 1000 MHz. Gain is 40 dB nominal and the amplifier features low harmonic and low intermodulation distortion; all harmonics are more than 18 dB below the main signal. These amplifiers are useful for EMI/RFI testing, broadband component and system analysis, and general laboratory applications.
ENI
INFO/CARD #229

Medium Power Amplifiers

New ultra broadband medium power amplifiers, using distributed technology, operate from 0.1 to 8.0 GHz with a power output of +23 dBm minimum at 1 dB

compression point. The VSWR is 2:1 maximum, gain flatness is ±1.5 dB maximum and 4.5 dB maximum noise figure. Power supply is +18 V minimum.
Miteq
INFO/CARD #228

Low Noise Amplifier

The model 310 amplifier covL ers 10 kHz to 1 GHz with a typical noise figure of only 1.8 dB. The gain is 32.5 dB at 100 MHz with a flatness specification of ±0.5 dB maximum from 25 kHz to 800 MHz. Output power at 1 dB gain compression is +11 dBm, and the third order intercept point is at +23 dBm. The amplifier measures 3.6" × 4.3" × 7.2" making it useful for applications such as spectrum analyzers, EMI/EMC test systems and near field probes.
Sonoma Instrument
INFO/CARD #227

L-Band Application

The model CPHC128148-5/1665 is a solid state, Class A linear power amplifier operating over the frequency range of 1200-1400 MHz. The power output is 5 watts at 1 dB compression and small signal gain is 30 ±2 dB. The power amplifier is unconditionally stable under any combination of input or output VSWR and is protected against thermal overload and output VSWR.
Power Systems Technology Inc.
INFO/CARD #226

SIGNAL PROCESSING

Increased Stability

A new line of equalizers offers electrical stability with temperature variation and vibration. Resonant frequencies remain constant as temperature varies over the operating range of −55 to +125 degrees C. VSWR performance is as low as 1.40:1 over multi-octave bandwidths. The line also offers stepped and variable loss elements.
Semflex, Inc.
INFO/CARD #225

IF Power Dividers

Two new IF power dividers offer phase and amplitude balance as well as high isolation. Model 432-26-2 operates from 5 MHz to 1 GHz with a minimum

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isolation of 24 dB. Model 432024-2 operates from 10 to 500 MHz with a minimum isolation of 27 dB. SMA connectors are standard and the components are available from stock.
Loral Microwave-Narda
INFO/CARD #224

Microstrip Mixers

Four new microstrip compatible carrier mixers are available from Magnum. Two of the mixers, an upconverter and a downconverter are available in miniature configuration. All of them operate from −54 degrees C to +100 degrees C and have an input power of 200 mW at +25 degrees C or 100 mW at +100 degrees C. IF is DC to 1.1 GHz and LO power is +10 dBm.
Magnum Microwave Corporation
INFO/CARD #223

8-Way Power Divider

New power dividers operate from 30 MHz to over 500 MHz with very low insertion loss, 11 dB per port including loss due to power split, with less than 0.5 dB amplitude imbalance. Port to port isolation is greater than 20 dB and maximum average power handling capability is 1 Watt minimum. Connector options are type N or SMA.
Microwave Solutions, Inc.
INFO/CARD #222

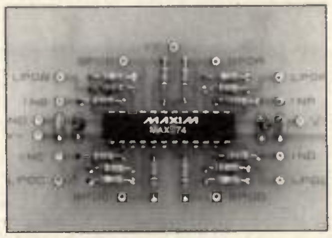
Easy Solder Joint Inspection

Two size chip attenuators are offered with metallized ground planes to allow fast, easy solder joint inspection. Model TS0300W1 and TS0500W1 have a wrapped ground with full ground plane metallization. Both models operate from DC to 18 GHz, with maximum VSWR of 1.30:1. Attenuation accuracy is ±0.5 dB or five percent for each value from 1 to 20 dB.
EMC Technology, Inc.
INFO/CARD #221

SEMI-CONDUCTORS

Low Noise Analog Filters

The MAX274 is an 8th order filter with four independent cascadable sections and the MAX275 is a 4th order filter with two independent sections. The filters can implement bandpass or lowpass filter responses and has user-programmable center



frequency and Q. Total harmonic distortion is less than −86 dB. The MAX274 comes in 24-pin narrow plastic DIP and CERDIP as well as 28-pin small outline packages. The MAX275 comes in 20-pin plastic DIP, CERDIP and small outline packages.
Maxim Integrated Products
INFO/CARD #220

SPDT GaAs Switches

Two new low cost single pole double throw GaAs monolithic switches are available in plastic surface mount packages for operation from DC to 3 GHz. The MGS-70008 is a reflective switch, with the switched terminal in the off state terminated to ground and the MGS-71008 is an absorptive switch, with the switched terminals in the off state terminated into an internal 50 Ohm load.
Avantek
INFO/CARD #219

PIN Diodes

The HIPAX™ series of PIN diodes are designed as equivalents to many Unitrode PIN diodes. The M/A-COM series features a full face bonded, passivated PIN diode chip in a thermally symmetrical package for high power performance. Package options include bondable chip, axial lead, studded and a non-rollable surface mount device.
M/A-COM Semiconductor Division
INFO/CARD #218

The Smith Chart and its Usage in RF Design

By Neal C. Silence
Microwave Engineering Consultant

The Smith® Chart is a design and analysis tool that can provide insight into the impedance and reflection characteristics of an RF circuit. An understanding of this tool and its use can enhance the performance of an RF engineer in the design, development, integration and test of RF and microwave circuits. The purpose of this tutorial is to explain the analytical basis of the chart, not to provide step-by-step manipulation instructions.

Many people mistakenly ignore the Smith Chart as a design tool because they feel that the large commercial CAD programs are all they need. However, a quick look at these programs reveals that they make extensive use of the Smith Chart. To use these programs effectively, an understanding of the chart is needed.

The Smith Chart is particularly valuable in that phase of design when modification of the impedance characteristics of the circuit is required. Even when purely numerical methods can be used, the Smith Chart's graphical representation can add an intuitive insight that saves considerable design time.

What is the Smith Chart?

The chart, as shown in simplified form in Figure 1, is a graphical representation that provides a transformation between the complex reflection coefficient (S11), in a polar format, to the real and imaginary parts of the impedance or admittance. In this form, it is ideally suited for the solution of transmission line problems, which was the main objective of its creation. Translation along a transmission line is represented solely by a change in the phase of the reflection coefficient, which becomes a simple rotation of a constant-length vector on the Smith Chart.

The chart has the property of being able to graphically display the entire range of real and imaginary values of input impedances (or admittances) of a network. This characteristic turns out to be a valuable asset of this design and analysis tool.

Transmission Line Analysis

The following equations describe transmission line characteristics (refer to Figure 2):

$$Z_{in}(l) = Z_o \frac{Z_L + jZ_o\text{Tan}[bl]}{Z_o + jZ_L\text{Tan}[bl]}\ ;\ b = \frac{2\pi}{\lambda} \qquad (1)$$

$$\Gamma_1 = \varrho_L e^{j\Theta_L} = \frac{Z_L - Z_o}{Z_L + Z_o} \qquad (2)$$

$$\Gamma_{in} = \Gamma e^{-j2bl} = \varrho_L e^{j[\Theta_L - 2bl]} \qquad (3)$$

$$Z_{in} = Z_o \frac{1 + \Gamma_{in}}{1 - \Gamma_{in}} \qquad (4)$$

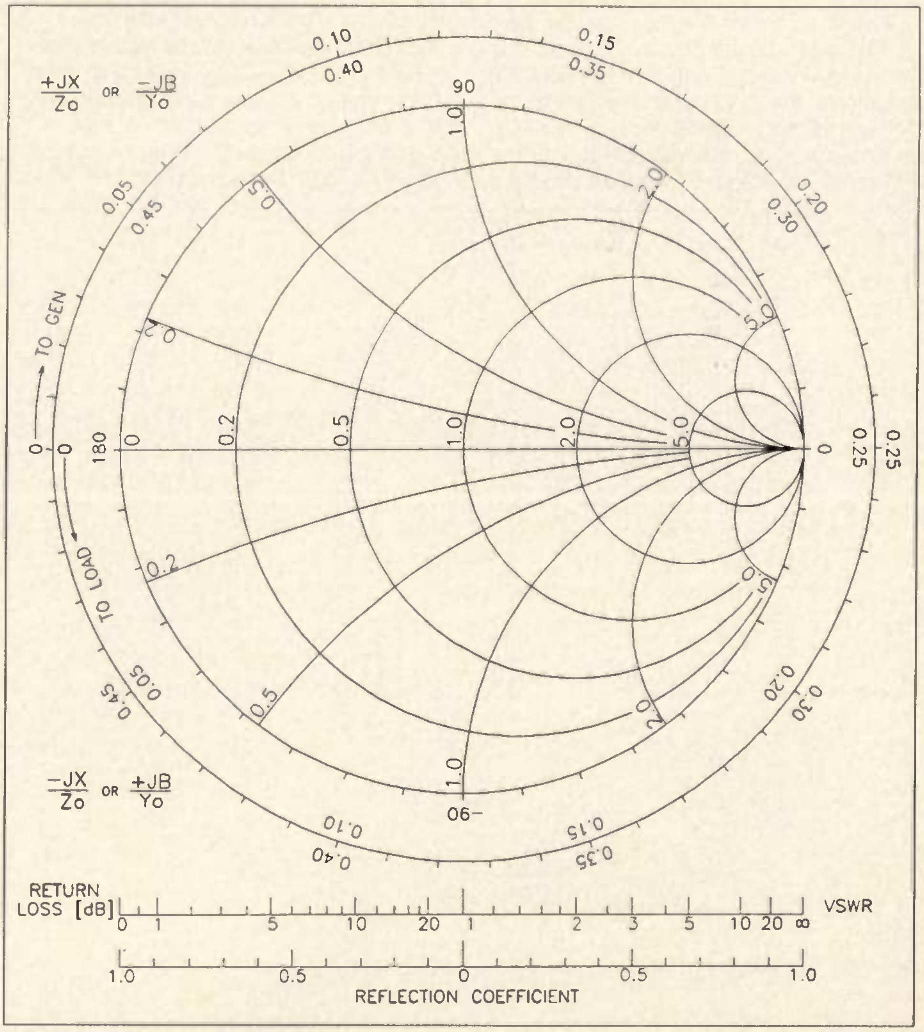


Figure 1. The Smith Chart.

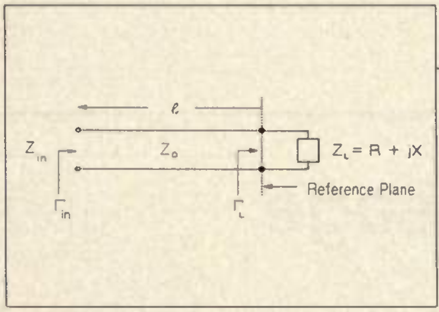


Figure 2. Circuit diagram of a transmission line terminated with an impedance.

Γ = Complex reflection coefficient
ϱ = Magnitude of the reflection coefficient
Θ = Phase of the reflection coefficient
λ = Wavelength in the transmission line
l = Transmission line length in degrees

Input impedance of a transmission line. A transmission line of characteristic impedance Z_0, terminated by an arbitrary impedance Z_L, will have an input impedance Z_{in} as described by equation (1). A lossless line is assumed, which is a good approximation for most applications.

However, this equation can be very cumbersome to use. For example, if one wants to know the length of line that will transform the load to a real value, the computation can be quite complex. With a lossless line, the magnitude of the reflection coefficient remains constant as its length is changed (equation 3). One could use this property to find values of Z_0 that solve this problem.

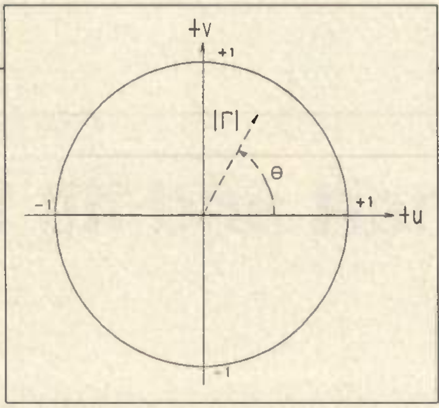


Figure 3. Reflection coefficient coordinates.

Reflection coefficient. The reflection coefficient is nothing more than a mathematical representation of the reflected voltage wave with respect to the incident wave at a specified port of a circuit. It is identical to the S parameter Sii, where "i" is the port number of the circuit. Equation (2) defines it in terms of a circuit input impedance referenced to the transmission line characteristic impedance.

For any circuit, the reflection coefficient can be represented graphically at any frequency as shown in Figure 3. Since reflection coefficient is a complex value, it can be represented in either polar or rectangular coordinates. Polar coordinates are the preferred choice, as translation along the transmission line is obtained by simply rotating the vector. The Smith Chart adds an overlay coordinate system for impedance as represented by equation (4), and problems such as transforming a complex impedance to a real value become quite easy to solve.

Construction of the chart. Since there is a multiplicity of impedances in use and because the Z_0 of waveguide cannot be uniquely defined, it is common practice to normalize impedances and admittances when using the Smith Chart. By normalizing Z_0 as shown in equation (5), equations (2) and (4) become (6) and (7):

$$z = \frac{Z}{Z_o} = \frac{R}{Z_o} + j\,\frac{X}{Z_o} \tag{5}$$

$$\Gamma = \frac{z-1}{z+1} = u + jv \tag{6}$$

$$z = \frac{1+\Gamma}{1-\Gamma} = r + jx \tag{7}$$

Substituting equation (6) into (7), we can eventually get:

$$\left[u - \frac{r}{1+r}\right]^2 + v^2 = \frac{1}{(1+r)^2} \tag{8}$$

This equation represents a circle of radius $1/(1+r)$ with its center at $u=r/(1+r)$ and $v=0$. From this, a family of circles is obtained that represent a loci of constant resistance with their centers on the u axis of Figure 3 and a common point at $u=1$ and $v=0$. For a range of r from zero to infinity all circles are contained within a circle described by a reflection coefficient of magnitude 1 and variable phase, which is also the circle for $r=0$ (the outer circle and maximum boundary of the chart, as in Figure 1).

The derivation of equation (8) can also yield the loci of constant reactance:

$$(u-1)^2 + \left[v - \frac{1}{x}\right]^2 = \frac{1}{x^2} \tag{9}$$

Again, a family of circles is obtained. However, this time the centers lie along a vertical line at points of $u=1$ and $v=\pm 1/x$. Since the radii of these circles are $1/x$, they also have a common point of $u=1$ and $v=0$. Figure 4 identifies a pair of constant resistance and reactance circles along with their centers and radii.

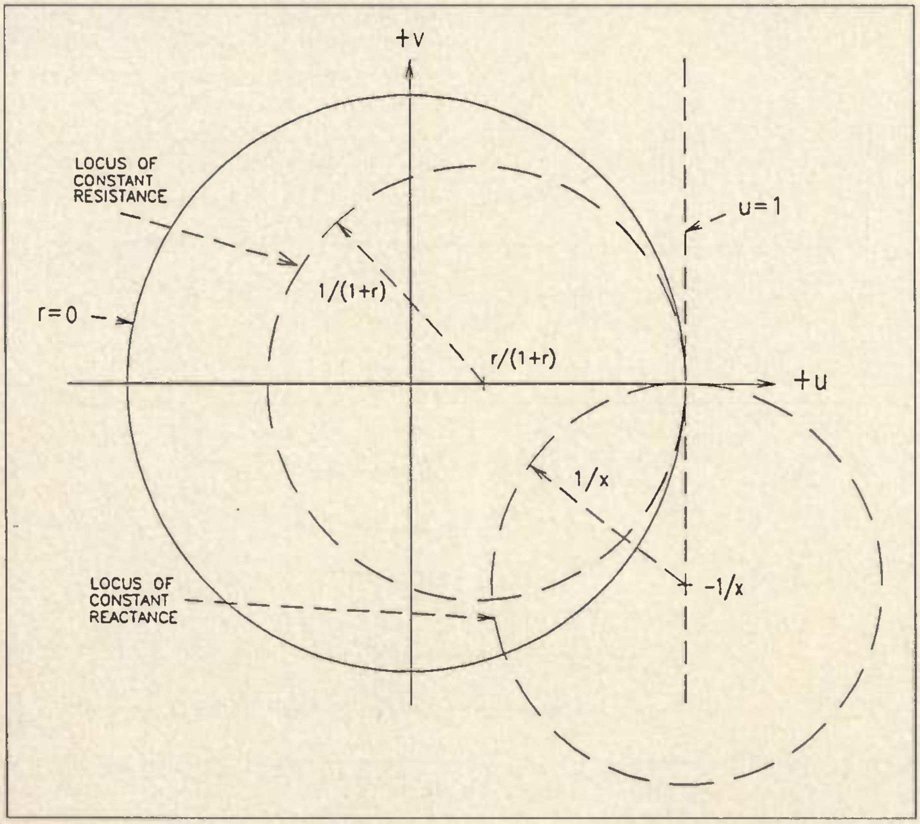


Figure 4. Smith Chart configuration.

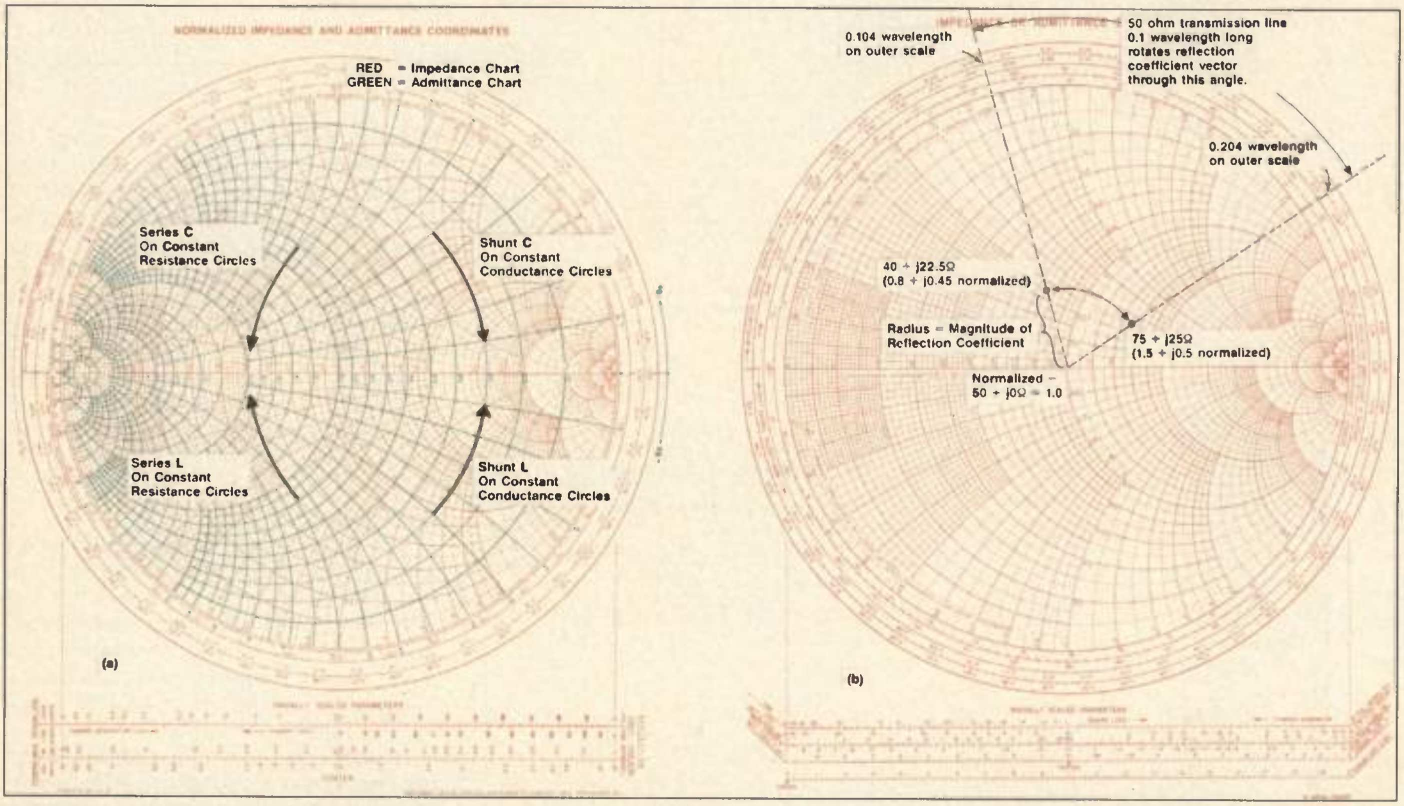


Figure 5. (a) Reactance changes along constant resistance and conductance circles; (b) rotation of impedance through a length of transmission line.

Properties of the Smith Chart

Range of values. For a passive circuit, the magnitude of the reflection coefficient is less than or equal to one. This implies that all possible values of input impedance of such a circuit will lie within the unit reflection coefficient circle. For an active circuit, the reflection coefficient may be greater than one. For cases of this nature, the input impedance will have a negative resistive component. Using this property, the Smith Chart can be used to analyze the stability of amplifier circuits.

Pure real and pure imaginary values. An impedance consisting of a purely resistive component lies only on the u axis of the reflection coefficient. On the other hand, pure reactance values occur only on the reflection coefficient unit circle (outer edge) of the chart. This latter property provides a convenient tool for determining the length of an open or short circuited transmission line that will provide a specific resistance.

Modification of values. If one adds series resistance to a load impedance, then the impedance moves along a constant reactance circle. Conversely, adding reactance will move the impedance value along a constant resistance circle (see Figure 5a). If one adds or subtracts transmission line length, then the impedance is transformed along a circle with its radius determined by the magnitude of the reflection coefficient. The angle of rotation is dependent on the wavelength of the added transmission line (Figure 5b). These properties are helpful in determining what type of circuit element is needed to obtain a match.

Impedance and admittance representation. The chart can be used to display impedance or admittance. The inversion process from one to the other is accomplished on the chart of Figure 1 simply by: 1) relocating the data diametrically across the chart at the same distance from center (as if the reflection coefficient was rotated 180 degrees), and 2) changing the sign of the imaginary component of the immitance (i.e., positive values of reactance are in the upper half of the chart while positive values of susceptance are in the lower half. Note that the phase angle of the voltage reflection coefficient is displayed correctly only when impedance coordinates are used.

There is a version of the Smith Chart available that always shows the reflection coefficient correctly. This chart has both impedance and admittance, and care is required to keep them from causing confusion. Figure 5a includes such a chart to illustrate reactance changes on both constant resistance and constant susceptance circles.

Radial and circumferencial scales. For convenience of use, several scales are provided with most Smith Charts. Radial scales are usually provided at the bottom of the chart; most commonly including reflection coefficient, VSWR and return loss. The normalized resistance values marked off to the right from the center of the chart also are equivalent to VSWR. The circumferential scales most often provided are reflection coefficient phase angle and fractional electrical wavelength. The latter is scaled in wavelengths toward the load and toward the generator. A zero reference is located at a reflection phase angle of 180 degrees.

Application Examples

Lumped element matching. A 75 + j25 ohm load is to be matched to a 50 ohm transmission line. On a chart normalized to 50 ohms, the normalized impedance of the load is 1.5 + j0.5, as plotted in Figure 6. The elements required are determined by following the constant reactance lines in both the impedance and admittance portions of the chart. From the load, we can follow the constant susceptance line to the point that lies at 1 + j0.8 (normalized) on the impedance chart. This route "travels" from values of −0.2 to −0.49 for a net change of 0.29 in the direction corresponding to a shunt inductor. On the impedance chart, the path from 1 + j0.8 to 1 + j0.0 corresponds to a series

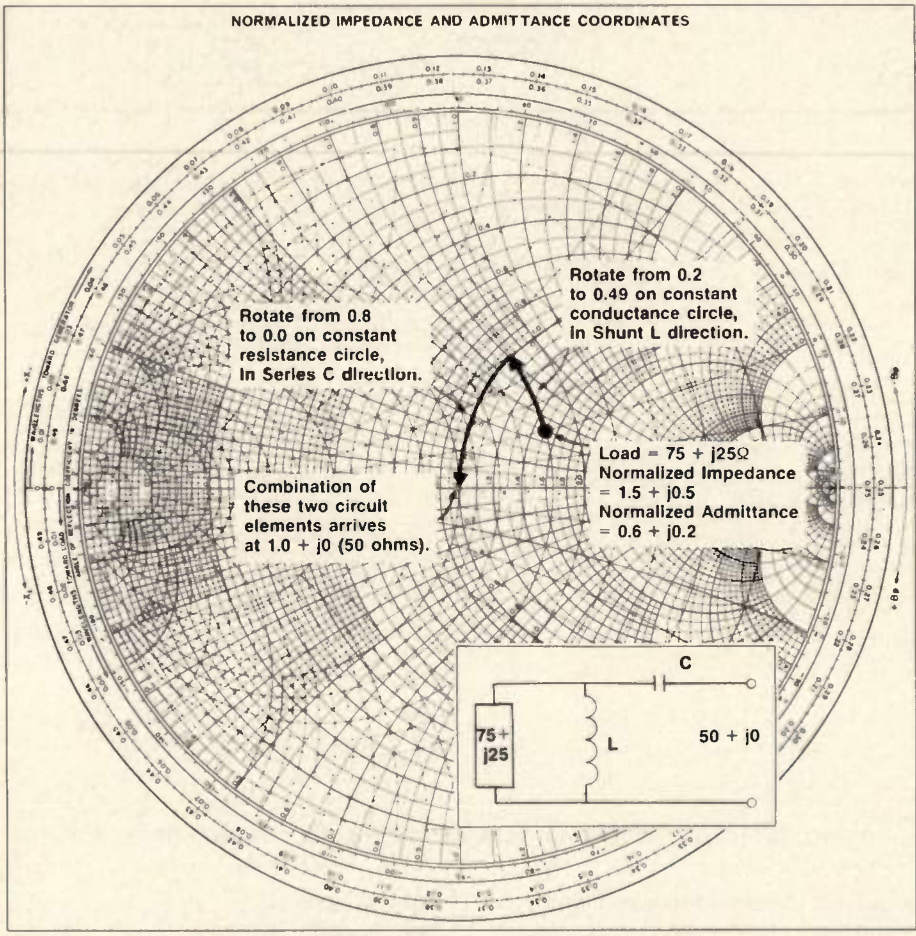


Figure 6. Lumped element impedance matching example.

capacitor with a normalized impedance of −j0.8. De-normalizing to a 50 ohm system, we see that a shunt inductor of 0.29 × 50 = 14.5 ohms is placed across the load, followed by a series capacitor of 0.8 × 50 = 40 ohms to the 50 ohm line.

Impedance matching using a single stub tuner. In this example, it is desired to match the same 75 + j25 ohm load to a 50 ohm transmission line using a single short-circuited stub. The parameters that need to be determined to solve this problem are the position of the stub on the transmission line and its length. The normalized load impedance Z1 is 1.5 + j0.5. Since the susceptance of the stub will be added in shunt, the impedance Z1 will be converted to its corresponding admittance of Y1 = 0.6 − j0.2. This admittance will lie on the unit conductance circle. The admittance obtained here is Y2 = 1 + j0.58. The length of the line is obtained from the chart's circumferential fractional wavelength scale. For this problem, the length is 0.195 times the operating wavelength of the transmission line. To obtain a match, a susceptance of −0.58 must be added by the stub. This value is obtained by transforming a short circuit (infinite conductance) through a length of line equal to 0.166 wavelengths along the outer circle of the chart in a clockwise direction from the infinite conductance and susceptance point to a susceptance of −0.58 as shown in Figure 7.

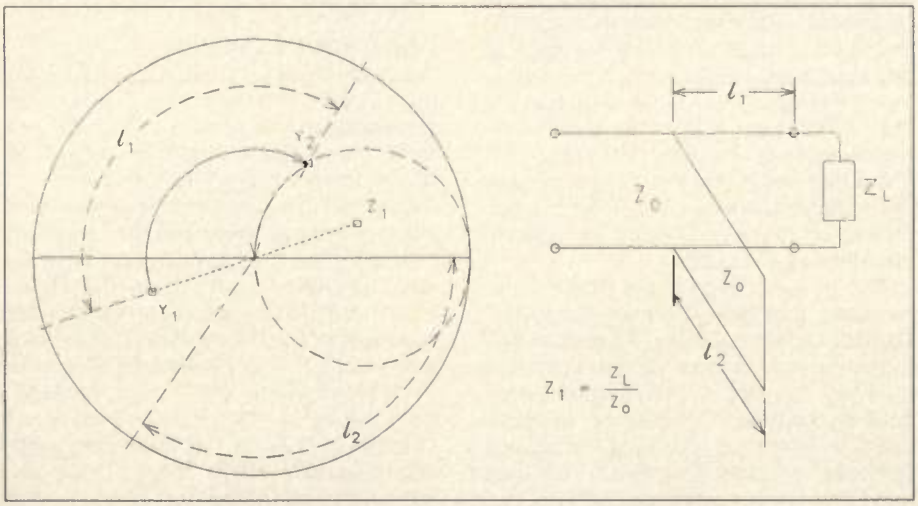


Figure 7. Impedance matching using a single stub tuner.

Conclusion

The Smith Chart is a very useful design and analysis tool that has withstood the test of time. This chart, which is nothing more than a mapping of constant reactance and resistance of the impedance plane onto the complex reflection coefficient plane, is one that every RF engineer should be familiar with.

Readers may want to do a second reading of the material presented here alongside instructions on the mechanics of data manipulation on the chart, such as those found in Reference (6).

Smith® is a registered trademark of Analog Instrument Company, P.O. Box 808, New Providence, NJ 07974. Tel. (908) 464-4214. This company supplies charts in various configurations, and has Mr. Smith's book on the chart (Reference 1). ***RF***

References

1. P.H. Smith, *Electronic Applications of the Smith Chart*, McGraw-Hill, New York, 1969.
2. S.F. Adam, *Microwave Theory and Applications*, Prentice-Hall, New York, 1969, Ch. 2.
3. G.H. Bryant, *Principles of Microwave Measurements*, IEE Electrical Measurement Series, Peter Peregrinus Ltd., London, 1988, Ch. 3.
4. R.E. Colin, *Foundations for Microwave Engineering*, McGraw-Hill, New York, 1966, Ch. 5.
5. C.G. Montgomery, R.H. Dicke, E.M. Purcell, *Principles of Microwave Circuits*, McGraw-Hill, New York, 1948.
6. C. Bowick, *RF Circuit Design*, Howard W. Sams & Co., 1982, Ch. 4.

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CAD Program for Analysis and Synthesis of Stripline, Microwave Circuits

By Przemyslaw Miazga and Dariusz Lubecki
Technical University of Warsaw

Stripline circuits, transmission lines between conducting plates, have not been as popular as microstrip, with its single ground plane. But these circuits are becoming increasingly important, especially in multi-layer printed circuit board construction. This program, an entry in the 1991 RF Design Awards, helps design stripline circuits.

The program STRIPLINE is a designer's tool for calculating dimensions and impedances of the following stripline (tri-plate strip transmission line) circuits:

- single and coupled stripline
- low-pass filters
- band-pass filters (coupled or branched)
- band-stop filters (branch type)
- hybrid couplers
- branch couplers

The program also computes parameters of the equivalent circuits of stripline discontinuities — open end, hole, gap, step in width, bend, parallel TEE junction and rectangular slot. Line losses can also be calculated.

The program operates on IBM PC/XT/AT/386 compatible computers with an EGA or Hercules card. Operating system DOS/MSDOS 3.1 or higher is required. A mouse driver is not supported. The source code was written in C and the program was compiled with Turbo C++ compiler v.1.01.

No installation is required. Before running the program you should only check the hardware specifications for the distribution copy. To run STRIPLINE type: STRIP, then press Enter.

Basic Program Usage

STRIPLINE is based on a system of pull-down menus. You can navigate among them using 'hot keys' — cursor keys and highlighted letters in the main menu. The Enter key chooses the highlighted option, Esc returns to the main menu, and used from there, quits the program. During calculations 'hot keys' are accessible only after all calculations are finished and final results are displayed. Comments describing what data is to be entered are given in the program. Some parameters have predefined values. Figure 1 is the screen display for the stripline lowpass filter option. The menu categories can be seen across the top of the display.

Main Menu Functions

Substrate: Allows you to input substrate parameters:

ε_r - relative dielectric permitivity
μ_r - relative magnetic permitivity
d - substrate plate height [mm]
t - metal film thickness [mm]

Stripline: ref. [1,2]

Analysis - analysis of single and coupled stripline
Synthesis - synthesis of single and coupled stripline
Losses - calculation of stripline losses
Open-end - calculates effective capacitance of open-ended stripline
Hole - calculates reactances of equivalent circuit of a symmetric hole in a center strip
Gap - calculates reactances of equivalent circuit of a gap in a center strip
Step in w. - calculates parameters of equivalent circuit of a symmetric step in width
Bend - calculates parameters of equivalent circuit of bend of a center strip
TEE - calculates parameters of

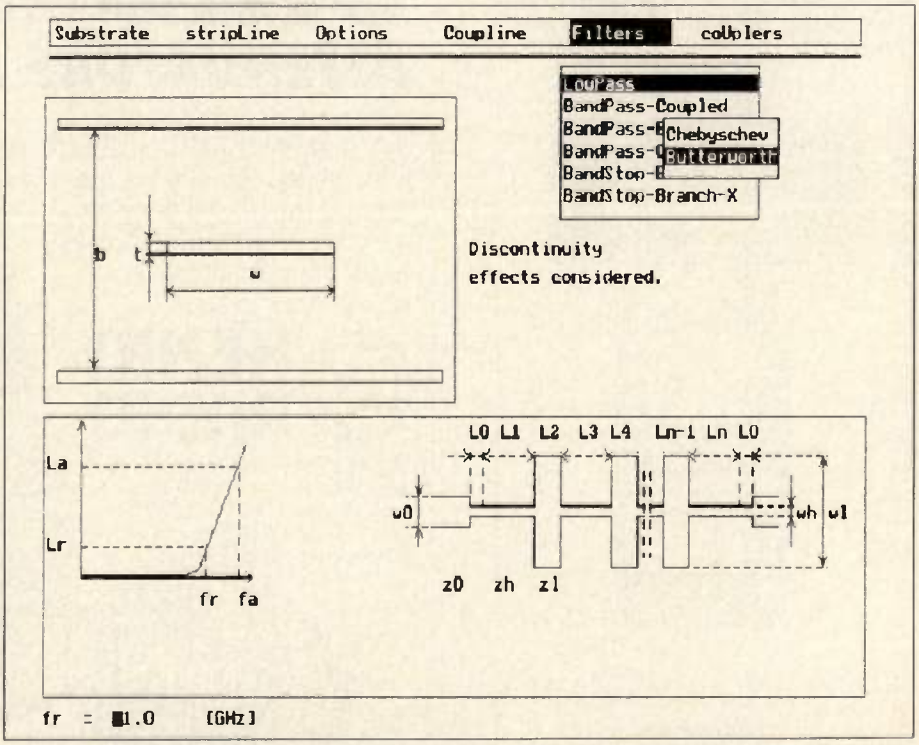

Figure 1. Screen display of the lowpass filter calculation option.

equivalent circuit of symmetric parallel TEE junction

Rect. slot - calculates reactances of equivalent circuit of symmetric rectangular slot in a strip

Options: lets you predefine limits for strip width and slot in a coupled lines

Filters: calculates dimensions for following filters [3] with either Chebyschev or Butterworth characteristics:

Low pass filter - on a stepped line
Band pass filter - coupled type
Band pass filter - branch type
Band stop filter - branch type
Letter X denotes that open-end discontinuity effects are considered.

Couplers: calculates dimensions for ring or hybrid couplers, [3].

This short note only describes the capabilities of the program. It is recommended that the user examine the references for understanding of the physical phenomena and mathematical analysis used for these computations.

Comments and technical support questions should be directed to the authors at the address given below.

This program is available on disk from the RF Design Software Service. See page 98 for ordering information. **RF**

References

1. H.M. Altschuler, A.A. Oliner, "Discontinuities in the Center Conductor of Symmetric Strip Transmission Line", *IRE Trans. MTT*, vol. MTT 8, 1960, p.328-339.
2. H. Howe Jr., *Stripline Circuit Design*, 1970 Artech House, Inc.
3. S. Rosloniec, *Algorithms for Computer-Aided Design of Linear Microwave Circuits*, 1990 Artech House, Inc. Boston, London.

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A Small, Low Cost BPSK Demodulator

By David M. Benzel
Lawrence Livermore National Laboratory

BPSK (Binary Phase Shift Keying) is a popular modulation system which is used because of its relative ease of implementation, its predictable behavior under various noise and propagation conditions, and its well known theory of operation. BPSK modulation of a carrier is accomplished by a number of simple means, where a reference phase can be used to represent a digital 1, and the complimentary phase can be used to represent a digital 0.

However, the demodulation process is not as simple; detecting a signal which varies in phase requires a-priori knowledge of the reference phase. A design can quickly evolve into large, complex and power hungry circuits involving precision delays, multiple phase locked loops, etc. In many applications this is not a problem and may in fact be necessary, especially when designing for optimum noise performance and lock-up time.

Sometimes, optimum noise performance and lock up time is not of the utmost importance. For hand-held or remote receiver applications, other factors can drive the design. The goals of this project were, therefore, three-fold: 1) reduce circuit size as much as possible, consistent with surface mount devices, 2) reduce circuit complexity and therefore, cost and 3) reduce power consumption for use in low power applications. These goals must be met while producing a circuit which performs adequately in the presence of noise, and which can achieve reasonable lock-up time.

Theory of Operation

A BPSK signal can be represented as:

$$f_{sig}(t) = A \cos(\omega_c + \theta_m) \qquad (1)$$

where ω_c is the carrier frequency and where $\theta_m = 0$ for a "1" bit and π for a "0" bit. To demodulate this BPSK signal, it can be multiplied by a reference oscillator signal:

$$f_{ref}(t) = B \cos(\omega_c + \theta_r) \qquad (2)$$

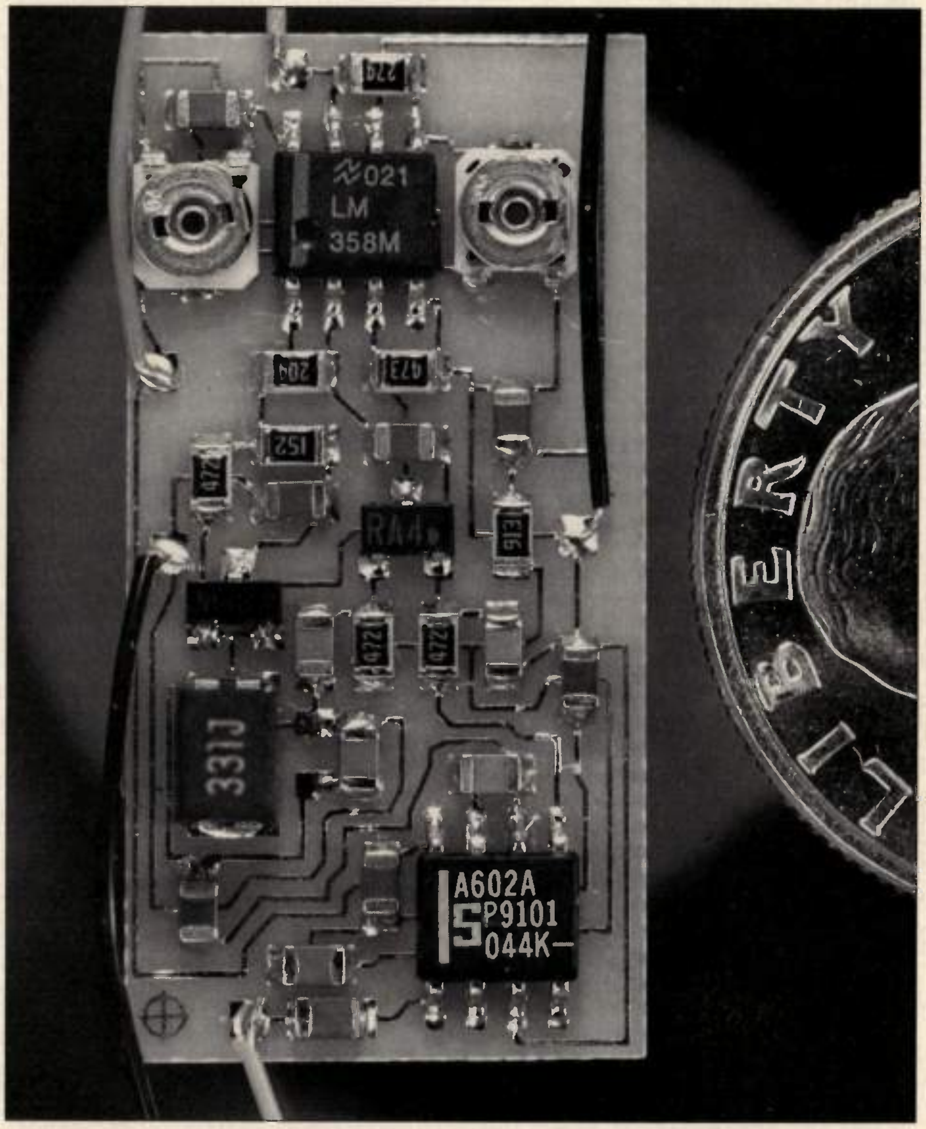
where θ_r is the constant phase difference between the reference oscillator signal and the original modulator phase. The result of this multiplication is:

$$V_o = \frac{AB}{2}[\cos\theta_r + \text{h.o.t.'s}] \qquad (3)$$

for a "1" bit

$$V_o = -\frac{AB}{2}[\cos\theta_r + \text{h.o.t.'s}] \qquad (4)$$

for a "0" bit



Completed circuit.

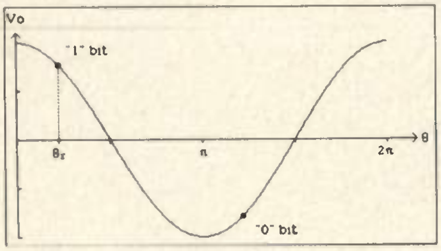


Figure 1. Transfer function of the phase demodulator.

Higher order terms are ignored, since we are only interested in the DC levels which represent the bits. Obviously, θ_r must not equal $\pi/2$ or $3\pi/2$ for there to be an output, and should ideally be 0 or π for maximum demodulator output voltage. The transfer function of this phase demodulator circuit is shown in Figure 1.

This is just fine for demodulation, when given a reference VCO which is already locked in frequency to the BPSK signal. But, how can the reference VCO be locked to this BPSK signal, when the phase is constantly changing with the data?

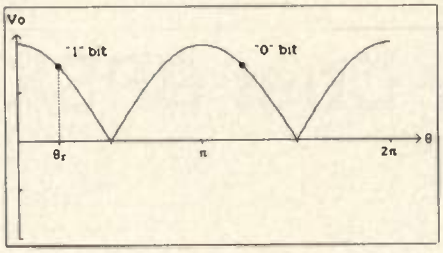


Figure 2. Transfer function of the reference phase recovery circuit.

As shown earlier, the output voltages of the multiplier differs only in sign, not in magnitude, depending on which bit is being demodulated. So, passing the output of the multiplier through an absolute value circuit, and then a low pass filter, produces an output whose value corresponds to θ_r only, to the nearest half cycle, and is represented by:

$$V_{error} = \frac{AB}{2} \cos \theta_r \qquad (5)$$

for a "1" or a "0" bit

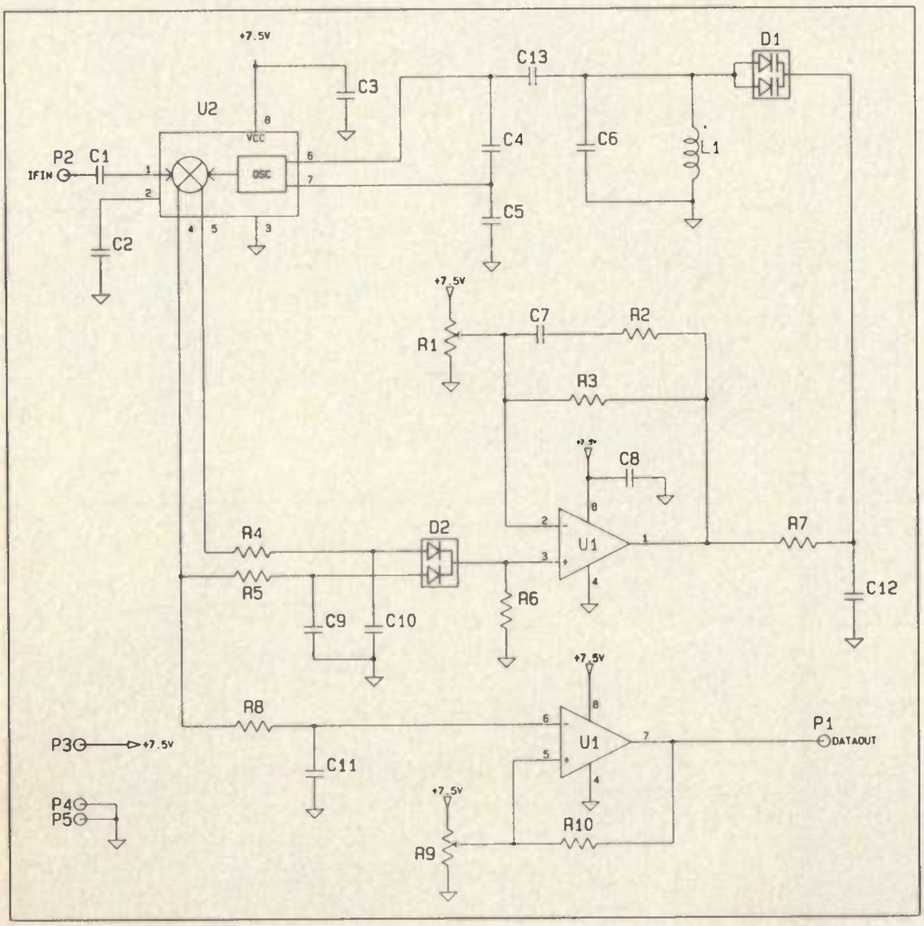


Figure 3. PLL schematic.

This is just the value needed for an error signal to control the reference VCO. The transfer function of this reference phase recovery circuit is shown in Figure 2.

The reference signal is therefore generated by a VCO which is phase locked to the incoming BPSK signal. With the exception of the absolute value circuit, this is just a standard PLL circuit. Note that the PLL will lock to either the "1" or the "0" phase, and that there is no way to tell which. This is usually resolved by sending polarity defining data headers, or by using polarity insensitive differential data encoding and decoding.

Data output, after filtering out the higher order terms, is seen directly at the output of the multiplier. Integrating the data over bit intervals improves performance in the presence of noise (1).

Prototype Circuit Design

To keep size and power consumption down, an NE602 is used as the heart of the PLL, as shown in the schematic, Figure 3. The NE602 is a low power IC which contains a Gilbert cell multiplier, which is used as a saturated phase detector, and an oscillator stage, which is in a vari-cap tuned, Colpitts VCO configuration. The IF and VCO frequency is 455 kHz.

Note that the NE602 has differential phase detector outputs. These differential signals are filtered to remove the $2\omega_c$ terms, and are passed through the dual diode chip, D2. The output of D2 is the desired phase detector absolute value signal, V_{error}. V_{error} is fed to the loop amplifier and loop filter.

Signal levels into the multiplier are intentionally set at a relatively high level. The IF input signal should be about 120 milli-Volts for saturated phase detector operation. An ideal saturated phase detector has a transfer function which is linear with phase, and is not dependant upon input signal level variations. The measured transfer function for this circuit is shown in Figure 4, and is fairly linear.

The design of the PLL is straightforward. The measured response of the phase detector, from Figure 4, is K_d = 1.36 Volts/πrad. Referring to Figure 4, the desired 20 kHz lock range is defined. The desired lock range is shifted toward the upper half of the phase detector transfer function in order to ensure an adequate output voltage difference between bits. After all, if $\theta_r = \pi/2$ or $3\pi/2$, the loop will be locked, but the bit output voltage will be 0!

C1 - 0.01μF	R1 - 100K pot	D1 - MMBV432
C2 - 0.01μF	R2 - 4.7K	D2 - DAN202KVRA
C3 - 0.1μF	R3 - 200K	U1 - LM358
C4 - 250pF	R4 - 4.7K	U2 - NE602
C5 - 1500pF	R5 - 4.7L	
C6 - see text	R6 - 47K	
C7 - 0.01μF	R7 - 1.5K	
C8 - 0.1μF	R8 - 91K	
C9 - 330pF	R9 - 100K pot	
C10 - 330pF	R10 - 270K	
C11 - 1000pF		
C12 - 1000pF		
C13 - 0.01μF		

Figure 3a. Final component values.

This 20 kHz lock range corresponds to a phase detector $\Delta V = 0.36$ Volts. The loop amplifier gain, A, is:

$$\frac{1 \text{ Volt}}{5 \text{ KHz}} \times \frac{20 \text{ KHz}}{.36 \text{ Volts}} = 11.1 \qquad (6)$$

The measured response of the VCO is $K_o = 2\pi(5 \times 10^3)$ rad/Volt. The loop filter time constant, τ_1, can now be determined from (2):

$$2\omega_c = 2\sqrt{\frac{K_v}{\tau_1}} \qquad (7)$$

$$K_v = K_d K_o A \qquad (8)$$

where ω_c now stands for 1/2 the capture range. The capture range, $2\omega_c$, is chosen to be 8 KHz. K_v is the loop gain as shown, and K_d, K_o, and A are as above. From this equation, τ_1 = 240 usec. The loop filter components for the prototype, a simple first order RC filter, were chosen accordingly.

Note that all other time constants in the loop, R7 and C12 for instance, are chosen to be much shorter than τ_1. This ensures that the dominant response of the loop filter will be the desired first order response. Unintended poles near τ_1 are an often overlooked source of loop instability.

The data output of the phase detector first passes through an integrator whose time constant is chosen to be less than 1/5 the bit width, giving the integrating capacitor time to charge to very nearly the ultimate bit voltage. The integrator is followed by a low power, single supply operational amplifier, the LM358. Hysteresis is added to reduce the risk of noise showing up in the output data near zero crossings. Also, hysteresis allows for a longer integration time

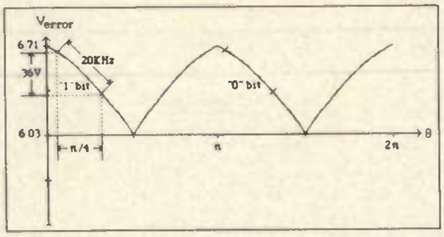


Figure 4. Measured transfer function.

before a bit decision is made, thereby reducing the bit error rate in the presence of noise. Data output is from 0.1 Volts to 6.3 Volts.

This prototype circuit, as designed above, and tested with a signal generator, performed with close to expected results. Deviation from predicted values, by chance, moved in the direction of larger lock and capture ranges. For this prototype circuit, actual capture range was measured at 10.4 kHz, and actual lock range was measured at 28.5 kHz. These values were valid for either a CW signal, or a 2400 Baud BPSK signal.

The Final Circuit

Of course, in the real world, the demodulator circuit will not get nice, ideal signals. Real signals will have their bandwidth modified by IF stages. Real signals will have noise.

Final component values, shown in Figure 3, were chosen with the demodulator circuit driven through the IF stage to which this circuit will be connected. Also, input signal levels were varied so that performance in the presence of noise could be optimized.

During final circuit test, it was found that the loop could loose lock during bit transitions, even with relatively high signal to noise ratios. This problem was caused by the limited bandwidth of the IF section, which caused amplitude and phase distortion of the BPSK signal at bit transition time. It is not surprising that the loop was upset at bit transition time, since the 240 usec time constant of the prototype loop filter is shorter than the bit width of 833 usec.

Increasing the time constant, τ_1, of the loop filter to the milli-second range prevented the loop from loosing lock during bit transitions. Lock range was unaffected since the lock range, $2\omega_c$, is equal to K_v, and is not a function of the loop filter time constant (3). However, capture range, as shown above, is a function of τ_1 and is reduced when τ_1 is increased.

The final circuit employs a first order, lead-lag RC filter (4). This type of filter, when implemented correctly, retains the characteristics of the long time constant filter, formed by R3 and C7, which is useful for loop stability during bit transitions and for noise immunity. However,

Quieting	5dB	8dB	10dB	15dB	20dB
Lock Range	3.7kHz	6.7kHz	7.2kHz	9.8kHz	14.0kHz
Capture Range	3.7kHz	6.7kHz	7.2kHz	9.7kHz	12.9kHz
Data	Noisy	Noisy	Usable	Good	Good

Figure 5. Measured lock and capture ranges.

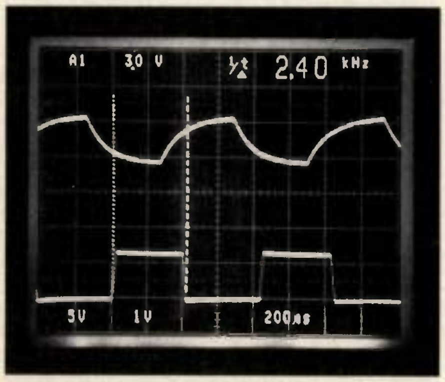


Figure 6. Typical data output for 20 dB receiver quieting.

the capture range is increased since the ultimate attenuation of the loop filter is limited by R2. It was found that a first order, lead-lag loop filter, with τ_1 = 2 msec and with τ_2 = 42 usec produced the best results.

Construction, Adjustment and Results

The final circuit is constructed on standard PC material. Since the frequency of operation is low, 455 kHz, no special circuit layout was required. Operation is stable, and component values, with the exceptions noted below, are not critical.

There are three components which must be adjusted for correct circuit operation. A VCO capacitor must be trimmed, and two offset pots must be adjusted.

The VCO center frequency is set by the following procedure. The D1, R7, C2 node is connected to a 2 Volt source. Then, C6 is chosen to produce a 455 kHz VCO output frequency. This sets the VCO to the IF frequency when the control voltage is in the middle of its range.

Trim pot R1 is used to set the offset voltage for the loop filter. It is most easily set by adjusting for phase lock at 455 kHz. The pot can then be tweaked to ensure lock over the correct range of IF frequencies, which should be at least ±10 kHz for a noiseless, full bandwidth input.

Figure 5 shows measured lock and capture ranges, and output data integrity, for the final circuit, when driven by a receiver, as a function of CW receiver quieting. Actual BER measurements were not yet made at the time of writing.

Trim pot R9 is used to set the offset voltage for the output data amplifier. With a square wave BPSK signal applied, R9 is adjust for symmetrical data output.

Figure 6 shows typical R8, C11 integrator output and LM358 data output for

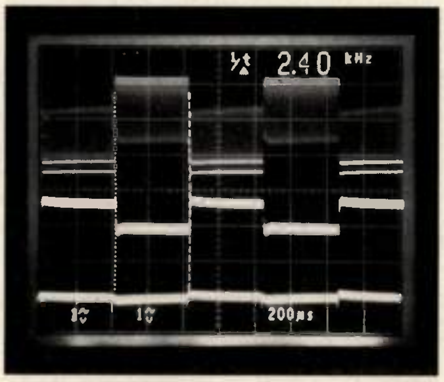


Figure 7. Output traces of circuit.

20 dB receiver quieting. Figure 7 has three traces, the upper trace is one output of the NE602 phase detector, the middle trace is the same signal after low pass filtering, while the bottom trace is the output of D2, the absolute value circuit.

Conclusion

The evolution of this circuit proceeded from the initial concept of a small, low cost BPSK demodulator, through the prototyping stage, where design tradeoffs were explored, the final circuit. The final circuit was optimized while being driven with noisy, real world signals. This circuit has met all design goals, and has been performing well in the system for which it was designed. ***RF***

References

1. M. Schwartz, *Information Transmission, Modulation, and Noise, a Unified Approach to Communications Systems*, McGraw-Hill, 1959, New York, NY, page 46.
2. Signetics Application Note AN178: Modeling the PLL, Signetics Linear Data Manual, Volume 1, 1989, USA, page 4-231.
3. Signetics Application Note AN178: Modeling the PLL, Signetics Linear Data Manual, Volume 1, 1989, USA, page 4-231.
4. F. M. Gardner, *Phaselock Techniques*, 2nd edition, John Wiley & Sons, 1979, New York, NY, page 23.

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RF product report

RF Signal Generators Go Digital

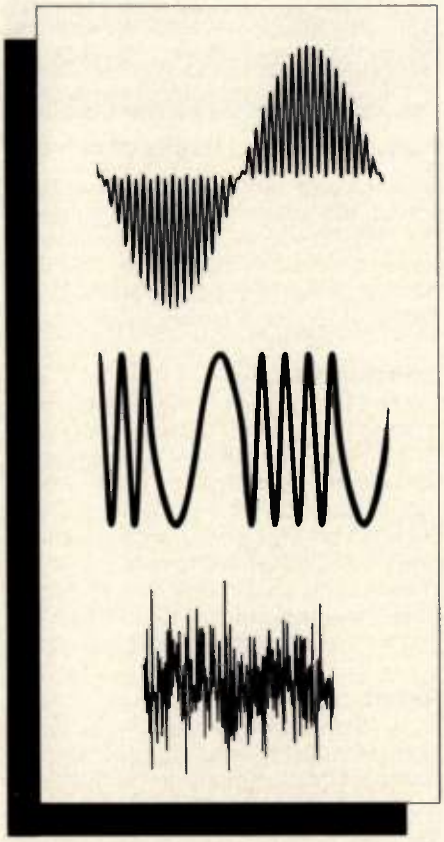
By Liane G. Pomfret
Associate Editor

RF signal generators, the primary piece of test equipment for engineers designing and testing radio receivers, have branched out into new areas and incorporated new technologies. The market focus is changing and is reflected in the use of more digital technologies. New applications, combined with a shifting market focus are keeping the RF signal generator market active.

While manufacturers are holding the line on cost, they're also improving the features available. For Wayne Kerr this means increasing frequency range and operator versatility in modulation and sweep facilities. Marconi Instruments now offers a family of low noise generators based on their standard performance generators. As a result, customers can buy a normally high priced product for mid range prices. The Fluke Philips Division of John Fluke Manufacturing offers a 50 MHz function generator based on the fact that there are not that many 50 MHz generators on the market. Each company has shaped its own approach, based on its analysis of customer needs.

The general state of the RF signal generator market mirrors the rest of the RF industry. For companies who have spread their products around and offer an extended product line, business is pretty good. Companies who offer only a limited line or sell almost exclusively to the military are feeling the squeeze. Overall, the market has held up well despite the gloom and doom predictions of forecasters. However, several manufacturers noted that they've seen a lot of "tire kicking" but very little in actual sales. Comments such as this are indicative of the overall soft test equipment market.

The need for traditional signal generators will remain strong for years to come. However, manufacturers are now having to include more in their products for the same price, such as IEEE-488 control capabilities and pre-programmed standard test configurations. Defense customers who are now "required to do more with less," are pushing for greater value in the generators they do buy.



In some cases, prices have dropped so much that signal generators are now considered commodity items. There are still the high performance, high priced models which continue to sell into their niche markets, but there are also models available for benchtop or production testing at a much more reasonable cost.

The military market, a large part of RF signal generator business, is in a decline, but the growing communications market is picking up the slack. Sales into the military market are still good, but manufacturers realize that they won't stay strong and have refocused their attention on telecommunications. With the increasing popularity of mobile and digital cellular and personal communications networks, manufacturers of mixed signal or pure digital signal generators are finding a very good market. By their nature and because increasing demand for spectrum space, these technologies have to use digital or mixed signal techniques, such as direct digital synthesis for fast frequency switching and fine resolution. Instruments with complex phase and amplitude modulation capabilities are required for new digital communications applications.

Commercial communications holds the largest market share at the moment for signal generators. Introductions of analog/digital or pure digital signal generators have been well received because of the number of new communications technologies that require digital testing. In addition to commercial communications there are other areas showing increased signal generator usage. Avionics, both military and commercial, are showing an increase. Programs such as the light helicopter and the advanced tactical fighter are using signal generators in the VXIbus format. Similarly, the Boeing 777 project is also using VXIbus signal generators.

While some of these applications have been around for a while, there are other, more unusual applications appearing. For instance, General Motors is putting together a VXIbus testing system to help verify that the microprocessors in their cars aren't affected by external radiation sources. Another unusual application calls for the testing of a submarine cable repeater. While this sounds out of the realm of applications for a signal generator, it involves many of the same procedures used in radio receiver testing.

The future for RF signal generators promises change. New technologies and new applications will force manufacturers to look at their products carefully and reevaluate their marketing strategies. Older, analog technology will continue to be the mainstay of engineers for a while to come, but digital and VXIbus technology will become strong competitors over the next few years. ***RF***

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RF software

Amplifier Program

SW.I.F.T. Enterprises has announced the latest release of the design tool ASP (Amplifier Simulation Program) Version 3.11 for interactive development of weak signal solid state amplifiers. Various auto or manual routines allow the developer to optimize for noise, gain, output VSWR while providing input/output matching circuits. ASP Version 3.11 is IBM compatible, requires DOS 3.2 or higher, 256K and EGA monitor. Price is $75 plus shipping.

SW.I.F.T.
INFO/CARD #210

Automatic Testing

AutoCAT™ 3.0, a software package for the automatic testing of electronic products, assemblies and components is now available. AutoCAT 3.0 interfaces directly with measuring instruments through IEEE-488 and RS-232 ports. The user can create any test program desired using the create mode and selecting the testing steps. Collected data can be graphed, printed and transferred to most spreadsheet or database programs. It requires an IBM 386 or compatible, 640K of memory, a 360K floppy drive, graphics card and IEEE-488 or RS-232 interface cards.

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Microstrip Filter Design

MSPCF is a new software tool for the design of parallel coupled line microstrip bandpass filters. Filters with 2 to 15 resonators can be designed using an accurate microstrip coupled line model which includes cover effects. The software can also write microstrip circuit files for the MMICAD™, Touchstone®, and Supercompact™ circuit analysis programs. Graphics and tabular outputs of the filter response with dissipative losses are included.

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INFO/CARD #208

Upgraded EDA Suite

EEsof's Version 3.5 software suite has been released. The upgrade has added new capabilities to OmniSys® and jOMEGA™. For OmniSys, the upgrades include a new set of noise sources and multi-signal excitation, providing realistic multi-path and signal plus noise analysis capability. jOMEGA now includes extensive circuit model libraries, including a 220-part silicon bipolar transistor library with parts from Avantek, HP, Motorola, NEC, Philips, Siemens and others. An air-core inductor set and a large-signal power MOSFET model are also included.

EEsof, Inc.
INFO/CARD #207

MMICAD Upgrade

MMICAD Version 5.0 is now available. The software can now run under Windows 3.0 as a DOS application, perform conditional analyses using logic flow statements, and import files from Touchstone. MMICAD is also equipped with oscillator design capabilities, intuitive user-defined model support that needs no programming and flexible Monte Carlo yield analysis.

Optotek Limited
INFO/CARD #206

Distance to Fault Software

A new fault analysis software can diagnose mismatches in long transmission line runs. The Distance-to-Fault software locates mismatches to within 0.1 percent of the total distance and displays return loss amplitude for a single mismatch to an accuracy of ±2.5 dB. The software runs on an MS-DOS computer, with Wiltron 5400A scalar measurement systems, or with 562 scalar network analyzers using Wiltron 6600B or 6700B Series signal sources. Frequency coverage is 1 MHz to 40 GHz, depending on the scalar analyzer model and source used.

Wiltron
INFO/CARD #205

RF literature

Cable Assembly Brochure

Penstock now has a fast fax brochure to help engineers design their own cable assembly. The four-page brochure details the custom services available in addition to custom cable assemblies.
Penstock, Inc.
INFO/CARD #204

Filter Products Catalog

Lark Engineering has released a 96-page filter products catalog. The catalog features RF and microwave filters covering the frequency range of 50 kHz to 18 GHz. Charts and graphs are presented showing the frequency ranges for standard and special filters of each type.
Lark Engineering Company
INFO/CARD #203

Test and Measurement Instrumentation

The 1992 Fluke and Philips test and measurement catalog is now available. The 440-page catalog breaks the product lines of the two companies into 17 major categories and includes an introduction section highlighting new products. Descriptions, photos, specifications, ordering information and customer support services are included as well as application literature, sales offices, technical centers, and distributors.
John Fluke Mfg. Co., Inc.
INFO/CARD #202

Power Amplifiers Catalog

A 15-page catalog presents data sheets, performance features, outline drawings, new product developments, and technical application notes on LCF's RF power amplifiers. Frequencies from 1 MHz to 2 GHz and power ranges from 1 W to 1 kW are covered.
LCF Enterprises
INFO/CARD #201

Capacitor and Inductor Catalog

Sprague-Goodman Electronics is now offering a four-page short form catalog of their complete line of trimmer capacitors and specialty inductors. Also featured is the company's line of insulated tuning tools. Catalog C-100A incorporates product features, specifications and photos, plus capacitor application information and a trimmer capacitor comparison chart.
Sprague-Goodman Electronics, Inc.
INFO/CARD #200

ADC Application Note

A 25-page application note is available from Datel titled, "Subranging ADCs." The note covers the architecture, design considerations, parameters, and testing of subranging analog to digital converters. The note is broken down into three parts: the architecture of the subranging ADC, dynamic specifications of subranging ADCs and a section titled "Classical tests are inadequate for modern high-speed converters."

Datel, Inc.
INFO/CARD #199

INMARSA Technical Brief

QUALCOMM has released a 12-page technical brief entitled Successful Integration of QUALCOMM VLSI Products in INMARSAT. The brief describes the application of frequency synthesis and forward error correction technology for the INMARSAT digital communication services. Topics addressed include: an introduction to the fundamentals, system performance and configurability, low power dissipation, full-duplex operation and cost effectiveness.

QUALCOMM, VLSI Products Div.
INFO/CARD #198

General Electronics

Newark Electronics has published a 1200-page catalog containing detailed, technical information and dimensions on over 100,000 products from 2500 manufacturers. Catalog 112 features twenty new manufacturers and more than 15,000 new products. Other features include an expanded 24-page, 4-color product section and an easy to follow "how to" section for using the catalog.

Newark Electronics
INFO/CARD #197

Spectrum Analysis Books

Two books are available from Joint Management Strategy. *Modern Spectrum Analyzer Theory and Applications* consists of 11 chapters, appendix, bibliography and index. It is a reference for practicing engineers and can be used as a text in a course on the frequency domain. *Modern Spectrum Analyzer Measurements* consists of eight chapters, bibliography and index. This volume is primarily a supplement and is intended to bring the reader up-to-date in the field of spectrum analysis.

JMS
INFO/CARD #196

Advertising Index

RF design

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INFO/CARD 92

PICOSECOND PULSE LABS.

BIAS TEES 10 kHz - 44 GHz

Model	Risetime	Low Freq. Cutoff	Insertion Loss	Voltage Max	Current Max
5520A	20 ps	DC	0.4 dB	15 V	30 mA
5530A	28 ps	25 kHz	0.2 dB	200 V	10 mA
5531	28 ps	750 kHz	0.2 dB	1500 V	20 mA
5532A	28 ps	150 kHz	0.2 dB	1000 V	20 mA
5535	32 ps	10 kHz	0.2 dB	50 V	10 mA
5540	8 ps	160 kHz	0.6 dB	50 V	100 mA
5550B	20 ps	100 kHz (<50 mA)	0.9 dB	50 V	500 mA
5555	20 ps	100 kHz	0.9 dB	50 V	500 mA
5575A	32 ps	10 kHz (<20 mA)	0.6 dB	50 V	500 mA
5580	32 ps	10 kHz	1.0 dB	50 V	1 Amp
5590	150 ps	10 kHz	0.1 dB	50 V	500 mA

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INFO/CARD 91

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INFO/CARD 93

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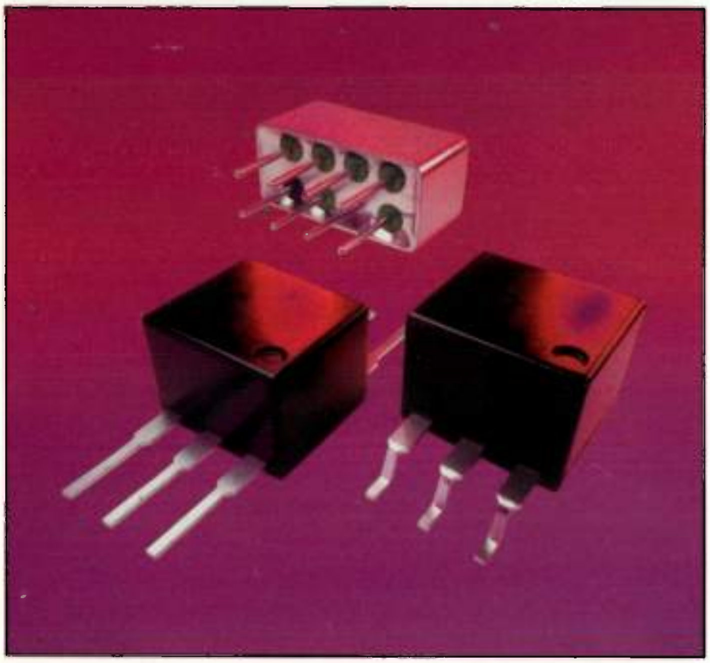
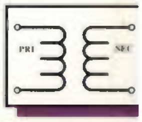
RF Transformers

3 kHz to 1000 MHz



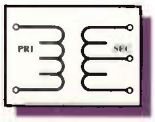
BROADBAND IMPEDANCE TRANSFORMATIO

ANZAC transformers offer low insertion loss, fast rise times f pulsed signals, and extremely wide bandwidth. They are offered in unbalanced to unbalanced, unbalanced to balanced, and balanced to balanced configurations, and hav impedance ratios from 1:1 to 16:1.



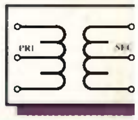
UNBALANCED/UNBALANCED

MODEL #	Ω Ratio	FREQUENCY MHz	INSERTION LOSS 3 dB MHz	2 dB MHz	1 dB MHz
ET1-1	1	.15 - 400	.15 - 400	.35 - 200	2 - 50
ET1-6	1	.01 - 150	.01 - 150	.02 - 100	.05 - 50
ET1.5-1	1.5	.1 - 300	.1 - 300	.2 - 150	.5 - 80
ET2.5-6	2.5	.01 - 100	.01 - 100	.02 - 50	.05 - 20
ET4-6	4	.02 - 200	.02 - 200	.05 - 150	.1 - 100
ET9-1	9	.15 - 200	.15 - 200	.3 - 150	2 - 40
ET16-1	16	.3 - 120	.3 - 120	.7 - 80	5 - 20
ETMO-1.5-1	1.5	.1 - 300	.1 - 300	.2 - 150	.5 - 8
ETMO-4-6	4	.02 - 200	.02 - 200	.05 - 150	.1 - 100



UNBALANCED/BALANCED

MODEL #	Ω Ratio	FREQUENCY MHz	INSERTION LOSS 3 dB MHz	2 dB MHz	1 dB MHz
ET1-1T	1	.05 - 200	.05 - 200	.08 - 150	.2 - 80
ET1-6T	1	.003 - 300	.003 - 300	.01 - 150	.02 - 50
ET2-1T	2	.07 - 200	.07 - 200	.1 - 100	.5 - 50
ET2.5-6T	2.5	.01 - 100	.01 - 100	.02 - 50	.5 - 20
ET3-1T	3	.05 - 250	.05 - 250	.1 - 200	.5 - 70
ET4-1	4	.2 - 350	.2 - 350	.35 - 300	2 - 100
ET4-6T	4	.02 - 250	.02 - 250	.05 - 150	.1 - 100
ET5-1T	5	.03 - 300	.03 - 300	.6 - 200	5 - 100
ET8-1T	8	.03 - 140	.03 - 140	.10 - 90	1 - 60
ET13-1T	13	.3 - 120	.3 - 120	.7 - 80	5 - 20
ET16-6T	16	.03 - 75	.03 - 75	.06 - 30	.1 - 20
ETMO-1-1T	1	.05 - 200	.05 - 200	.08 - 150	.2 - 80
ETMO-5-1T	5	.3 - 300	.3 - 300	.6 - 200	5 - 100



BALANCED/BALANCED

MODEL #	Ω Ratio	FREQUENCY MHz	INSERTION LOSS 3 dB MHz	2 dB MHz	1 dB MHz
ETT1-6	1	.004 - 500	.004 - 500	.02 - 200	.1 - 50
ETT2.5-6	2.5	.01 - 50	.01 - 50	.025 - 25	.05 - 10
ETT4-1	3	.05 - 200	.05 - 200	.2 - 50	1 - 30

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