rf design

engineering principles and practices

1978–1988 10th Anniversary

September 1988

RFI Susceptibility Test System Spans Five Decades

Featured Technology — Electromagnetics Modeling

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The **A-8000** Spectrum Analyzer. A step beyond the A-7550.

Now 2.6 GHz frequency coverage!

Fully synthesized. Tracking generator.* Quasi-peak detector.* Truly portable. And again, an exceptional value!

The new A-8000, quite simply put, is our response to industry's demand for a higher frequency, yet still economical, Spectrum Analyzer.

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The commonality of the A-8000 and A-7550 offer you many benefits. Two powerful microprocessors, menu driven display modes and single function keyboard entry aid the user in the operation of all analyzer functions. To further increase the operational simplicity of the A-8000 and A-7550, the microprocessor systems automatically select and optimize the analyzer's bandwidth, sweep rate and center frequency display resolution, with manual override if desired.

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10200 West York Street / Wichita, Kansas 67215-8935 U.S.A.
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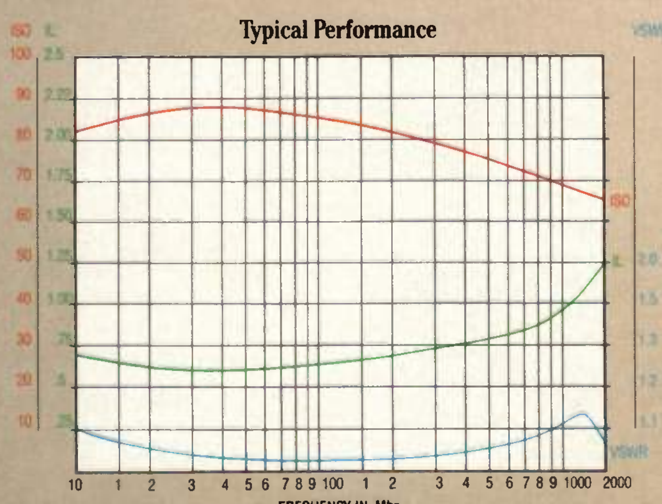
INFO/CARD 90

DAICO MIL-TOUGH

Miniature Connectorized Switches

Typical Performance



Typical Characteristics

Frequency:	20 - 2000MHz	
Isolation:	75dB	20 - 500MHz
	70dB	500 - 1000MHz
	60dB	1000 - 2000MHz
Insertion Loss:	0.9dB	20 - 1000MHz
	1.3dB	1000 - 2000MHz
DC Power:	12mA at +5VDC	

DAICO miniature connectorized switches are hermetically sealed packages designed to survive the toughest military environments. Removable SMA connectors make for quick field replacement.

These switches have high isolation while maintaining low insertion loss, low DC current, and broad bandwidth.

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2139 East Del Amo Blvd Compton, CA 90220
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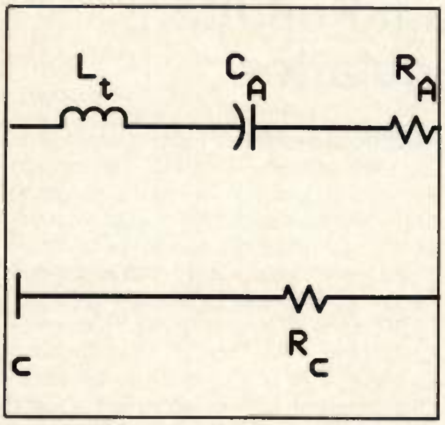
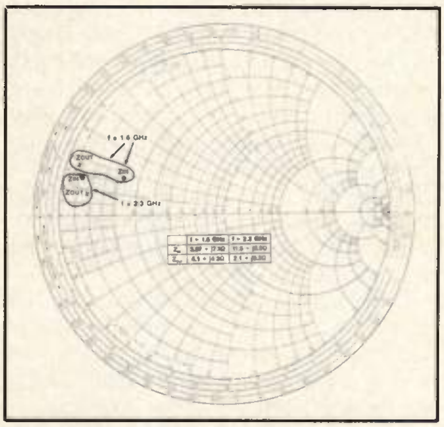
INFO/CARD 3

rf design

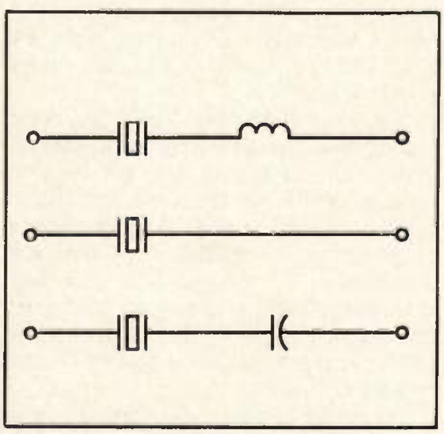
September 1988



Page 24 — Plate Antenna Couplers



Page 41 — 20-Watt Power Amplifier



Page 48 — Quartz Crystals

Cover Story

20 **A Five-Decade System for Testing RFI Susceptibility**

Two amplifiers and two antennas are all that is needed to cover 10 kHz-1 GHz RFI susceptibility testing, along with fiber-optic coupled field monitor probes. Together with the user's signal generator and small shielded room, the system will handle perhaps 90 percent of testing needs. — *Donald R. Shepherd*

Featured Technology

24 **Plate Antenna Couplers**

This article reports on measurements and radio wave behavior models the author has developed for short range communications, primarily for industrial control and security applications. — *Dr. Koryu Ishii*

32 **RFI/EMC Corner — Software for EMC Analysis**

This column presents a description and review of EMC design software from Interference Control Technologies, covering radiated emissions and RFI susceptibility performance of equipment in shielded enclosures. — *Gary A. Breed*

41 **A 20-Watt L-Band Class A Power Amplifier**

Presented here is the design of a linear power amplifier utilizing the NE345L-20B GaAs FET. Features of note include a 13.5-volt power supply, 20-watt power output, and 11 dB gain. — *Katsunori Miyagaki*

48 **Quartz Crystals and Aperiodic Oscillators in RF Systems — Part II**

A tutorial on oscillator configurations is the focus of this article. Last month, Part I covered crystal specifications. Part II emphasizes crystal oscillator applications. — *Dr. I.J. Dilworth*

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rf editorial

Living With Spectrum Pollution: A Case for More Regulation

By Gary A. Breed
Editor

Electromagnetic waves are the foundation of RF, a technology that has served mankind well. Those waves still command a high level of importance—there is no end in sight for growth in new applications and existing uses. However, these uses, plus the RF byproducts of other electronics, have combined to create an "electronic smog" within which our RF devices must operate.

RF professionals, the military and commercial customers, are usually able to obtain the performance they need by specifying RFI standards. There are occasional problems, like Army helicopters which malfunction near high power broadcast transmitters, but most RFI problems are solved out of need for reliability. Unfortunately, this isn't true for consumer electronics, where the customers are not RF professionals.

Right now, the individual consumer is in a difficult spot—there are few effective standards, and no clear means of dealing with RFI problems when they occur. Yet, the RF environment is getting more polluted every day. Suburban developments are being built near broadcast transmitter sites that once were rural. Cellular telephone, mobile radio, amateur radio, aviation and other radio services continue to grow and add to ambient RF levels. As a result, no consumer can be certain that his latest electronic gadget will work when it is installed at home. The U.S. electronics industry claims that RFI is a problem to only 1 per cent of people. I suggest 3 per cent might be more realistic, but even at 1 per cent there will be two-and-a-half million people with RFI problems!

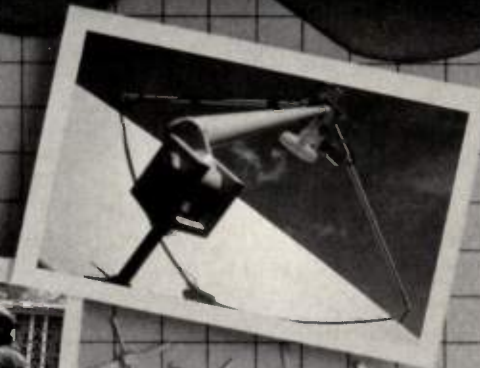
RFI to or from consumer electronics is nothing new, but it is a growing problem and won't go away by itself. One reason for my concern is the Federal government's trend toward deregulation (and non-regulation). In 1982, amendments to the Communications Act gave the FCC authority to regulate RFI susceptibility, but the Commission has chosen not to implement such rules in favor of voluntary standards which are limited at best, ineffective at worst. Part 15 of the FCC Rules may be adequate for most unintentional sources of RFI, but the FCC is actually considering relaxing requirements for low power unlicensed transmitters operating under this section.

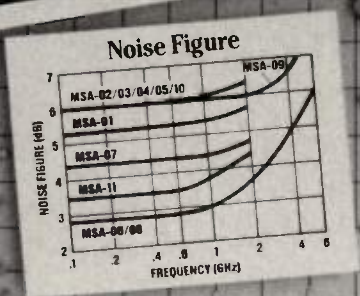
Deregulation of industries such as telephone service has brought many new products to the market, but it has removed any clear line of responsibility for dealing with RFI. For example, a consumer experiencing telephone interference may have to deal with several equipment manufacturers and the radio facility involved, not just "the phone company." Of course, each will assure the consumer that its equipment is not at fault!

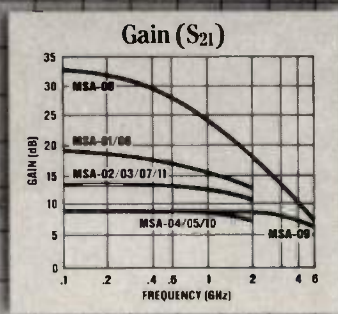
Voluntary standards and an open marketplace may be interesting to sociologists and economists, but the laws of Nature aren't under their influence. Electromagnetic waves are not subject to government regulations. They will continue to be created and detected, both intentionally and not, by electronic circuits of all types. The only controls available are regulations placed on the makers of those circuits.

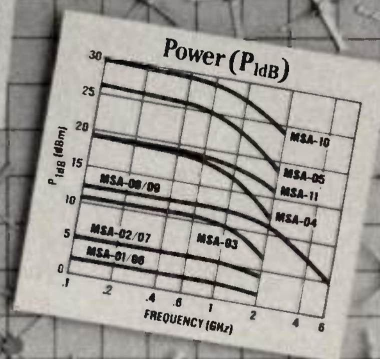
I'm no fan of big government, but it is any government's duty to keep watch over those things that affect every one of its citizens. The electromagnetic spectrum is one of those things, just like the rest of our environment. The EPA is fighting an uphill battle to remedy years of air, water and land pollution. There is still time for the FCC to implement realistic regulations that will keep the RF environment clean and healthy.

Silicon MMICs Any Way You Want!









Avantek Offers the Widest Selection of Wideband Silicon MMIC Amplifiers

Now the trade off between performance, package and price is easier. Avantek has a package/die combination that offers the ideal solution to your overall system performance and cost goals. Our MODAMP™ series, DC to 6 GHz silicon MMIC wideband amplifiers, includes eleven different amplifier die types and nine package options. A total of more than 70 different models. These MMIC amplifiers are available with a wide spectrum of performance options to satisfy nearly every design need.... Minimum noise figures as low as 2.8 dB, gains as high as 33 dB, and P_{1dB} as high as 29 dBm.

Packages — Low Cost to High Rel

The MMIC performance you need is available in a range of packages to fit your overall system design and cost needs. Avantek's new Package "86" (85 mil surface mount plastic package) combines premium performance with low cost. Both Package "86" and the industry standard SOT-143, are available on tape and reel, making them ideal for low cost, high volume applications. For high reliability applications, such as space or military environments, we offer MODAMP MMICs in a range of hermetic metal/ceramic packages. MODAMP packages include:

- SOT-143 Plastic
- 4-Pac Plastic
- 85-Mil Plastic
- 85-Mil Plastic Surface Mount
- micro-X Stripline
- 70 Mil Hermetic
- 100 Mil Hermetic
- 200 Mil BeO
- 230 Mil Flange

Available in Quantity for Volume Applications

Avantek presently produces more than 1,000,000 MMICs per month. So you can be assured the MMICs you need will be available to support your volume production programs. And, all MODAMP MMICs are in stock at your local Avantek distributor. For additional information, or the name and address of your local distributor, contact the regional sales office nearest you.

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INFO/CARD 5

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"They must have used a very high performance signal generator to get quality like this!"

The 'theatrephone' entertaining guests of a grand hotel in Paris. Late 19th century. The Bettmann Archive

"How could they afford it?"

To make top quality receivers, you need top-dollar signal generators. Right? Wrong. The new HP 8657A has shattered all the old ideas about the cost of high performance signal generation.

The HP 8657A Synthesized Signal Generator.

For just $7900,* you can make the measurements you need to design, build and test better two-way radios, cellular phones, pagers and any other receivers.

That low price buys you great spectral purity from 100 kHZ to 1040 MHz. Phase noise is < −130 dBc/Hz @ 500 MHz, 20 kHz (< −136 dBc/Hz typically). Residual FM <2 Hz RMS (0.3 to 3 kHz) @ 500 MHz (<1 Hz RMS typically). Spurious as good as < −72 dBc.

Another breakthrough keeps our signal generator going strong, even in high-use situations. We invented an electronic attenuator. With no moving parts, it's virtually failure-free. Even after a billion cycles, operating at temperatures from −50° to +95°C, and 99% humidity.

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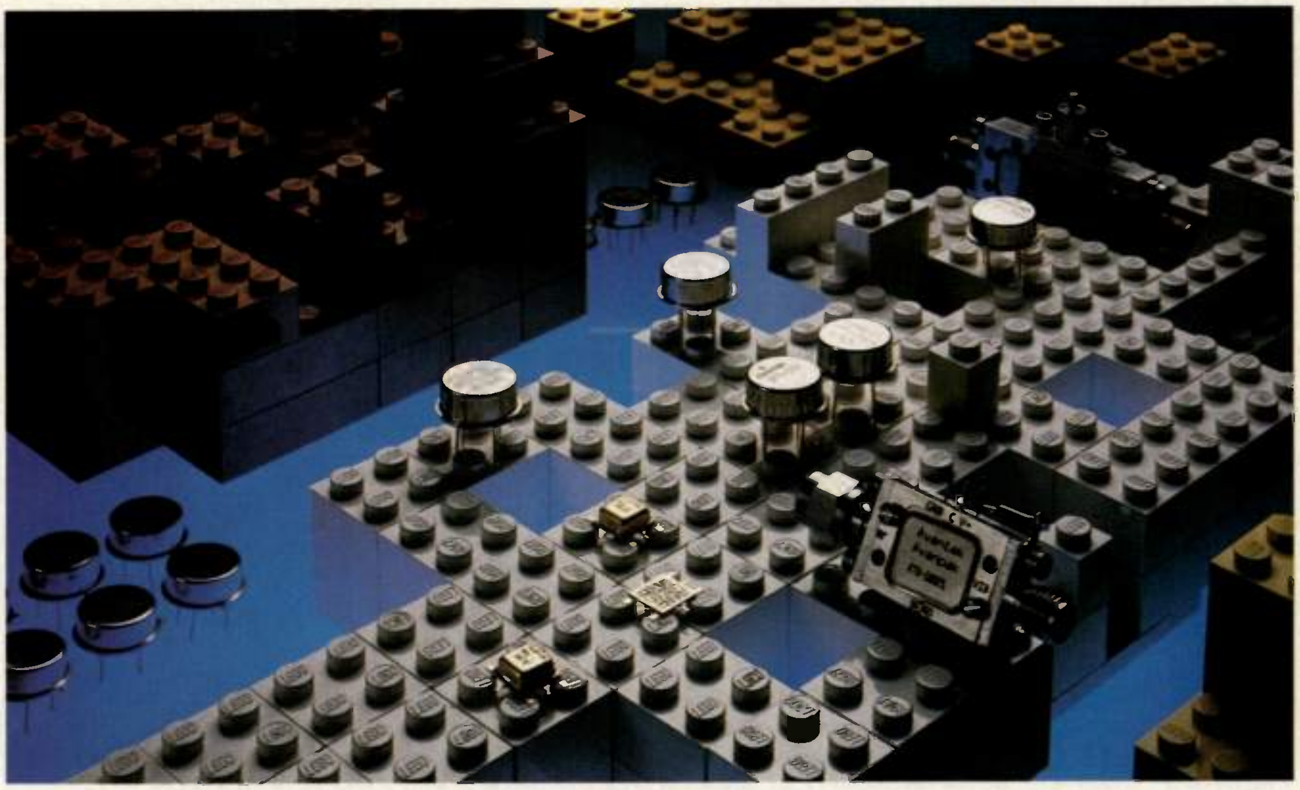
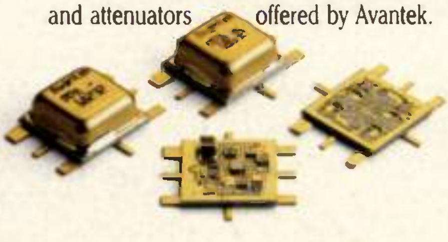
Components. . . Off-



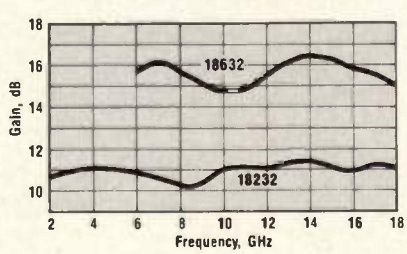
Avantek, the leading manufacturer of high-performance modular microwave components, is your single source for all your IF component needs. Easy-to-use, modular "building blocks" offer improved system performance, reduced development time and increased component density. Avantek modular components utilize proven thin-film circuitry and advanced packaging technology for unmatched performance, reliability and low cost. These wideband PlanarPak™ gain blocks, high power and high efficiency TO-8 amplifiers, ultra low noise cascadable amplifiers and detectors are new additions to the over 800 amplifiers, oscillators, mixers, switches, limiters, detectors and attenuators offered by Avantek.



New, Affordable Surface Mount Gain Blocks Cover 6–18 & 2–18 GHz

Avantek has just made the 6–18 and 2–18 GHz gain blocks that you need more affordable and available. These .25 inch square amplifiers are ideal for applications where wideband coverage, gain and board density are critical. The PPA-18632 MIC GaAs FET amplifier is the newest addition to Avantek's PlanarPak family of surface mount microwave components. It provides outstanding performance; 14 dB gain, 5.5 dB noise figure, and +15 dBm output power (P_{1dB}) with only 50 mA current draw. The PPA-18232 MMIC amplifier utilizes two Avantek 2–18 GHz GaAs monolithic distributed amplifiers for ultra-broadband performance. . . 11 dB gain and P_{1dB} of +13 dBm.

PPA-18632 & 18232
Gain vs Frequency



INFO/CARD 74

New, High Power Cascadable TO-8 Amplifiers Cover 10–2000 MHz

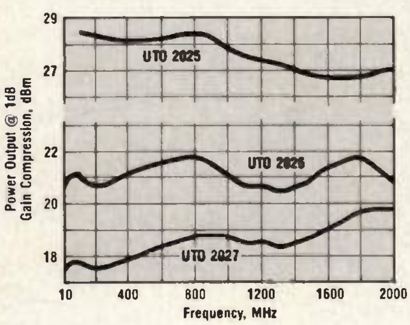
Avantek's three new models in the UTO series of low cost, hermetic TO-8 amplifiers combine wide bandwidth, high power output and low noise figure. The new UTO-2025 has P_{1dB} of +27 dBm with a low 3 dB noise figure and gain of 11 dB. The UTO-2026 and UTO-2027 both cover the 10–2000 MHz range with 15 dB gain.

ding Block" IF
the-Shelf Solutions

UTO-2026 has a noise figure of 6.5 dB with P_{1dB} of +20.5 dBm. UTO-2027 offers 6.3 dB noise figure with P_{1dB} of +17.5 dBm. UTO-series amplifiers offer optimized performance in applications as single or cascaded gain blocks. More than 90 different models are available with a variety of frequency, gain, power and noise level options.

INFO/CARD 75

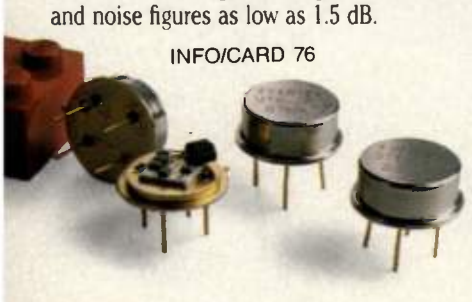
UTO-2025, 2026 and 2027 Power Vs Frequency



New High Efficiency 5–1000 MHz UTOs

Avantek's new +5 volt UTO amplifiers feature power levels up to +8 dBm (typ) with extremely low noise performance and only 90 milliwatts of power dissipation. These TO-8 amplifiers are ideal for portable radios and other high density, low power equipment applications. UTO-552 has an outstanding noise figure of only 2.9 dB (typ) with gain of 15 dB (typ). Power output is +9.5 dBm over the 5–500 MHz range. UTO-1052 covers 5–1000 MHz with 3.7 dB noise figure, 14.3 dB gain and P_{1dB} of +9.0 dBm. Additional high efficiency UTO models offer gains as high as 29.5 dB and noise figures as low as 1.5 dB.

INFO/CARD 76



New Ultra Low Noise Cascaded Amplifiers—10–2000 MHz

Avantek offers more than 25 ACT-series cascaded amplifiers designed for applications where small size, premium performance and microstrip compatibility are required. ACT amplifiers consist of one, two or three amplifier stages cascaded in an Avanpak™ miniature flatpack. Two new additions, ACT-120923 and ACT-141223 are narrowband models designed for RF and IF front-end applications where low noise and high gain are critical.

Narrowband ACT Performance

Model	Frequency (MHz)	Gain (dB, typ)	Noise Figure (dB, typ)	P_{1dB} (dBm, typ)
ACT-120923	950–1250	37.0	1.2	+16.0
ACT-141223	1200–1400	35.0	1.5	+13.0

INFO/CARD 77

New Programmable Power Level Detectors 0.1 to 18 GHz

Avantek's new one-bit digital level detectors allow easy, accurate microwave power level measurement. These versatile devices are typically used for built-in subsystem test or in-band signal detection. Internally biased Schottky diodes, temperature compensated amplification and easily programmable threshold levels provide easy to use, accurate solution for system designers.

Threshold Detectors—TTL Output

Model	Frequency (GHz)	Threshold Range (dBm, typ)	Supply Current (mA, typ)	Package
ATD-18021	.1 to 18.0	−30 to −10	2	Avanpak
PPD-6002	.1 to 6.0	−10 to +10	12	PlanarPak
UTD-2004	.01 to 2.0	−30 to −10	2	TO-8

INFO/CARD 78

Distributor Direct Availability

These new modular IF products and the entire line of Avantek .01 to 18 GHz components are in stock at your local Avantek distributor.

MMIC Technology Leadership

AVANTEK

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rf letters

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

RF Corrections

Editor:

In the July, 1988 issue of *RF Design*, the article titled "Shielding — An Overview" contained some errors. The article infers that spray coatings require a thickness of 1 cm to produce effective shielding. This is incorrect as only 1 to 2 mm will achieve 40 to 60 dB of isolation. The article further states that these coatings are insufficient below 1 MHz. This is also an error. It is true that these coating are not recommended for low impedance shielding such as 60 hertz power transformers. These are very effective at frequencies above 10 kHz. Also, these coatings are often supplied as non-toxic water base paints, which allow application without complications from the EPA or OSHA.

Wayne L. Gindrup
Carolina Solvents, Inc.
Hickory, N.C.

A Coplaner Rectification

Editor:

A few editing gremlins managed to hitch a ride in my article, "A Coplanar Waveguide Primer", published in the July 1988 issue.

1. In equation 14 on page 54, the term "w(0.7t)" should read "w/(0.7t)".
2. Guideline 2 on page 56 should read "2. Use as thin of a substrate as practical for the application under consideration. The dispersion and higher-order mode cut-off frequencies decrease with increasing substrate height."
3. Guideline 5 on the same page should read "For enclosed CPW, it has been shown through numerical field calculations that the effect of the enclosure cover on Z_0 calculations may be neglected for cover heights in excess of 2.5 ns, for $0.5 \leqslant k \leqslant 0.9$ and $0.75 \leqslant h/s \leqslant 3.0$ (ref. 8). The proximity of sidewalls to the CPW will have no effect on Z_0 if the sidewall-to-sidewall dimensions is at least $1.75(s + 2w)$."

Finally, if readers desire to contact me, they should know that the gremlins even got my phone number. My correct number is (602) 244-3903.

Pete Bachert
Motorola Semiconductor
Phoenix, AZ

rf courses

UCLA Extension

Radiation Effects on Electronic Systems
October 10-14, 1988, Los Angeles, CA

Superconducting Detectors
November 1-3, 1988, Los Angeles, CA

Kalman Filtering II
November 28-December 2, Los Angeles, CA

Microwave Circuit Design I
November 28-December 2, 1988, Los Angeles, CA

Information: UCLA Extension, P.O. Box 24901, Los Angeles, CA. Tel: (213) 825-1047

The George Washington University

Introduction to Digital and Analog Modulation
October 3-7, 1988, Washington, DC

Satellite Communications Engineering Priciples
October 5-7, 1988, Washington, DC

Modern Communications and Signal Processing
October 10-14, 1988, Washington, DC

New HF Communications Technology: Advanced Techniques
October 17-21, 1988, San Diego, CA

Radiowave Propagation for Communications System Engineering
November 7-11, 1988, Orlando, FL

Information: Shirley Forlenzo, Continuing Education Program, George Washington University, Washington, DC 20052; Tel:(800) 424-9773, (202) 994- 8530

TriQuint Semiconductor

Digital/Microwave Multi-Project Chip GaAs IC Design
October 9-14, 1988, Portland, OR

Information: Leslie Kasinger, TriQuint Semiconductor, P.O. Box 4935, Group 700, Beaverton, OR 97076. Tel: (503) 644-3535 ext. 4081

R and B Enterprises

EMI/EMC in the Automotive System
October 3-5, 1988, Dearborn, MI

TEMPEST: A Detailed Design Course
October 3-7, 1988, Philadelphia, PA
November 14-18, 1988, Philadelphia, PA

Real Life Solutions to EMI Problems
October 4-6, 1988, Washington, DC

Architectural Shielding
October 11-12, 1988, Philadelphia, PA

Grounding, Bonding & Shielding
October 13-14, 1988, Philadelphia, PA
October 31-November 1, 1988, Washington, DC
November 21-22, 1988, Orlando, FL

TEMPEST: Documentation and Reports
October 26-28, 1988, Philadelphia, PA

Worst Case Circuit Analysis
October 31-November 2, 1988, Philadelphia, PA

Information: Grant R. Brown, R & B Enterprises, West Conshohocken, PA 19428. Tel: (215) 825-1960

EEsof, Inc.

Introduction to Microwave Computer Aided Engineering
November 7-8, 1988, Westlake Village, CA

Introduction to Microwave Computer Aided Layout and Design
November 9, 1988, Westlake Village, CA

Advanced CAE
November 14-15, 1988, Westlake Village, CA

Advanced Microwave Computer Aided Layout and Design
November 16, 1988, Westlake Village, CA

Nonlinear Circuit Design
November 21-22, 1988, Westlake Village, CA

Information: Sandra Scoredos, EEsof, Inc., 5795 Lindero Canyon Road, Westlake Village, CA 91362. Tel: (818) 991-7530

Interference Control Technologies, Inc

Grounding and Shielding
October 24-28, Atlanta, GA

Information: Penny Caran, Registrar, Interference Control Technologies, Inc., State Route 625, P.O. Box D, Gainsville, VA 22056. Tel:(703) 347- 0030

Integrated Computer Systems

Advanced C Programming: Hands-On Workshop
October 25-28, 1988, Boston, MA
November 15-18, 1988, San Francisco, CA

Digital Signal Processing: Techniques and Applications
October 4-7, 1988, Boston, MA
October 4-7, 1988, Toronto, Canada
October 18-21, 1988, Los Angeles, CA
November 1-4, 1988, Washington, DC
November 15-18, 1988, San Francisco, CA
November 29-December 2, 1988, San Diego, CA

Information: John Valenti, Integrated Computer Systems, 5800 Hannum Avenue, P.O. Box 3614, Culver City, CA 90321-3614; Tel:(800) 421-8166, (213) 417-8888

rf calendar

September 12-16, 1988
10th Annual Antenna Measurements Techniques Association Meeting
Atlanta Hilton and Tower Hotel
Information: Becky Clark, 1988 AMTA Symposium, c/o Scientific-Atlanta, Inc., Mail Station ATL 28-I, P.O. Box 105027, Atlanta, GA 30348.

1988 RF/Microwave Symposia
Hewlett-Packard Company
September 21, 1988, Indianapolis, IN
October 4,5, 1988, Baltimore, MD
October 11,12, 1988, Boston, MA
October 17,18, 1988, Ottawa, Canada
Information: Contact local HP sales offices listed in the white pages of the telephone book.

September 14-15, 1988
Mountain States Electronic Expo
Denver Merchandise Mart, Denver, CO
Information: Dick Porter, Midland Exposition Group, 4501 Wadsworth Blvd., Wheat Ridge, CO 80033. Tel: (303) 424-9024

September 30, 1988
5th David Sarnoff Symposium on New Trends in Microwave, Milli-meter Wave and Photonic Device Technologies
David Sarnoff Research Center, Princeton, NJ
Information: Judy Hohman, David Sarnoff Research Center, CN5300, Princeton, NJ 08543-5300. Tel: (609) 734-2037

October 4-6, 1988
Northcon '88
Seattle Center Colliseum, Seattle, WA
Information: Electronic Conventions Management, 8110 Airport Boulevard, Los Angeles, CA. Tel: (213) 772-2965

October 9-11, 1988
ASYST '88
University of Rochester, Rochester, NY
Information: Kristen Bartles, Asyst Software Technologies, Inc., 100 Corporate Woods, Rochester, NY 14623. Tel: (716) 272-0070

October 23-26, 1988
MILCOM '88
San Diego Marriott, San Diego, CA
Information: Timothy L. Dolan, MILCOM '88, TRW Space Defense Sector, P.O. Box 2568, Redondo Beach, CA 90278. Tel: (213) 812-4722

October 25-27, 1988
RF Expo East 88
Philadelphia Civic Center, Philadelphia, PA
Information: Linda Fortunato, Cardiff Publishing, 6300 S.Syracuse Way, Suite 650, Englewood, CO 80110. Tel: (303) 220-0600; (800) 525-9154

October 27, 1988
3rd Annual EMC Event
Minneapolis Hilton Inn, Minneapolis, MN
Information: Diane Swenson, Tel: (612) 462-7001

November 8-12, 1988
Electronica '88
Munich Trade Fair Centre, Munich, W. Germany
Information: Gerald Kallman, Kallman Associates, 5 Maple Ct., Ridgewood, NJ 07450-4431. Tel: (201) 652-7070

Refurbished Satellite to Return to Space

A communications satellite retrieved from space by astronauts during a 1984 recovery operation is being readied for a historic return to space. The Palapa-B2 satellite is being refurbished by its original manufacturer, Hughes Aircraft Company, for Sattel Technologies, Inc. of Van Nuys, Calif., under a $14 million contract. Sattel purchased the satellite from insurance underwriters in 1986 and renamed it Palapa-B2R.

When it is launched on a McDonnell Douglas Delta rocket in March 1990, the spacecraft will become the first satellite to be recovered in space, brought back to earth for repairs and returned to orbit. In February 1984, the Palapa-B2 and a similar satellite, Western Union's Westar VI, were launched on NASA Space mission 41-B. After being released from the shuttle, the satellites' attached PAM (payload assist module) rocket engines shut down prematurely, stranding the satellites in orbit where they were useless to their owners. Consequently, neither satellite was activated.

During the following months, Hughes controllers used the satellites' remaining fuel to ease the spacecraft into lower orbits that could be reached by the space shuttle. In November 1984, the crew of shuttle mission 51-A spent two days capturing the wayward satellites and securing them in the shuttle cargo bay for the return trip home. While both satellites weathered the experience well, the space environment near earth and the rescue mission itself took their toll. Numerous micrometeorite hits were detected on the satellite's covering of solar cells, and some thermal surfaces were eroded by atomic oxygen near earth. Orbital maneuvers pumped a lifetime of fuel through the overworked thrusters and drained the batteries. Some parts such as the telemetry and command antenna were damaged during the recovery and will be replaced, making Palapa-B2R nearly the same satellite it was four years ago.

A consortium of space insurance underwriters, represented primarily by Merrett Syndicates, Ltd. of London (Westar VI and Palapa-B) and International Technology Underwriters Inc. of Washington, D.C., (Palapa-B), acquired the two satellites and contracted Hughes and NASA to mount the first space salvage effort. Perumtel, Indonesia's telecommunications agency and original owner of the Palapa-B2 has agreed to repurchase the refurbished satellite and associated services such as launch and insurance from Sattel. The project is expected to take about 16 months.

New Company Creates RF Software for the Macintosh

JAG Electronics has been established to pursue the RF design software market. The company recently made its debut with the introduction of RF Designer, a software tool for Macintosh users. According to Zelko Jagaric, president of JAG Electronics, the main goal of the company is to improve productivity of engineers designing RF circuits with a powerful analog circuit simulator integrated into the Macintosh environment. The software is intended for RF (lumped elements and microstrip), rather than microwave design. The company also publishes a quarterly newsletter, with the purpose of illustrating high frequency design techniques and shortcuts, as well as providing update information and RF Designer program tips. JAG Electronics is located at 213 Dunview Ave., Willowdale, Ontario, M2N 4H9, Canada. Tel: (416) 730-9611; Fax: (416) 733-3884.

Liberty Labs Formed to Provide EMC Support Services

Liberty Labs specializes in laboratory support through documentation, software, consulting, research and training. The company has been established to provide the needed day-to-day tools and services that labs require to achieve and maintain excellence in EMC testing. As part of its initial offerings, Liberty Labs has developed a line of software tools to aid in data recording, storage, and plotting of measured data.

Also being offered are logbooks designed to provide a professional and organized means of recording, collating and filing for EMC measurement data. Along with the logbooks, the company will provide a line of documentation services ranging from test reports, quality assurance & calibration manuals to regulatory applications (ie., FCC, VDE, etc). Liberty Labs, Inc. can be reached at P.O. Box 8268, Cedar Rapids, IA 52408. Tel: (319) 390-3646; Fax: (319) 390-3802.

Gould to Sell Ocean Systems Unit to Martin Marietta

Gould has announced that it has signed a letter of intent to sell its Ocean Systems Division in Glen Burnie, Md., to Martin Marietta Corp. of Bethesda, Md. The sale of the antisubmarine unit is expected to be consummated within 30 to 90 days, subject to execution of a definitive agreement, the approval of the Martin Marietta board and customary regulatory approvals. The company noted that the sale of the unit is part of its previously announced plan to divest its defense systems businesses.

Penstock Expands Headquarters

Penstock has added an additional 3,000 square feet to their corporate headquarters in Sunnyvale, California. The expansion will allow for a fully automated vertical inventory racking system and Federal Express terminal. The addition of these systems will enable Penstock to deliver inventoried components with one to two day delivery and track any order in transit.

Wiltron Establishes Office in Sweden

Wiltron Company has established Wiltron A.B., a sales and service office in Skarholmen, Sweden. This office will provide sales and support service to Wiltron equipment in Sweden and Norway plus support and service for Finland and Denmark. The move is designed to further strengthen Wiltron's European presence.

New Cable Manufacturing Company

A new company, Connecting Devices Limited, has been formed as a joint venture between March Microwave Limited and Connecting Devices Inc. of Long Beach, Calif. It has commenced production in Shoeburyness, Essex, in England and will be manufacturing a full range of semi-rigid and flexible microwave cable assemblies.

Leasametric Moves Branch to Calif.

Leasametric Instrument Rental Division has moved its equipment sales branch, Metric Resources Company of Gaithersburg, Md., to its headquarters in Foster City, Calif. This move was made as a major effort by the company to intensify its penetration of the test-equipment sales market.

American Superconductor and Inco Alloy Sign Joint Development Program

American Superconductor Corporation and Inco Alloys International have announced a joint program to develop high-volume manufacturing technology for high-temperature superconductors. American Superconductor has an exclusive license to technology from Massachusetts Institute of Technology to produce high temperature superconductors in usable forms, primarily wire and cable, by the oxidation of metallic precursors. Under the agreement, Inco Alloys International will apply its proprietary mechanical alloying technology for manufacturing the metallic precursors. Metallic precursors to be studied include rare-earth-barium-copper and bismuth-strontium-calcium-copper alloys that American Superconductor has demonstrated are superconducting when oxidized. American Superconductor will conduct research in which it will use its proprietary oxidation technology to convert the alloys produced by Inco Alloys into superconductors.

Gould Receives Automation Unit Sale Proceeds

Gould announced that it received, from escrow, proceeds of $270 million from the sale of its Industrial Automation Systems Group to AEG of West Germany. As announced previously (Aug *RF Design*), proceeds will be used to further reduce debt and for a stock repurchase program. Under the program, Gould expects to repurchase about 20 percent of its outstanding common stock from time to time in the open market or privately negotiate purchases, or through other means over the next 12-months as dictated by market conditions. As of March 31, 1988, Gould had 45 million average shares outstanding. The company said the balance of the originally announced proceeds of approximately $290 million is subject to adjustments provided for in the transfer agreement and will be determined upon satisfactory completion of remaining post-closing requirements.

Ericsson Awarded Cellular Radio Systems Contract

Ericsson has been awarded two contract totalling $2.5 million from Crowley Cellular Development Corporation for cellular radio equipment to be used in Joplin, Mo., and in Springfield, Champaign and Decatur, Ill. The contracts initially call for installation of CMS 8800/S small market systems that include Ericsson's AXE digital switch and cell site equipment.

M/A-COM Receives HARM Contract

M/A-COM, Inc. has received a contract in excess of $7 million for an integrated assembly on the HARM program. The award was made by the Defense Systems and Electronics Group of Texas Instruments. The contract calls for the production of an integrated microwave receiver which is used in the HARM missile guidance section. The work will be performed by M/A-COM's EW systems division located in Burlington, MA. The AGM-88 HARM is a high speed anti-radar air-to-surface missile. Its mission is to suppress or destroy enemy electronic emitters, especially those associated with radar sites where the radar is used to direct anti-aircraft guns and surface-to-air missiles. The HARM missile is deployed on a large number of tactical aircraft including the Navy F/A-18 Hornet strike fighter and the Air Force F-4G wild weasel. Currently HARM is being integrated on the F-16 Fighting Falcon.

In addition to the above contract, M/A-COM received funding for production work on HARM missile components. The company's solid state circuits division in Hudson, N.H., was awarded a contract in excess of $3 million to supply a series of microwave components. Also, M/A-COM's Semiconductor Division in Burlington, Mass., received an order in excess of $1 million for microwave semiconductors. The awards for the HARM missile were made by the Defense Systems and Electronics Group of Texas Instruments.

Hughes Receives International Contracts

Hughes Aircraft Company and Nippon Electric Company (NEC) have been named to build Japan's newest weather satellite. A unit of GM Hughes Electronics, Hughes will receive $74 million to build the satellite; NEC will supply elements of the communications and sensing payloads. NEC is the prime contractor to the National Space Development Agency of Japan (NASDA), which is administering the program for the Japan Meteorological Agency. The GM-5 satellite is the fifth in a series of Japanese weather satellites since 1977 based on a Hughes spin-stabilized design. GMS-3 is currently in operation and GMS-4 is awaiting launch in August 1989. GMS-5 could be launched as early as August 1993 on the Japanese H2 rocket.

Japan's geostationary meteorological satellite (GMS) constantly monitors changing weather patterns for 65 million square miles around the island nation. An updated image of cloud cover can be transmitted by the satellite every half hour. GM-5 will have added capability of determining the distribution of water vapor in the lower atmosphere, which is expected to assist in predicting where and when potential storm clouds will form. The satellite, which will have a design life of 5 years, will also have a second infrared channel for improved viewing of nighttime weather conditions.

Hughes has also received a middle eastern contract. Egypt has awarded $159 million to Hughes Aircraft Company to expand it's air defense system. Hughes will integrate additional command and control sites into the air defense system and will provide operational software, aircraft control displays, large screen displays, computer and other electronics equipment. The network will enable Egypt to detect and monitor unidentified aircraft approaching its borders and quickly initiate defensive measures, including fighter interceptors and missile batteries. Egypt's new E2C early warning aircraft will also become part of the network to detect low level aircraft in the long range.

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CV-2220	3CX1500A7	86–108	1.5 kW
CV-2225	4CX3500A	86–108	5 kW
CV-2240	3CX10,000U7	54–88	10 kW†
CV-2250	3CX10,000U7	170–227	10 kW†
CV-2400	8874	420–450	300/1250 W*
CV-2800	3CX400U7	850–970	225 W
CV-2810	3CX400U7	910–970	190 W

*pulsed power
†peak sync. or 2.5 kW combined in translator service

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INFO/CARD 16

A Five-Decade System for Testing RFI Susceptibility

Field Intensity up to Nearly 200 V/M is Available for Small Shielded Rooms.

By Donald R. Shepherd
Amplifier Research Corp.

Long after the need for RFI susceptibility testing became apparent, for commercial as well as military electronics, the practice remains as much a black art as a science, further clouded in the difficult range below 100 MHz. This article examines a low cost answer to testing new and developmental-stage products for susceptibility to RF interference.

It is clear that interference abounds at lower frequencies. Due to physical problems related to longwave antenna and room construction, susceptibility testing has not progressed as demanded by the industry. Unfortunately, at the high audio and lower radio frequencies, calculation of field strengths has had to suffice in lieu of actual measurement, except in the best-equipped test labs.

The equipment discussed here is a low-cost system for small shielded rooms —a system which promises to satisfy field-intensity requirements for 90 percent of susceptibility testing of small to medium-size test items in the five decades from 10 kHz through 1 GHz. In this system, band breaks are minimized, permitting sweep testing with two or three interruptions (Figure 1). These interruptions can be overcome by programming RF switching at the band breaks.

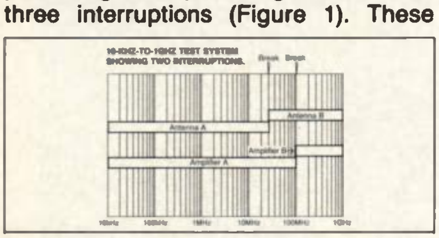


Figure 1. Test system showing two interruptions.

System Components

The basic system, without frills, consists of a pair of power amplifiers bandwidth-matched to a pair of compact antennas designed for shielded-room duty. A field-sensor system with a pair of electric-field probes delivers field-strength information to the operator outside the shielded room over fiber optic cable. Additional components required, usually available around any RF

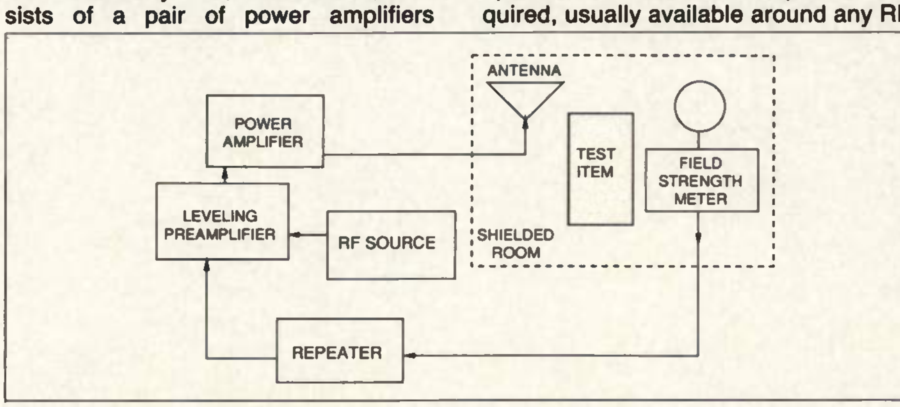


Figure 1a. Simplified system diagram.

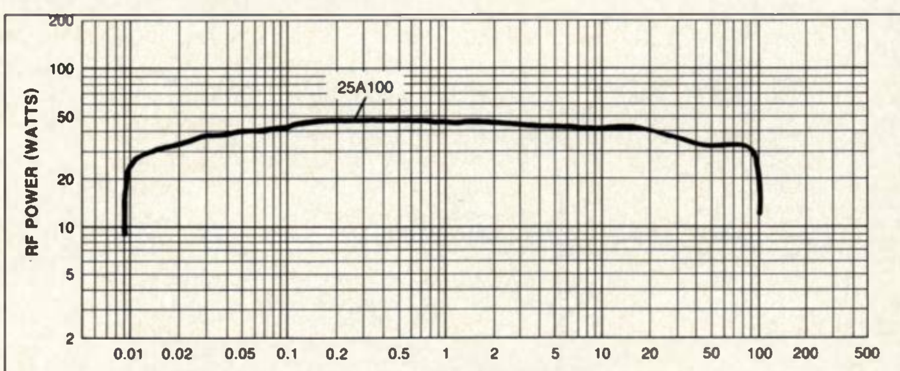


Figure 2. Amplifier "A" output power.

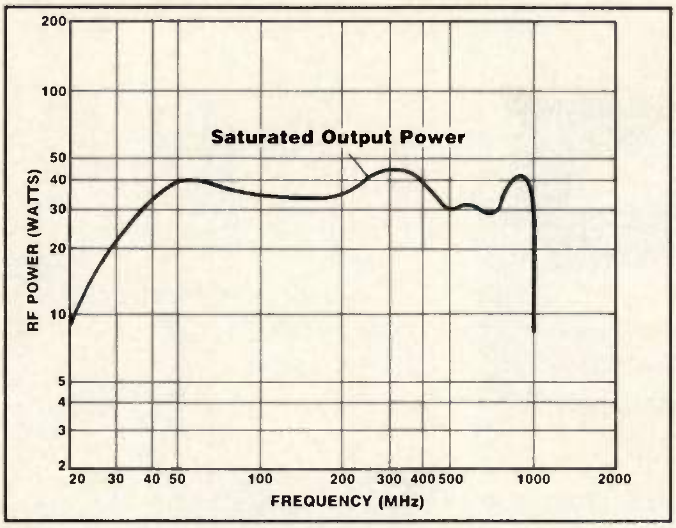
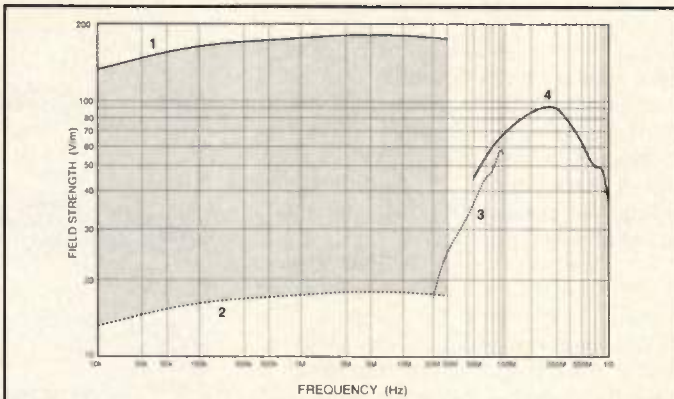


Figure 3. Amplifier B output power.



1. Amplifier A and antenna A with EUT one meter on center line from elements.
2. Amplifier A and antenna A with EUT between elements.
3. Amplifier A and antenna B.
4. Amplifier B and antenna B.

Figure 4. System performance.

lab, are a sweep signal generator with 1 mW output from 10 kHz to 1 GHz and a shielded room preferably with absorbing material.

1. Amplifiers

At the heart of any susceptibility test system is a broadband RF amplifier with enough reserve power beyond its published specification to fill in those gaps in field strength caused by reflections (VSWR) which are bound to occur. The term "reserve power" is important. It means that the manufacturer has not rated the amplifier at its maximum saturated power but rather at the minimum a user can expect at any point in the bandwidth. A look at the actual output power curves of the amplifiers in the system (Figures 2 and 3) reveals that their minimum rated power (25 watts in both cases) is, at most points in their respective bandwidths, no more than one-half to two-thirds their actual output capability. Reserve power is comforting to the test engineer who may find surprise drops in field intensity around the equipment under test (EUT) as the sweep progresses.

Both amplifiers (Model 25A100 and Model 25W1000M7) are 100 percent immune to damage from the volatile VSWR climate prevalent in shielded rooms. Also, in both units, bandwidth is instantly available without tuning, and the only band breaks occur at the coincidence of amplifier and antenna bandwidth limits.

One milliwatt of RF input power from the laboratory's broadband sweep signal generator is necessary to provide full output power as indicated on the curves in Figures 2 and 3. At the low-frequency end (10 kHz to 100 MHz), the Model 25A100 feeds the two antennas in succession—antenna A (Figure 1) from 10 kHz to 30 MHz, and then antenna B from 30 to 100 MHz. At 100 MHz, the Model 25W1000M7 takes over and operates entirely with antenna B up to the highest frequency, 1000 MHz.

Figure 5. Amplifier A (top) and amplifier B (bottom).

2. Antennas

Antenna A (Model AT3000) is a parallel-element E-field generator with an effective bandwidth from 10 kHz to 30 MHz. Light in weight and tripod-

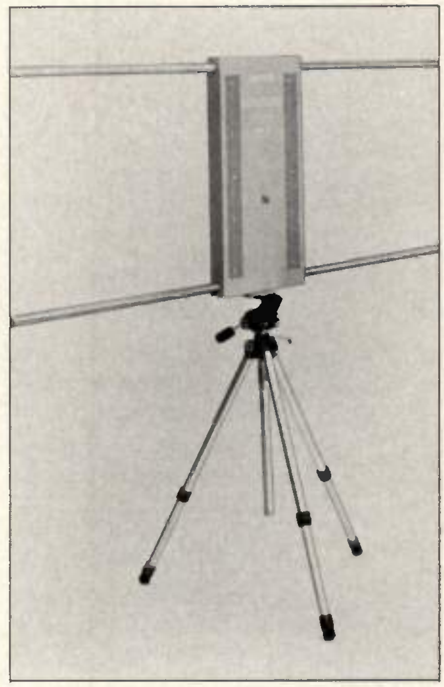


Figure 6. Antenna A — Model AT3000.

mounted, it is easily moved about in the shielded room to provide optimum field intensities for a wide range of test items. The lower curve in Figure 4 has been calculated at one meter on center line from the elements. The upper curve shows field strength obtained when the test item is positioned between the elements. So, the test engineer who tries different locations for the EUT can find a position giving the desired field strength somewhere between the two extremes.

Antenna B is the Cavitenna®. It mounts with magnetic clamps to a wall or ceiling of the shielded room, which becomes a groundplane. Thus the antenna excites the entire room similarly to a resonant cavity. Measuring four feet wide, the Cavitenna takes over at 30 MHz from antenna A—the low end of the difficult band which would otherwise require a log-periodic antenna four times its size to provide a usable field for susceptibility testing. For frequencies from 30 to 100 MHz, the Cavitenna takes its power from the 25A100 amplifier, which drove the AT3000 E-field generator at the extreme low frequencies. It continues under power from the 25W1000M7 to deliver fields up to nearly 100 volts/meter in the final decade of bandwidth to 1 GHz.

General Observations

Anyone engaged in RFI susceptibility testing knows that there are no universal truths. The field strengths found yesterday when testing one piece of equipment suddenly change today when another item is put to the same apparent test. The field-strength curves shown here are averages, and results may vary considerably (both higher and lower) depending on the size and shape of the room, operating bandwidth, size and location of the test item, and many unforeseen variables.

The total cost for the two amplifiers is $9900; the two antennas are $5900; in-room field sensor is $3500; and sensor/repeater with fiber optic cable is $3,550.

Figure 7. Antenna B — Model AT2000.

About the Author

Donald R. Shepherd is president of Amplifier Research Corporation, 160 School House Road, Souderton, PA 18964-9990. Tel: (215) 723-8181.

Plate Antenna Couplers

By Dr. T. Koryu Ishii
Marquette University

A small plate antenna coupler measuring λ/40 × λ/120 was comparatively tested with a large conventional inductively loaded antenna. This article introduces the concept of coupling through ground or surface waves. The plate antenna, which is not a microstrip patch device, is floating ground and has neither a ground plate nor ground plane. The ungrounded plate antenna showed strong coupling with ground and surface waves. Experiments and theoretical calculations were done at 49.83 MHz with actual reception tests done in a sectionalized large building with floor area of 87 m × 60 m using a calibrated transmitter to meet FCC requirement Part 15-D-3. The performance of the plate antenna showed strong dependence on the location and orientation of the antenna within a building, and characteristic of the building itself. When optimally adjusted, the small plate antenna worked as well as a large conventional inductively loaded half wave dipole antenna. Portability and compactness are the advantages of small plate antennas over conventional ones. Microstrip antennas are favored due to their compactness, portability, mass production capability, and array adaptability. This paper presents a study of a plate antenna coupler as applied for a receiver antenna coupler for non-licensed 49.83 MHz indoor communications and remote control.

Most antennas studied in the past were accompanied by a ground plate due to the basic structure of microstrip versions. The size of microstrip antennas would be acceptable if operated in high microwave frequencies. If operated at low radio frequencies, the half wavelength size microstrip antenna is no longer microstrip; it becomes a macrostrip or giant strip. The plate antenna discussed does not accompany the ground plate. For indoor applications, especially for a large building, more often than not, the plate antenna couples scattered waves and surface waves rather than directly radiated waves from a transmitter. Often the transmitter is out of the line of sight from the receiver. Therefore, in the indoor application, the antenna is considered to be a coupler to the building rather than the launcher or the receiver of spatial waves.

Small Plate Antenna

The plate antenna consists of a 14 cm × 4.5 cm piece of single sided copper-clad 1.2 mm thick Rexolite 2200 with relative permitivity of 2.62, loss tangent of 0.001 (4) and no ground plate. This is known as a floating ground plate antenna. The median antenna impedance measured at the middle of the 4.5 cm edge was 131 − j616 ohms at 49.83 MHz with an attached BNC connector. The impedance meter reading varied noticeably depending on how the antenna coupled to the building.

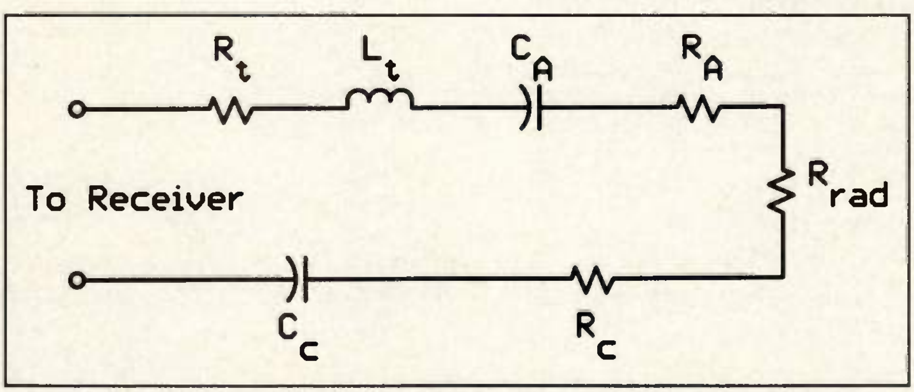


Figure 1. Equivalent circuit of a floating ground plate antenna system.

The antenna location and orientation made the impedance reading different. The capacitive reactance of this antenna was tuned out by a tuning coil for a particular antenna location and orientation. The antenna and tuning coil assembly was connected to a battery operated FM receiver with sensitivity of −115 dBm without any co-axial cable between them.

Coupling Characteristic

The plate antenna and receiver system were connected to a spectrum analyzer for output display. A test FM transmitter was calibrated to produce 10 mV/m of electric field strength at 3 m from the transmitter to meet FCC Rules and Regulations Part 15-D-3 for non-licensed radios following the calibration procedure specified in FCC Procedure T-7001 at 49.83 MHz. The receiver was placed at the northeast corner on a ceiling plenum above the windows of a 87 m × 60 m sectionalized building. The calibrated transmitter was carried around in the building and the reception range was tested to produce usable signal level which was set at −100 dBm. When the receiver plate antenna was oriented parallel to the window, the maximum range was 80 m along windows. At the same antenna location, when the receiver antenna was oriented perpendicular to the window, the maximum communication range was 147 m along the windows.

This shows that the method of coupling to the building makes appreciable difference in the reception area pattern of the plate antenna. Note that the building exterior is covered by a large area of glass window panes. Results suggest that the small plate antenna is coupling to the surface waves propagating along the window pane (7,8). Since the operating wavelength is about 6 m long, the 3 dB down detectable surface waves extended over 25 m from the window (7).

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SAS-200/530	150 - 550 MHz	Broadband Dipole
SAS-200/540	20 - 300 MHz	Biconical
SAS-200/541	20 - 300 MHz	Bicon'l Collapsible

MODEL #	FREQ. RESP.	DESCRIPTION
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SAS-200/560	per MIL-STD-461	Loop - Emission
SAS-200/561	per MIL-STD-461	Loop - Radiating
BCP-200/510	20 Hz - 1 MHz	LF Current Probe
BCP-200/511	100 KHz-100 MHz	HF/VHF Cont. Probe

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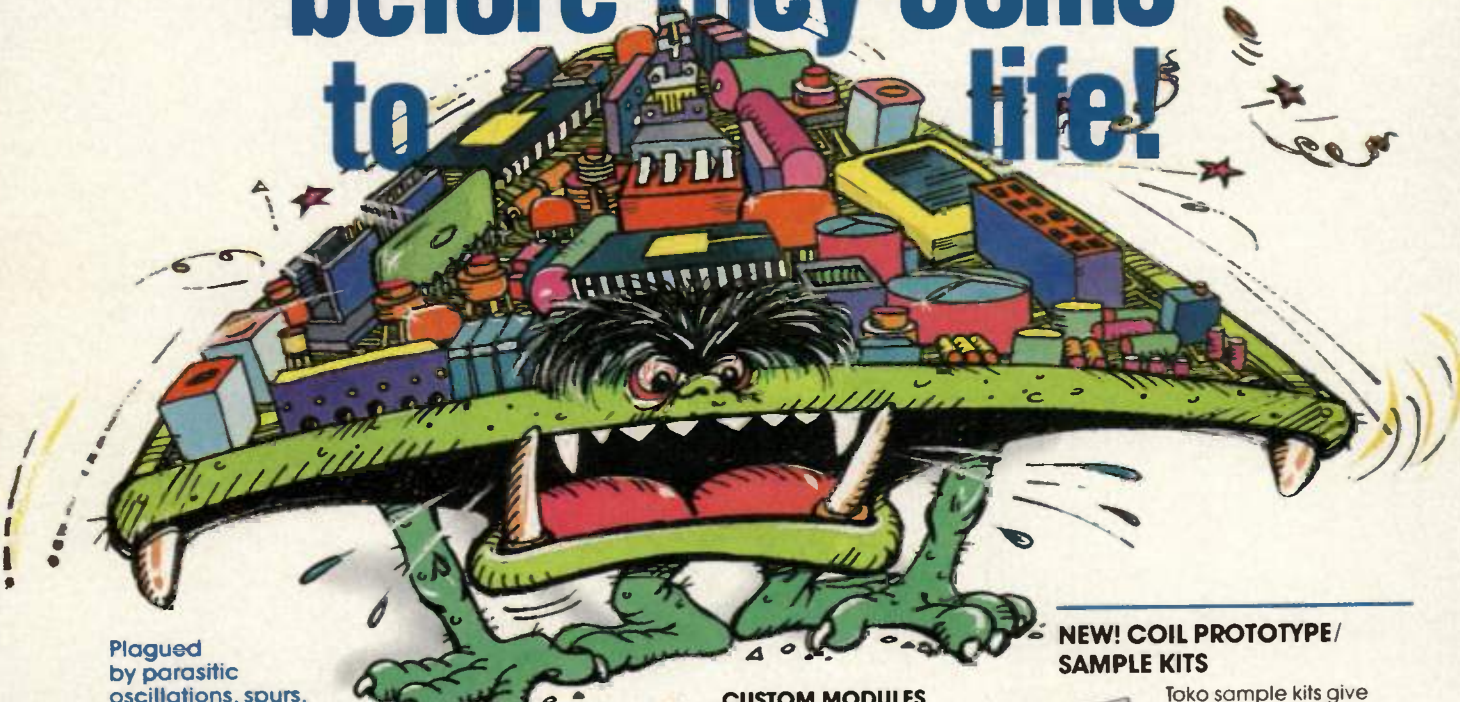

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Comparative Experiments

Reception capability of a 15 cm long plate antenna and a 86 cm long conventional inductively loaded halfwave dipole antenna was comparatively tested in the same building using the same transmitter as described in the previous section. This time however, the receiver antenna was moved to the ceiling plenum of the north center window to cover the maximum area of the building. The location, the orientation and the impedance of the receiving antenna was adjusted to produce the optimum signal reception capability. Then, the reception range pattern was taken. Later, the 86 cm long conventional inductively loaded halfwave dipole antenna was replaced by the 15 cm long plate antenna, and the reception area pattern was obtained again.

The receiver and tuning coil were carefully tuned to produce maximum receiver signal output. Comparing the two reception range patterns, the total area within the pattern was almost equal to each other eventhough the patterns differed slightly. Both patterns covered 80 percent of the 87 m × 60 m floor. When they are well tuned and carefully mounted, the small plate antenna functions almost as well as conventional inductively loaded half wavelength dipole antenna, yet the small plate antenna is compact and portable for indoor applications.

Coupling Principles

The small plate antenna tested is approximately $\lambda/40 \times \lambda/120$ (14 cm × 4.5 cm) at 49.83 MHz. Therefore, for simplicity, this is considered as an equivalent short linear antenna. The directive gain of a short antenna is (9):

$$g_d = 1.5 \qquad (1)$$

The effect aperture of the short antenna(9) is, at 49.83 MHz,

$$A = \frac{\lambda^2}{4\pi} g_d = 4.3 \text{ m}^2 \qquad (2)$$

and the radiation resistance of a short antenna is:

$$R_{rad} = 80\pi^2\left(\frac{H}{\lambda}\right)^2 = 0.4742 \text{ ohms} \qquad (3)$$

where H is the length of the short antenna which in this case is equal to:

$$H = \frac{1}{40}\lambda \qquad (4)$$

Normally, the short antenna with low radiation resistance as shown in equation 3 is considered to be useless (11, 12). But, for indoor application, this floating ground antenna coupler system is quite different. An equivalent circuit of a floating ground plate antenna coupler is shown in Figure 1. In this circuit, R_{rad} is the radiation resistance to space, R_a is the antenna resistance, C_a is the antenna capacitance, and L_t is the tuning coil inductance. R_t is the tuning coil resistance, R_c is the return circuit resistance and C_c is the return circuit capacitance. The return circuit coupling parameters R_c and C_c appear because of the floating ground receiver antenna coupler system. Note that the ground side of the receiver antenna is floating. Therefore, the ground impedance or return circuit impedance $R_c + jX_c$ must be in series to the antenna equivalent circuit. Input impedance of this small plate antenna was measured under floating ground conditions in a laboratory. An impedance meter was used to measure the input antenna impedance at 49.83 MHz as described previously. According to this measurement, radiation R_{rad} is negligible in comparison with other resistances. Combining the information presented and Figure 1.

$$R_A + R_C \approx 131 \text{ ohms} \qquad (5)$$

$$\frac{C_A + C_C}{\omega C_A C_C} = 616 \text{ ohms} \qquad (6)$$

The ground return circuit impedance $R_c + jX_c$ represents the impedance of the RF waves coupled to wall, ceiling, floor, equipment, utilities, pipes, machines and people in the building. Dispersion, dissipation, scattering and diffractions due to obstacles and objects indoors are represented by the ground coupling impedance $R_c + jX_c$. In many indoor applications, both the receivers and the transmitters are closely coupled to the walls, floor, ceiling or people in the floating ground antenna coupler system.

The antenna input reactance $(C_a + C_c)/C_a C_c$ is matched by a tuning coil of impedance $R_t + jL_t$ as illustrated in Figure 1. If the quality factor of this tuning coil is Q, after tuning;

$$R_t = \frac{\omega L_t}{Q} = \frac{1}{Q} \cdot \frac{C_A + C_C}{\omega C_A C_C} \qquad (7)$$

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Substituting equation 6 and Q = 80 into equation 7,

$$R_t = 7.7 \text{ ohms} \quad (8)$$

The antenna resistance R_a can be estimated assuming that the small plate antenna is a thin short monopole. Using a chart by Jordan and Balmain (9), R_a is estimated to be in the order of 1 ohm.

$$R_A = 1 \text{ ohm} \quad (9)$$

Therefore, the coupling efficiency of this floating ground small plate antenna coupler to the ground return circuit is,

$$\eta_c = \frac{R_{rad} + R_C}{R_{rad} + R_c + R_A + R_t} \quad (10)$$

Substituting equations 3, 5, 8 and 9 into equation 10, the coupling efficiency of the small plate antenna is:

$$\eta_c = 0.94 \quad (11)$$

The floating ground small plate antenna couples well to the signals coming in from the ground return circuit as the ground waves.

The antenna factor (9) of this floating ground small plate antenna is then,

$$K = 120 \sqrt{\frac{A}{g_d R_r} \cdot \frac{1}{\eta_c}} \quad (12)$$

Where R_r is the total antenna system resistance at the receiver terminal including the tuning coil resistance R_t and the ground return circuit resistance R_c.

$$R_r = R_t + R_A + R_{rad} + R_c = 139.2 \text{ ohms} \quad (13)$$

Substituting equations 2, 11 and 13 into equation 12,

$$K = 17.76 \text{ m}^{-1} \quad (14)$$

Comparatively, when the input impedance of the conventional inductively loaded halfwave dipole antenna was measured in a laboratory under the same condition as the (floating ground) small plate antenna coupler, the input antenna resistance was,

$$R_A + R_{rad} = 23 \text{ ohms} \quad (15)$$

and the input antenna reactance was,

$$X_A = \frac{1}{\omega C_A} \quad (16)$$

The physical length of this reference antenna is,

$$2H = 86 \text{ cm} \quad (17)$$

The normalized half length to the operating wavelength at 49 MHz is then,

$$\frac{H}{\lambda} = 0.07 \quad (18)$$

Therefore, this 86 cm long dipole has almost equal directive gain g_d, and effective aperture A, with the measured value shown in equation 15. Assuming an ideal 100 percent radiation efficiency, the lower bound of the antenna factor of this reference dipole antenna is, using equation 12,

$$K = 42.36 \text{ m}^{-1} \quad (19)$$

The above calculations show that for indoor applications for non-licensed wireless RF, data communications and remote control, the compact floating ground plate antenna functions as well as the conventional inductively loaded halfwave dipole antenna.

Conclusions

Experiments and principles presented in this paper showed that a floating ground compact plate antenna, as compact as (λ/40) × (λ/120), functions as well as a large conventional inductively loaded half-wave dipole antenna as a receiver antenna for indoor applications in non-licensed wireless RF data communications and remote control techniques. The floating ground compact PCB antenna coupler is better in the compactness and portability over a conventional half wavelength dipole antenna. The antenna impedance measured under practical indoor conditions is different from the value obtained under the anechoic condition. The input impedance of floating ground compact plate antenna differ greatly depending on the building, the mounting location, orientation and proximity to other objects and obstacles, indicating the close coupling to the ground waves through the ground return circuit. Coupling of the floating ground compact plate antenna to the spatial waves is relatively small due to its low radiation resistance.

References

1. Robert J. Mailloux, "Trends in Array Antenna Research," *Electromagnetic Scattering*, Academic Press, New York, NY 1978.

2. J.O. Howell, "Microstrip Antennas," *IEEE Trans. Antennas and Propa-*

gation, Vol. AP-23, pp. 90-93; January, 1975.

3. Anders G. Deyneryd, "Analysis of the Microstrip Disk Antenna Element," *IEEE Trans. Antennas and Propagation*, Vol. AP-27, pp. 660-664; September, 1979.

4. T.Y. Lo, D. Solomon, and W.F. Richards, "Theory and Experiment on Microstrip Antennas," *IEEE Trans. Antenna and Propagation*, Vol. AP-27, pp. 137-145; March, 1979.

5. R.E. Munson, "Conformed Microstrip Antennas and Microstrip Phased Arrays," *IEEE Trans. Antenna and Propagation*, Vol. AP-22, pp. 74-78; January, 1974.

6. P. Hammer, D. Van Bouchante, D. Verschraeven, and A. Van De Capelle, "A Model for Calculating the Radiation Field of Microstrip Antenna," *IEEE Trans. Antenna and Propagation*, Vol. AP-27, pp. 267-270; March, 1979.

7. M. Sugi and T. Nakahara, "O-Guide and X-Guide, Advanced Surface Wave Transmission Concept," *IRE Transactions on Microwave Theory and Techniques*, Vol. MTT-7, pp. 366-369; July, 1959.

8. T. Koryu Ishii, Michael K. Ownes and Freddie L. Hampton, "Applications of Plexiglass Waveguiding Devices (PWD) in Microwave Communication Systems," *Proceedings of the National Electronics Conference - 1974*, Vol. 29, pp. 471-476, October, 1974, Chicago, IL.

9. E.C. Jordan and K.G. Balmain, *Electromagnetic Waves and Radiating Systems*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1968

10. A.D. Krall, J.M. McCorkle, J.F. Scarzello, and A.M. Syeles, "The Omini Microstrip Antenna: A New Small Antenna," *IEEE Transactions on Antennas and Propagation*, Vol. AP-27, pp. 850-853; November, 1979.

11. H.A. Wheeler, "Small Antennas," *IEEE Transactions on Antennas and Propagation*, Vol. AP-23, pp. 462-469, July 1975.

12. K. Fujimoto, A. Henderson, K. Hirasawa, and J. James, *Small Antennas*, John Wiley and Sons, Inc., New York, NY; 1987.

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INFO/CARD 46

Software for Shielding Design and Analysis

Description and Review of Three EMC Programs Dealing with Box-Level Emissions and Susceptibility

By Gary A. Breed
Editor

Most EMC engineering is based on experience. Designs are created using methods that have been previously successful, then modified as needed when actual measurements are made on prototypes. The use of computer modeling to eliminate many steps in this time-consuming practice is well known. The EMC community is certainly experienced with computers. Automated test and analysis software is used at every laboratory, and of course, one of the largest area of EMC work is computing equipment. But, EMC has been one of the last areas of RF engineering to get design-oriented software. The three packages described here are one company's effort to provide such software.

Interference Control Technologies, Inc. (ICT) offers a wide range of EMC-related products and services: books and magazines, training and seminars, consulting services, and software. This article describes the operation of three software packages from ICT, covering electromagnetic radiation and susceptibility. The primary emphasis of these programs is on

EMC DESIGN AND RETROFIT TO MEET
FCC AND VDE REGULATIONS AND
MIL-STD-461A/461B SPECIFICATIONS LIMITS

PERFORMANCE SUMMARY

WORST CASE OUT-OF-SPEC IS 4 dB (24 dB WITH MARGIN) AT 24 MHz
FAILURE MODE IS CHIP-TO-CHIP INTERCONNECT TRACES (LINES 4-7 AND 11-13)

GENERAL INPUT DATA:
1: REGULATION OR STANDARD TO BE MET = FCC PART 15.J CLASS B
2: ALLOWABLE ERROR MARGIN = 20 dB
3: COARSE, MEDIUM OR FINE RESOLUTION PLOT = MEDIUM

ENCLOSURE, CONFIGURATION AND LOGIC SELECTION:
4: OUTER BOX ANALYZED = ALL PLASTIC BOX
SHIELDING AT WORST-CASE FREQUENCY = 0 dB
5: WIREBOARD CONFIGURATION ANALYZED = DOUBLE-SIDED SINGLE LAYER BOARD
AVERAGE SPACING BETWEEN RETURN PARALLEL GROUND TRACES = 5 CM
SHIELDING AT WORST-CASE FREQUENCY = 0 dB
6: HIGHEST-SPEED LOGIC FAMILY USED = HCMOS
7: HIGHEST CLOCK RATE USED = 8 MHz

RADIATION SOURCES

RADIATION FROM CHIPS AND DECOUPLING CAPACITORS:
8: TOTAL NUMBER OF NON-MEMORY DIP CHIPS ON PCB(S) = 80
9: AVERAGE NUMBER OF GATES PER CHIP = 4
10: AVERAGE NUMBER OF CHIPS PER DECOUPLING CAPACITOR = 2

RADIATION FROM CHIP-TO-CHIP INTERCONNECT TRACES:
11: NUMBER OF CHIP-TO-CHIP INTERCONNECT TRACES PER CHIP = 6
12: AVERAGE LENGTH OF INTERCONNECT TRACES = 13 CM
13: AVERAGE FANOUT PER INTERCONNECT TRACE = 2

RADIATION FROM PCB-TO-PCB INTERCONNECT RIBBON CABLE:
14: NUMBER OF WIRE PAIRS IN INTERCONNECT RIBBON CABLE(S) = 20
15: NUMBER OF INTERCONNECT RIBBON CABLE WIRE PAIRS PER CM = 4
16: AVERAGE LENGTH OF RIBBON CABLES = 30 CM
17: NUMBER OF TWISTS PER METER = 0

==================== SPECTRUM RADIATION PERFORMANCE ====================

FREQUENCY IN MHz	CHIP RADATON dBuV/m	TRACE RADATON dBuV/m	CABLE RADATON dBuV/m	BOX ATTN dB	COMBINED* RADATON dBuV/m	SPEC LIMIT dBuV/m	OUT-OF SPEC dB	OUT-OF-SPEC PLUS MARGIN dB
8	-1	41	-4	0	41	40	1	21
24	2	44	-1	0	44	40	4	24
40	1	43	-2	0	44	40	4	24
56	0	43	-3	0	43	40	3	23
72	0	42	-3	0	42	40	2	22
86	0	42	-3	0	42	40	2	22
102	0	42	-3	0	42	43	-1	19
122	0	42	-3	0	42	43	-1	19
145	0	42	-3	0	42	43	-1	19
173	0	42	-3	0	42	43	-1	19
206	0	42	-3	0	42	43	-1	19
246	0	42	-3	0	42	46	-4	16
293	1	43	-2	0	43	46	-3	17
349	1	43	-2	0	43	46	-3	17
416	1	43	-2	0	43	46	-3	17
496	1	43	-2	0	43	46	-3	17
591	1	43	-4	0	43	46	-3	17
704	0	43	-6	0	43	46	-3	17
839	0	43	-7	0	43	46	-3	17
1000	0	43	-9	0	43	46	-3	17

Figure 1. Radiation program (5300) output.

INPUT DATA LISTING FOR SHIELDED BOX/CASE DESIGN OR RETROFIT
(EMI DIAGNOSTICS AND FIXES)

1 SYSTEM OF UNITS: Metric

2 SHIELDED CASE DESIGN REQUIREMENTS: Licensed Transmitter Threats
2.2 TRANSMITTER AMBIENT: E = 1 V/m (10 kHz-25 MHz): 10 V/m (25 MHz-10 GHz)
2.5 BUILDING/VEHICLE ATTENUATION: Box/Case Not in Building/Vehicle

3 VICTIM(S) TO BE PROTECTED: Both Analog and Logic Victims
3.1 LOW-LEVEL ANALOG VICTIM:
Noise Sensitivity = .12 mV
Bandwidth = 5000 kHz
Length of Trace + Wire Pair Feeding Device = 40 cm
PCB Typo used: single-layer board
3.2 HIGH-SPEED LOGIC VICTIM:
Highest-Speed Victim Logic Used: ECL-10K
Length of Trace + Wire Pair Feeding Device = 40 cm
PCB Type Used: single-layer board

4 PROTECTION MARGIN: 10 dB

5 BOX SKIN CONSTRUCTION: Metalized Plastic Box
Box Height = 20 cm
Box Width = 40 cm
Box Depth = 30 cm
Box Thickness = 1 mm
Conductive Coating Performance Calculated from Surface Impedance
Surface Impedance = .7 ohms/square

6 LEAKAGES:
CRT DISPLAY - Located in Front or Back Panel
Shape and Size of Individual Aperture:
Rectangular Hole 25 cm x 19 cm
Orientation: Running from Side to Side in Front or Back Panel
EMI Protection: None
CONVECTION COOLING - Located in Top or Bottom Panel
Thickness of Panel = 1 mm
Shape and Size of Individual Aperture:
Rectangular Hole 8 cm x .4 cm
Orientation: Running from Front to Back in Top or Bottom Panel
Apertures are Arranged in an Array Measuring 8 cm x 15 cm
EMI Protection: None
MATING PANEL MEMBERS
Center-Center Spacing Between Recessed Fasteners in Base = 150 mm
Type of Mating Member Joint/Seam: Tongue & Groove
Mating Member Average Gap Spacing = .3 mm
EMI Protection: None

ANALYSIS AND PERFORMANCE OF SHIELDED BOX/CASE DESIGN OR RETROFIT
(EMI DIAGNOSTICS AND FIXES)

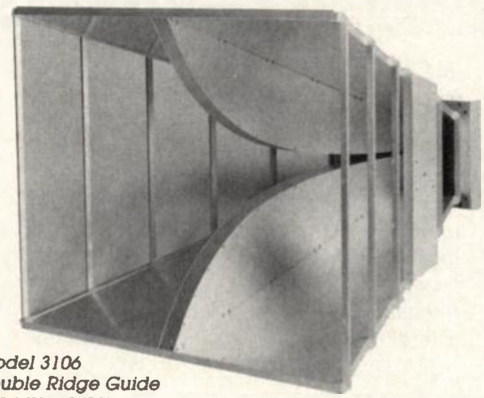
INITIAL PERFORMANCE	10kH	100k	1MHz	3MHz	10MH	30MH	100M	300M	1GHz	3GHz	10GH
SE OBJECTIVES:	0	0	8	18	22	47	42	42	34	24	20
BOX MATERIAL PERFORMNC:	117	97	77	67	57	47	43	43	43	43	43
----- LEAKAGES -----											
CRT DISPLAY:	92	72	52	43	32	[illegible]	12	[illegible]	3	1	1
CONVECTION COOLING:	115	95	75	65	55	45	35	25	15	11	8
MATING PANEL MEMBERS:	122	102	82	73	62	57	42	33	22	18	16
OVERALL PERFORMANCE:	91	71	51	42	31	27	11	2	0	0	0
OVER OR UNDER(-)DESIGN:	91	71	43	24	9	-20	-31	-40	-34	-24	-20

UNDER-DESIGNED: DESIGN FAILED OBJECTIVE. MORE DESIGN REQUIRED.

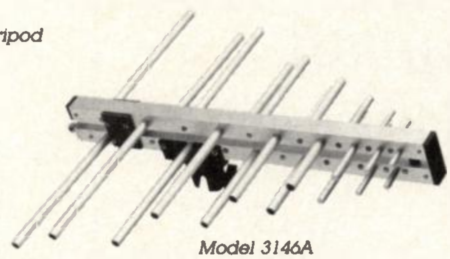
Figure 2. Program 5500 data printout.

Model 3115 Double Ridge Guide 1–18 GHz
Model 3116 Double Ridge Guide 18–40 GHz

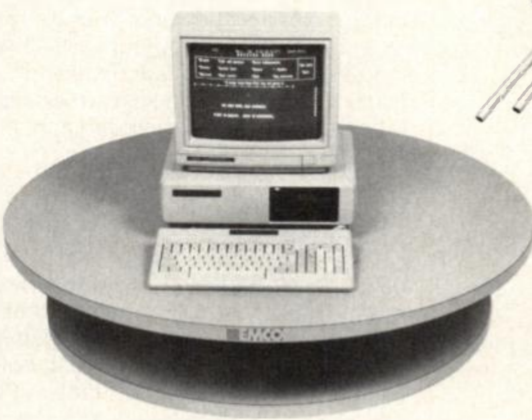
Model TR3 Non-Metallic Tripod 22.68 kg capacity



Model 3106 Double Ridge Guide 200 MHz–2 GHz

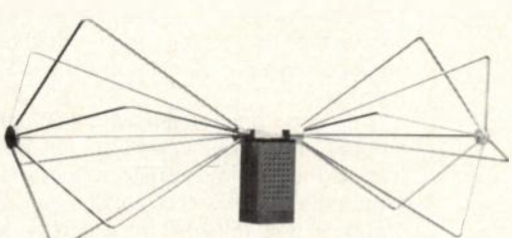


Model 3146A Log Periodic 300 MHz–1 GHz four other models available

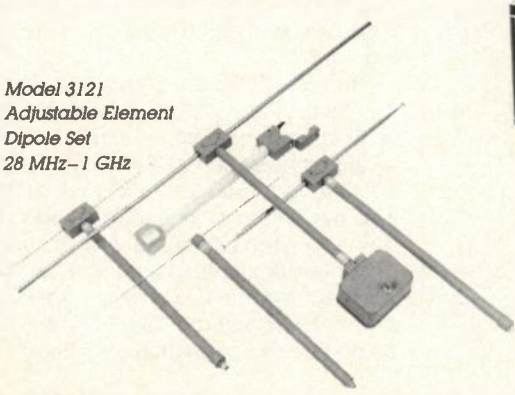


Model 1060 Turntable with controller and IEEE-488 bus option 1–7.6 meter diameter available

Model 6502 Active Loop Antenna 10 kHz–30 MHz



Model 3109 Biconical 20–200 MHz three other models available



Model 3121 Adjustable Element Dipole Set 28 MHz–1 GHz

Model 3925 PLISN 2 kHz–1 GHz five other models available

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Program 5300 deals with radiation from digital circuits, including internal standards for FCC Part 15.J, Class A and B; VDE Part 0871 Class A and C or Class B; and MIL-STD-461A/461B. The necessary input data includes cabinet configuration and material, p.c. board type and trace spacing, logic family and number of interconnects, and internal cabling. To evaluate the results, the user also specifies the margin of protection and the resolution of the spectral-amplitude output plot.

Analysis is performed using several models. For p.c. traces and cabling, established electromagnetic models for straight wires and small loops are used, including allowances for twisted pairs within multiwire cables. Each logic family is characterized for direct radiation at fundamental and harmonic frequencies, and includes allowances for the number of bypass capacitors chosen by the user. Once the analysis is complete, the program proceeds to a graphical output, which has selectable coarse, medium, and fine resolution.

The first pass through the program usually will expose areas where additional protection is required, or it may show an over- design situation, giving the engineer an opportunity to implement less costly radiation control methods. The program format allows the user to look over all of the data and results, then change parameters to explore alternate solutions. The manual offers a number of possible fixes for problem areas. The program itself tells the user where the general areas of difficulty are located in the design example it has analyzed. A sample program output is shown in Figure 1.

Designing for Control of Susceptibility

The other two programs deal with susceptibility of equipment to interference from various electromagnetic threats, such as licensed transmitters, lightning stroke radiation, electromagnetic pulse (EMP), or combinations of threats. Program 5500 deals with susceptibility involving shielded enclosures of all types. The methods of analysis are based on the book "Shielding Design Methodology and Procedures." Program 5220 provides susceptibility analysis of two boxes interconnected by cables, using methods gleaned from the 52 references cited in the manual.

Both programs begin with the user-defined standards: the type of interference threat, the shielding effectiveness requirements, and the outside electromagnetic ambient environment to be protected against. This can be done by selecting standard configurations or by entering specific information on the types, distances, and magnitudes of the interfering sources.

Program 5500 continues by defining the "victim" according to circuit type (low-level analog, high-speed logic, or both), including noise sensitivity level for analog circuits, logic family for digital circuits, plus the length of interconnecting wires. The enclosure is then defined according to dimensions, material used, plus apertures for controls, displays, ventilation, and cabinet seams. The program then computes the protection achieved.

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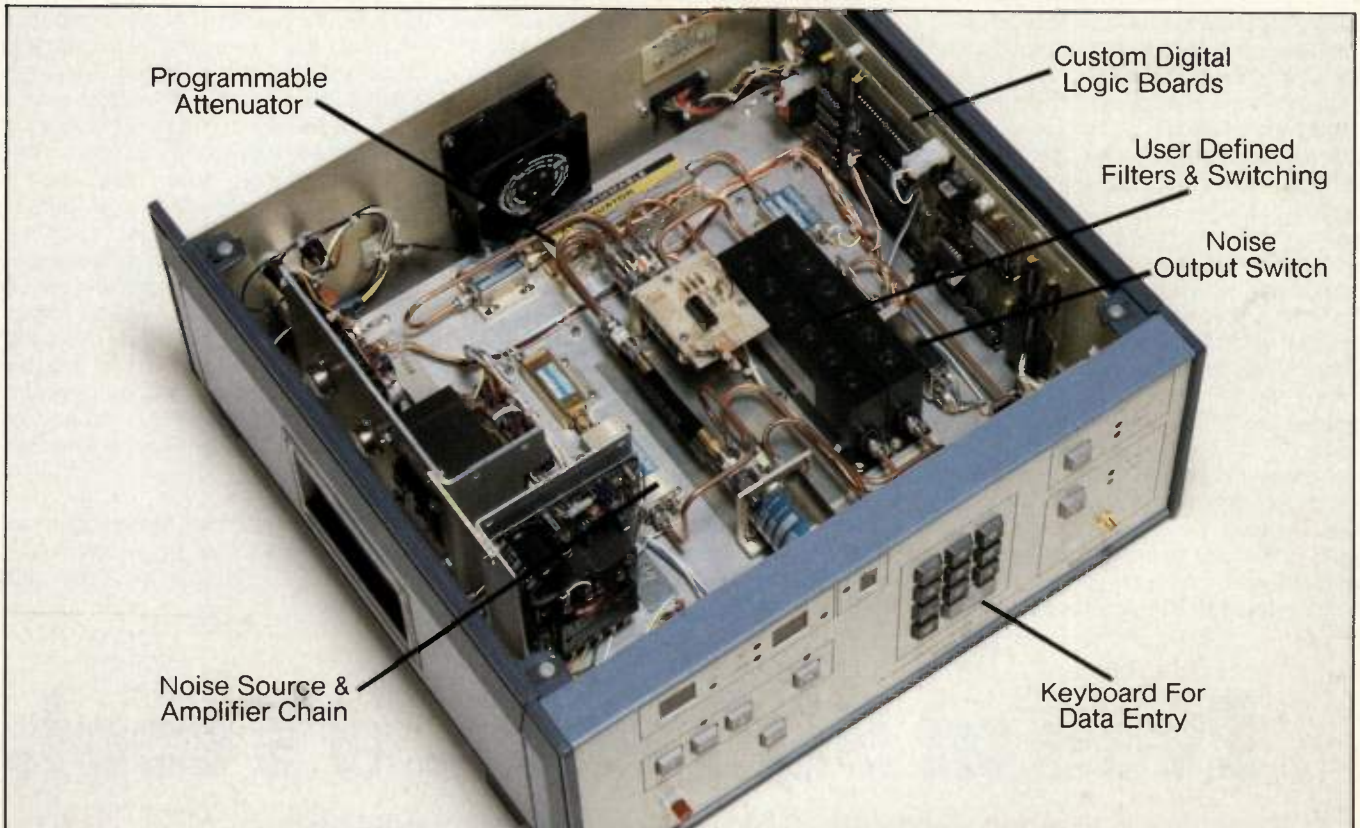

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SPECIFICATIONS

MODEL NO.	FREQUENCY RANGE	FLATNESS	VSWR	OUTPUT DBM/HZ
MX5101	10Hz-20KHz	±0.5 dB	1.5:1	-33
MX5102	10Hz-100KHz	±0.5 dB	1.5:1	-40
MX5103	10Hz-500KHz	±0.5 dB	1.5:1	-47
MX5104	100Hz-3MHz	±0.75 dB	1.5:1	-55
MX5105	100Hz-10MHz	±1.00 dB	1.5:1	-60
MX5106	100Hz-25MHz	±1.00 dB	1.5:1	-64
MX5107	100Hz-100MHz	±1.00 dB	1.5:1	-70
MX5108	1Mz-300MHz	±1.5 dB	1.5:1	-75
MX5109	30Hz-500MHz	±2.0 dB	1.5:1	-77
MX5110	300MHz-1GHz	±2.0 dB	1.5:1	-79
MX5111	1GHz-2GHz	±2.0 dB	2.0:1	-80
MX5200	100Hz-1000MHz	±2.0 dB	2.0:1	-80
MX5250	100Hz-1500MHz	±2.5 dB	2.0:1	-82

STANDARD FEATURES

THESE STANDARD SPECIFICATIONS ARE INCLUDED IN THE MX-5000.

1. Attenuation Range 0-99 dB in 1 dB steps.
2. Noise standby and on.
3. IEEE 488 programmable.
4. Standard output 50 ohms.
5. 5:1 minimum crest factor.
6. Power selectable 110 to 230 volts 50/60 Hz.
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The most obvious benefit of this program (and the others) is the ability to modify the input data and quickly see the results. Using the suggestions included in the manual, changes in the configuration of the unit under examination can be evaluated, resulting in selection of an acceptable combination of performance, cost, and manufacturability.

Figure 2 is a summary of input and output data for a specific unit which will require further work to meet the design specifications. In this case, the problems are at frequencies above 30 MHz. Examination of the data shows that nearly all characteristics of the box have decreasing shielding with increasing frequency, yet the protection requirements generally increase with frequency. The worst offenders are easy to spot: the CRT display opening and the convection cooling slots. Because of the large degree of underdesign (40 dB), extensive shielding of these openings will be required. To see what might work, and to observe the program operation, wire mesh shielding was added to the CRT opening and the cooling vents were changed to an array of smaller openings. This improved the design to within 13 dB of the objective, still short of the desired performance.

Program 5220 adds the next dimension to susceptibility design by analyzing interconnected boxes. This program starts with input/output characteristics of each box, then allows the user to determine the performance of various interconnection configurations. Case-to-board bonding, shielding, balanced (parallel or twisted) or unbalanced (coaxial) lines, optical isolators, and transformers are areas covered by the program.

Input of all necessary data for the program requires a significant amount of time (the manual says 10 minutes, a realistic figure for most engineers). The complexity of the system requires 50 entries to define the boxes and cabling. This is after the user has defined the operating electromagnetic environment. Once the information is on file, it can be recalled for analysis or modification.

Fortunately, all three programs prompt the user for the required data in a question-and-answer format. This conversational style is generally easy to follow, even for someone (like the author) who is using them for the first time. Expected features for any design software are included, such as keeping data on file, easy modification of data, simple print commands, "help" function, and menu-driven operation.

These programs are designed primarily for EMC evaluation of digital equipment, although the susceptibility programs include specification of analog circuit sensitivity. However, this is a major area of EMC engineering, and the principles involved have applicability to other circuit types, particularly when evaluation of enclosure performance is of primary concern.

The programs appear to be a combination of computations based on various field equations, tables of device and circuit characteristics, and "rule of thumb" approximations. As such, the program should be a good parallel to the various "manual" methods which have been used with success by experienced EMC engineers. rf

Interference Control Technologies, Inc. can be reached at State Route 625, P.O. Box D, Gainesville, VA 22065, (703) 347-0030.

Design of a 20 W L-Band Class A Amplifier

By Katsunori Miyagaki
NEC

In recent years, there has been a shift in the trend towards mobile communications using microwave bands — 1.6 GHz and 2.3 GHz bands are now used not only for communication between land-based mobile stations, but also for aircraft and marine communication using satellites. Microwave band use for mobile communication is expected to show the greatest growth in the coming years. This report describes the design and production of a 20 watt output class A power amplifier with a 1.6 GHz and 2.3 GHz operating frequency using the NE345L-20B.

Typical requirements for power amplifiers used in transmission equipment are as follows:

1. Power supply voltage of 13.5 V or less (battery operable)
2. High power output (to increase the communication range)
3. High gain level (to improve total power efficiency)
4. High efficiency level (to achieve low power consumption)
5. Class A linear operation (to enable multi-value digital communication)

The design shown here is centered around the NE345L-20B GaAs power FET since it meets the above requirements.

FET Description

The NE345L-20B is a GaAs power FET with a gate length of 0.6 um. T-shaped gates are used to reduce gate resistance and obtain high gain. An important design consideration for high-power GaAs FETs is thermal resistance minimization. The NE345L-20B uses plated heat sink (PHS) technology to lower thermal resistance and raise power output and reliability. Table 1 summarizes the properties of the NE345L-20B while Figure 1 shows an outline drawing.

Figure 2 shows the circuit configuration of the NE345L-20B. An input matching circuit matches the NE345L-20 to the input terminal's 50 ohm impedance while an output matching circuit matches the output terminal's 50 ohm impedance.

One of the parameters for consideration when designing a high power amplifier is the dynamic impedance (the impedance that results from operating on large signals). Table 2 lists input and output dynamic impedance data for the NE345L-20B operating at 1.6 GHz and 2.3 GHz.

Power Amplifier Design

The example below is centered around an amplifier operating at 2.3 GHz. Pattern and electrical characteris-

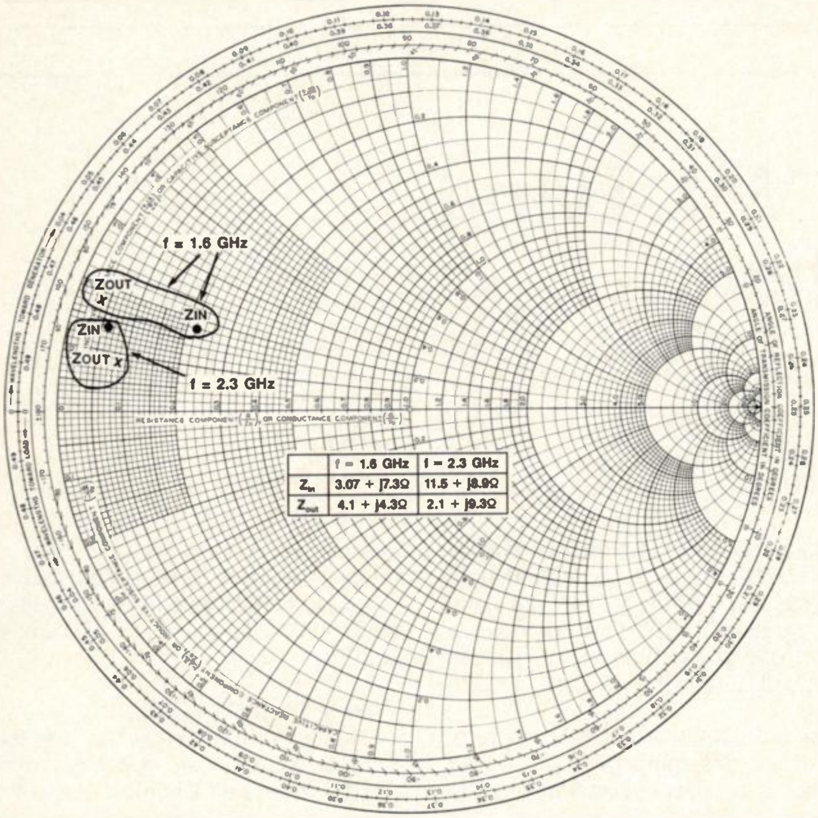
Absolute Maximum Ratings (T_a = 25°C)	NE345L-20B		
Drain to Source Voltage	V_{DS}	15	V
Gate to Drain Voltage	V_{GD}	−18	V
Gate to Source Voltage	V_{GS}	−7	V
Drain Current	I_D	18	A
Gate Current	I_G	120	mA
Total Power Dissipation	P_{tot}	100	W
Channel Temperature	T_{ch}	175	°C
Storage Temperature	T_{stg}	−65 to +175	°C

Electrical Characteristics (T_a = 25°C) NE345L-20B

Characteristic	Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Drain Current	I_{DSS}	10	14	18	A	V_{DS} = 2.5V, V_{GS} = 0
Pinch-off Voltage	V_p	−5.0	−3.5	−2.0	V	V_{DS} = 2.5V, I_D = 60 mA
Transconductance	g_m	—	4000	—	mS	V_{DS} = 2.5V, I_D = 4 A
Thermal Resistance	$R_{th(c-c)}$	—	1.2	1.5	°C/W	T_{ch} = 125°C
Output Power at 1 dB G.C.P.*	$P_{O(1\ dB)}$	42.0	43.0	—	dBm	V_{DS} = 10 V, f = 2.3 GHz, I_D = 4.0 A (RF Off)
Linear Power Gain	G_L	10	11	—	dB	
Drain Current	I_D	—	4.6	6.0	A	
Gate Current	I_G	—	—	20	mA	
Power Added Efficiency	η_{add}	—	40	—	%	
Output Power	P_o	—	44.0	—	dBm	V_{DS} = 10 V, f = 2.3 GHz, I_D = 4.0 A (RF Off), P_{in} = 35 dBm
Output Power at 1 dB G.C.P.*	P_o (1 dB)		43.0		dBm	f = 1.6 GHz
Linear Power Gain	G_L		10		dB	

*G.C.P. Gain Compression Point

Table 1. Electrical properties.



	f = 1.6 GHz	f = 2.3 GHz
Z_{in}	3.07 + j7.3Ω	11.5 + j8.9Ω
Z_{out}	4.1 + j4.3Ω	2.1 + j9.3Ω

Table 2. Dynamic impedance data.

tics for the 1.6 GHz application are provided for reference. This sample power amplifier is designed with a λ/4 impedance conversion circuit.

In general, the input impedance of a device contains lead inductance. Hence, it can be replaced with an equivalent circuit as shown in Figure 3a. To simplify circuit design, the serial circuit shown in Figure 3a is converted to a parallel circuit (Figure 3b). For this conversion, the following expressions are used:

$$R_p = R_S \left[1 + \left(\frac{X_S}{R_S}\right)^2\right] \quad (1)$$

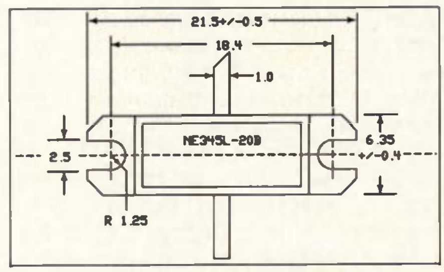


Figure 1. Outline drawing.

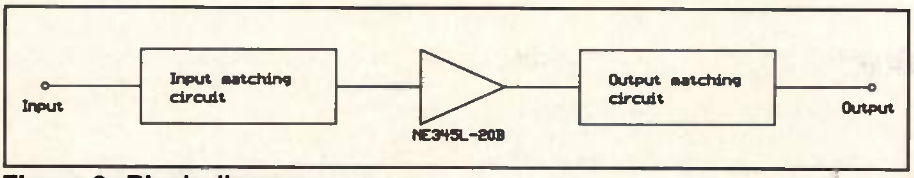


Figure 2. Block diagram.

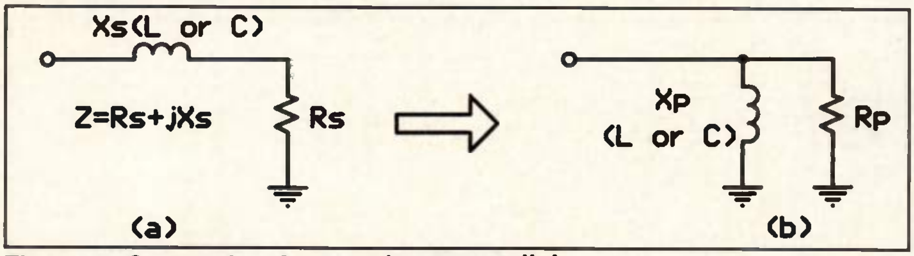


Figure 3. Conversion from series to parallel.

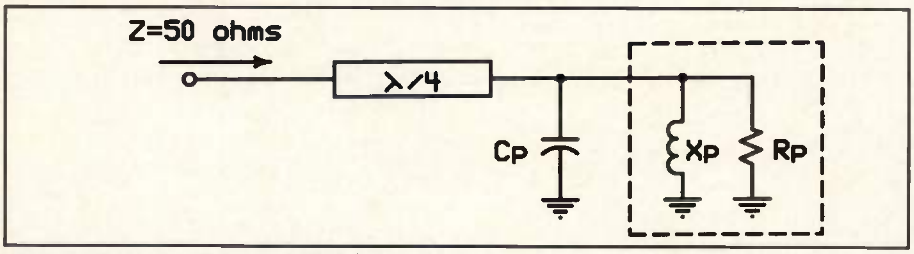


Figure 4. Impedance matching.

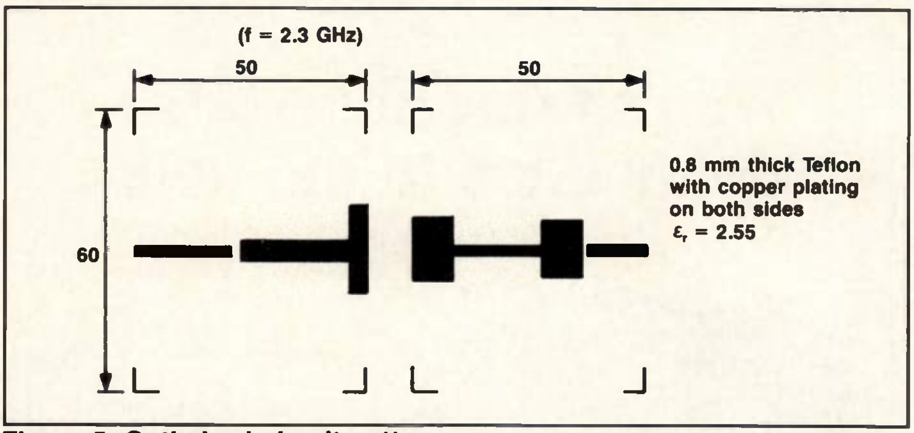


Figure 5. Optimized circuit pattern.

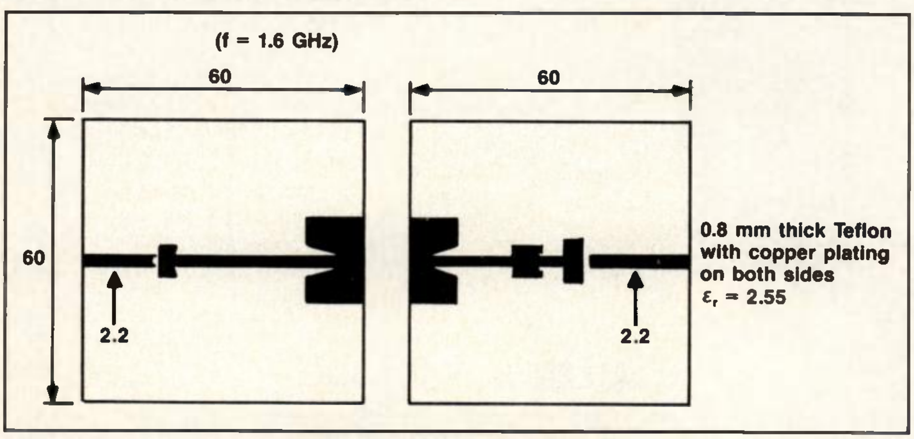


Figure 6. Actual circuit pattern after trimming.

$$X_P = R_S \cdot \frac{R_P}{X_S} \qquad (2)$$

Here, impedance can be restricted to the real part by connecting C_p in parallel to cancel X_p (equal impedance) as shown in Figure 4. The actual value of C_p can be obtained by first obtaining the values of R_p and X_p from expressions 1 and 2:

$$R_P = 11.5\left[1 + \left(\frac{8.9}{11.5}\right)^2\right] = 18.39$$

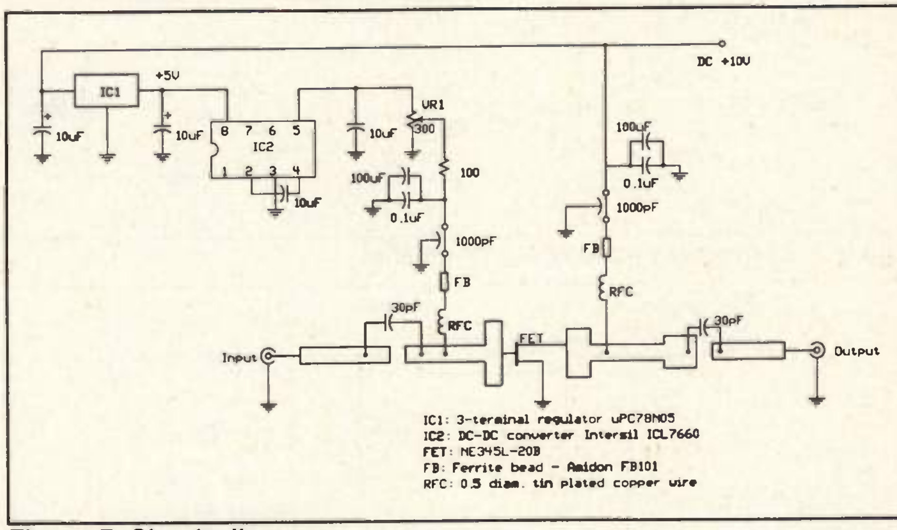


Figure 7. Circuit diagram.

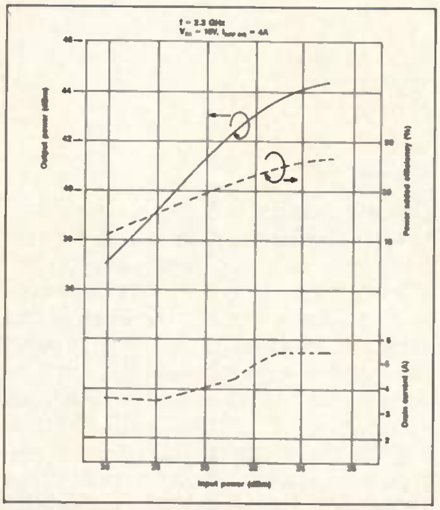


Figure 8. 2.3 GHz 20W Class A amplifier I/O characteristics.

$$X_P = 11.5\left(\frac{18.39}{8.9}\right) = 23.76$$

Therefore,

$$C_P = \frac{1}{2\pi f_C X_P} =$$

$$\frac{1}{2\pi(2.3 \times 10^9)\ 23.76} = 2.91 \text{ pF}$$

With the value of C_p determined, input impedance (the real number part only) is matched with 50 ohms using the following expression:

$$Z_o = \sqrt{50 \times R_P} = \sqrt{50 \times 18.39} = 30.3\Omega$$

Such a converter can be realized by setting characteristic impedance for the $\lambda/4$ transmission path shown in Figure 4 to 30 ohms.

If C_p is not a centralized constant but a distributed constant (open stub type), its

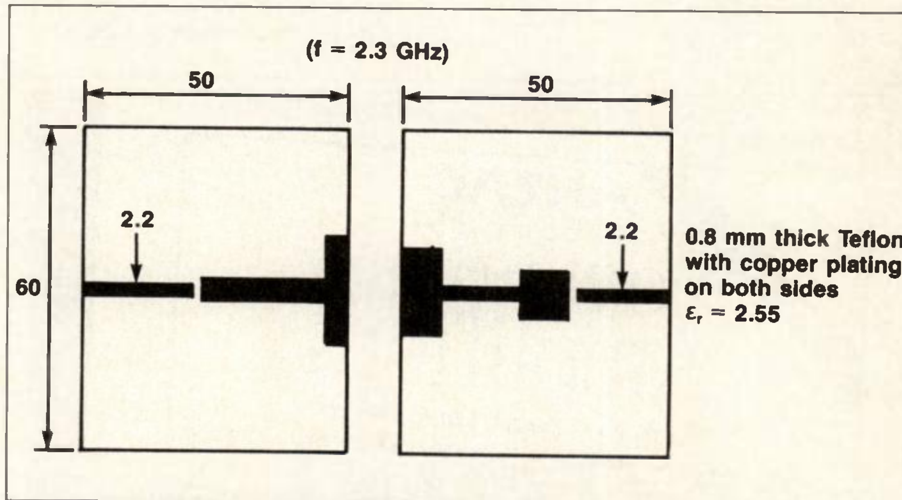


Figure 9. Actual pattern at 1.6 GHz.

length can be calculated using expression 7.

$$l = \frac{\lambda \tan^{-1} (2\pi f\, C_P Z_o)}{2\pi} \qquad (7)$$

where, l is length of open stub (cm);
λ is wavelength (cm);
f is frequency (Hz); and
Z_o is open stub characteristic impedance

$$l = \frac{13.04 \tan^{-1} (2\pi \times 2.3 \times 10^{9} \times 2.91 \times 10^{-12} \times 30)}{2\pi}$$

$$= 1.87 \text{ cm} \qquad (8)$$

The output matching circuit can be designed using the same procedure used for the input matching circuit.

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$R_P = 43.29\Omega$
$X_P = 9.774\Omega$
$C_P = 7.08$ pF
$Z_o = 46.52\Omega$
$l = 2.32$ cm

Circuit Design

After determining the values for various circuit elements (taking into consideration such factors as the thickness and specific dielectric constant of the substrate material to be used), circuitry constants are optimized using a microwave circuit CAD package such as Touchstone® or SuperCompact®, using the above figures as initial values. Figure 5 shows an optimized circuit pattern.

Circuit Adjustment

The device is mounted using the circuit pattern obtained from equation 7

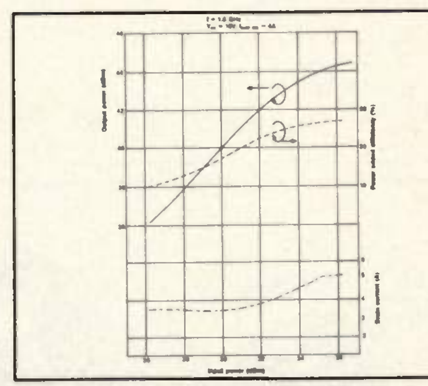


Figure 10. 1.6 GHz 20W Class A amplifier I/O characteristics.

and fine adjustments are made to generate maximum output. Theoretically, the best device characteristics are obtained from the pattern optimized for that purpose. However, some trimming is always necessary due to errors entering the circuit when the pattern is put onto the substrate, effects from chip capacitors for input and output DC cut, or a stripline to 50 ohms coaxial connector interfacing problem. Figure 6 shows an actual pattern after adjustments.

Circuit Diagram

Figure 7 shows the complete circuit diagram including the bias circuit. For this circuit, the bias circuit is simplified using a DC-DC converter IC to obtain a negative voltage for the base bias.

Tin plated copper wires are used for input and output RFC, or instead a high impedance (200-500 ohms) strip wiring path can be formed on the substrate. RFC should be connected as close to the device as possible (5-20 mm). If it is not close enough, low frequency (10-30 MHz) oscillations may occur.

Amplifier Characteristics

Figure 8 shows input and output, and efficiency and current characteristics of an actual 2.3 GHz 20 watt class A power amplifier. As the figure shows, linear gain (G_L) at 2.3 GHz is as high as 11 dB, and P_o (1 dB) is 43 dBm (20 watt) or higher.

Note that since this amplifier is a high power consumption device, a heat dissipator with high capacity should be used to prevent overheating. Also to be noted is that circuit adjustment should first be performed at an input power of about 30 dBm. Final adjustment should be performed at the specified input power of 34 dBm.

1.6 GHz 20 watt Amplifier

For a 1.6 GHz amplifier designed using a procedure similar to that used for the 2.3 GHz unit, calculated values are as follows:

Input side:	Output side:
$R_P = 20.4\Omega$	$R_P = 8.6\Omega$
$X_P = 8.6\Omega$	$X_P = 8.2\Omega$
$C_P = 11.6$ pF	$C_P = 12.1$ pF
$Z_o = 32\Omega$	$Z_o = 20.75\Omega$
$l = 2.42$ cm	$l = 2.45$ cm

Figure 9 shows the actual circuit pattern for this amplifier while Figure 10 shows its characteristics.

Summary

This report covered the design procedure, circuit and characteristics of an L band 20 watt Class A amplifier using the NE345L-20B GaAs power FET. In the past, silicon bipolar transistors were used primarily as L band Class A operation power devices. Due to the relatively low output per unit and gain of these devices, several units had to be connected to obtain the required output, resulting in the need for a large device mounting area. Such amplifiers also required tedious circuit adjustment work. Because the NE345L-20B is designed to take advantage of the advanced features of the GaAs FET, it enables the design of a high gain and output power amplifier with a much smaller device mounting area requirement, contributing to the reduction in size of mobile communication equipment. rf

About the Author

Katsunori Miyagaki joined NEC in 1974 as a design engineer and is presently supervisor of applications engineering for microwave GaAs products and microwave silicon power transistors. He can be reached through Robert J. Tyson at California Eastern Laboratories, Inc., 3260 Jay St., Santa Clara, CA 95054. Tel: (408) 988-3500.

Quartz Crystals and Aperiodic Oscillators in RF Systems

Part 2: Oscillator Circuit Configurations

By Dr. I.J. Dilworth
University of Essex

There is no doubt that someone must have said that an oscillator is an amplifier gone wrong. Certainly there should not be any RF engineers, worth their title, who have not experienced a self oscillating amplifier. It is useful to remember that whether an oscillator be controlled by a simple RC or LC circuit, coaxial or waveguide cavity, stripline resonator, ceramic resonator, SAW device, dielectric resonator, YIG sphere or quartz crystal, the common element is an amplifier capable of providing greater than unity gain feedback at the oscillation frequency. As was indicated in Part I of this article (August RF Design*), a requirement of oscillator design is that it be properly matched to the resonator.*

Pierce and Colpitts feedback oscillator circuits have proved to be the most reliable and repeatable performers for most non-specialized quartz crystal oscillator requirements. The Pierce circuit offers some advantages over the Colpitts particularly at higher frequencies where frequency stability is better. However, the Colpitts is easier to design and get going over a wide frequency range since in its simple form it is aperiodic, or untuned.

It should be noted that different crystal oscillator configurations force oscillation at differing operating points. This should be taken into account in overtone oscillator design selection and in specifying the exact frequency for a crystal. For example, the Pierce circuit operates at about 10-40 ppm above the series resonant frequency of the crystal whereas the Colpitts overtone circuit (Figure 4) typically operates 30-200 ppm above series resonance.

It is difficult to analytically predict the exact frequency at which oscillation will occur for a given crystal in various circuit configurations. If possible, the chosen circuit and component values should be supplied to the manufacturer when ordering the crystal unit to avoid gross errors.

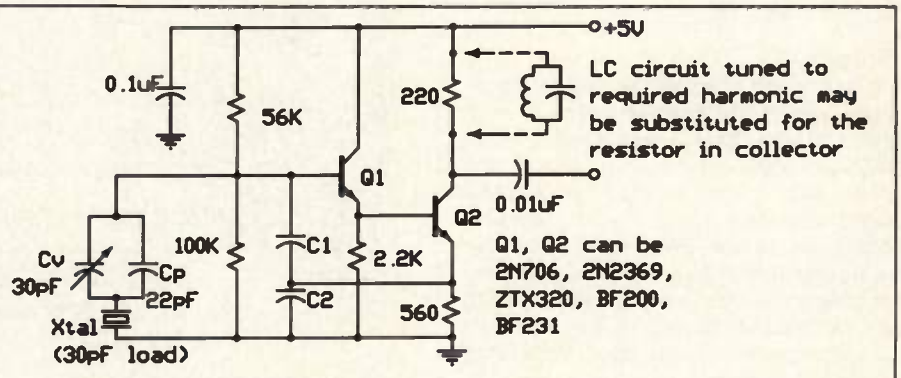
Figure 1 shows a Darlington configuration and bipolar transistors in a feedback oscillator which is based on a Colpitts circuit. Although the circuit requires two active devices, the component count is not significantly greater than the more usual single transistor Colpitts oscillator. The first and most helpful is that the gain provided by the two stages and subsequent lack of loading effects from the first transistor mean that the oscillator works reliably with crystals up to the 5th overtone and frequencies up to about 90 MHz. In addition, useful output levels can be expected and loading of the output transistor does not significantly effect the oscillator. The major attribute however proves to be the repeatability and reliability of the configuration to quartz crystal controlled oscillation even when using "sluggish" or high ESR crystals.

Frequency Adjustment

Of course the main virtue of using a quartz crystal, instead of an LC oscillator, is to take advantage of the intrinsic frequency stability of the material when used in an oscillator configuration. Assuming the circuit and crystal have been well defined and specified, then for most applications there is no requirement for the provision of frequency trimming or adjustment to a quartz crystal controlled oscillator. The introduction of frequency trimming components can deleteriously affect the frequency stability. Nevertheless the provision of such adjustment is worthwhile if it permits using a cheaper crystal specification and it also allows for compensation of any subsequent drift due to aging.

Figure 2 indicates that, below and at resonance, the slope of the reactance is relatively small compared to above resonance in the capacitative region, where the slope increases rapidly. Frequency change due to a series variable capacitor C_{vs} (which shifts frequency upward) is:

$\delta F = -C_1/2\ (C_o + C_{vs})$ ppm/F
(typically 10 ppm)



For fundamental mode crystals:

Frequency	C1pF	C2pF
3-6MHz	560	470
6-15MHz	560	220
15-30MHz	220	100

Note: The parallel combination of $((Cv/2)+Cp)^{-1} + C1^{-1} + C2^{-1}$ should approximately equal the crystal load capacitance

Figure 1. Feedback oscillator

In Figure 2, the reactance curve when a series capacitance is included, indicates the upward frequency shift and the increased slope of the reactance. Similarly a series inductance produces a downward frequency displacement and lowering of the reactance slope indicates a greater available frequency shift but at the potential expense of losing frequency control from the crystal. The combined reactance of an inductance and capacitor can be also used to vary the crystal frequency around resonance.

Figure 3 indicates one method a varactor diode element can be used in such a configuration. Care should be exercised to avoid exceeding the approximate 0.6 V forward bias voltage of the varactor. This will happen if the crystal RF voltage is allowed to develop to a higher potential. Although in this example a capacitive divider is used to reduce the capacitive swing available from the varactor (and hence across the tuned circuit) and at the same time the RF potential across the varactor, it should be remembered that relatively large AC potentials can develop across parallel tuned circuits so caution is required when employing such configurations. For example, it may be useful to employ the effective damping properties of a relatively low Q varactor in the circuit shown in Figure 3.

In the Colpitts circuit using series resonance and fundamental mode, a variable series capacitor can be used (usually in parallel with a fixed capacitor) to provide a few hundred hertz of frequency adjustment capability. The usual design criteria is that the series combination of the two feedback capacitors and the mid value of the variable capacitor (plus any parallel capacitor) should approximately equal the specified crystal load capacitance.

Although not recommended, such an arrangement also works well with 3rd overtone crystals providing sufficient frequency variation to allow for very minor frequency adjustment which will result in

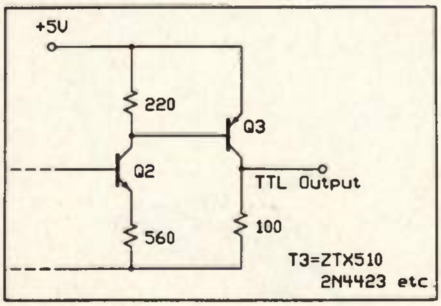


Figure 1B. TTL output

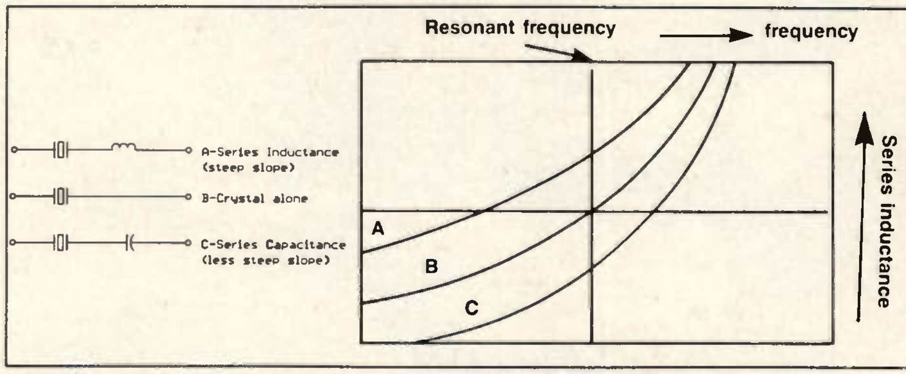


Figure 2. Behavior of crystal close to its resonant frequency

increased frequency. For a larger frequency swing, allowing for greater circuit parasitics due for example to the shunting effect of the oscillator amplifier and to stray capacitances, an impedance inverting form of the Colpitts circuit can be employed by introducing a small series inductance with the crystal. Note that in this case if the crystal is short circuited (to ac), an LC Colpitts is formed and oscillation will take place at the resonant frequency of the LC components. Reintroducing the crystal will then govern the frequency of oscillation provided that the reactive slope at the crystal resonance is high enough.

Crystals manufactured for a high inductive component and hence steeper reactance slope cannot be pulled in frequency as much as lower inductance crystals. Hence for VXO applications low inductance and consequently ESR crystals should be used.

The provision of frequency shifting in quartz crystal controlled oscillators is not without drawbacks. The variable capacitors and inductors need to possess zero change in value with variation in temperature. Otherwise, they may seriously affect the intrinsic frequency controlling characteristics of the quartz crystal. Since it is not possible, in reality, to control these effects, there is no reason to overspecify the quartz crystal ppm/ C characteristics if such adjustment are incorporated.

Fundamental Mode Operation

Fundamental mode frequency oscillation is straightforward. Feedback is provided by capacitors C_1 and C_2 as shown in Figure 1. A range of suitable values for these capacitors for frequency up to 25 MHz is shown in the table in Figure 1. The specified crystal load capacitance should approximately equal the series combination of C_1 and C_2 and any trimming capacitance used in series with the crystal.

The NPN transistors used are not in any way critical provided they are capable of operating with significant gain at least five times the oscillation frequency. Useful available types are shown as well.

TTL Output from a 5 V Supply

Fundamental oscillators most frequently find applications in logic systems where TTL drive levels are required and fan-outs that commensurate with simple logic gates have to be provided. Therefore, the designer is sometimes faced with designing an oscillator in the 1-20 MHz range which will work from a 5 V supply rail (to avoid having to employ a dedicated higher voltage supply to the oscillator) and provide TTL compatible outputs.

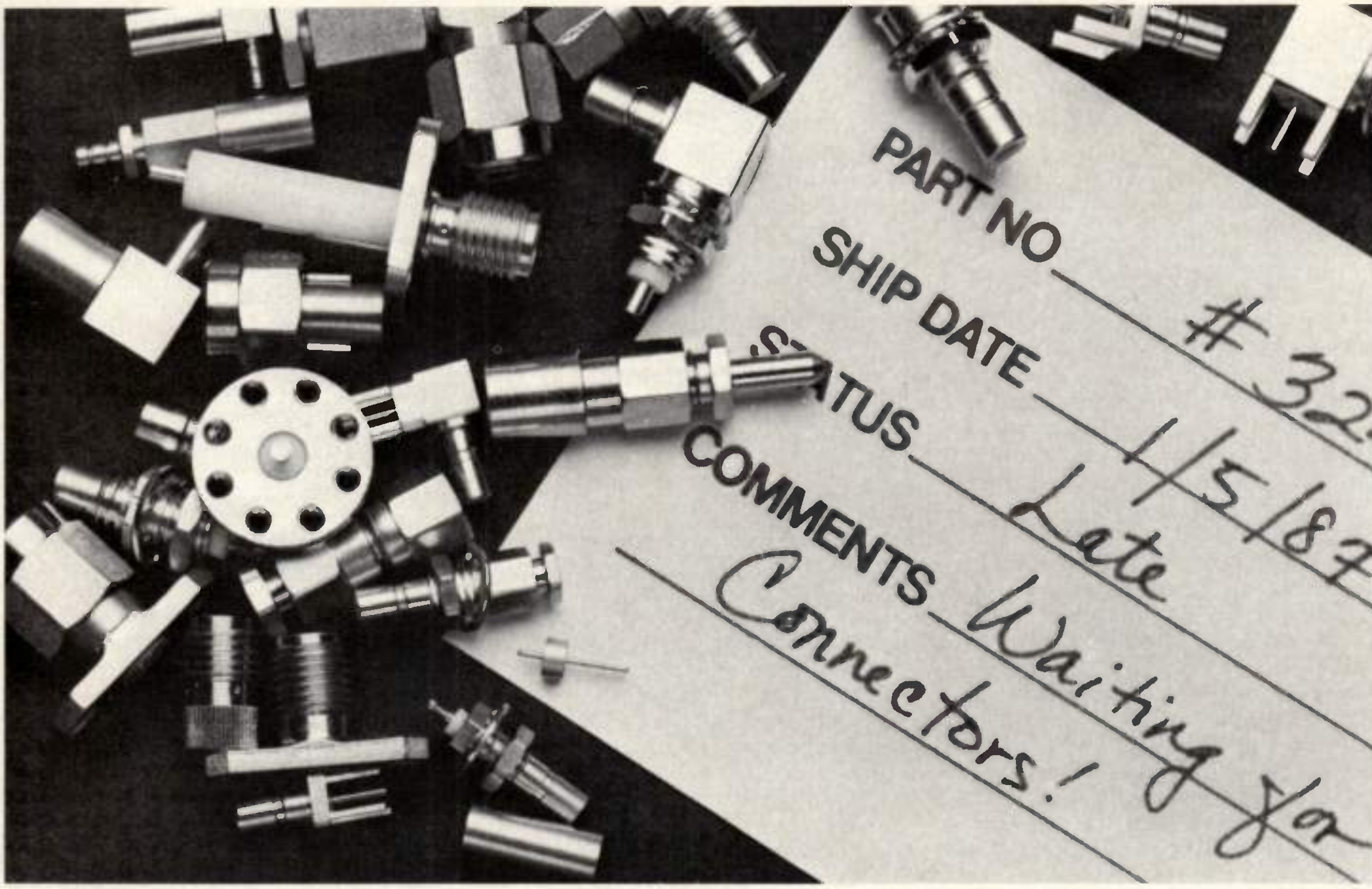
A minimum component count arrangement using a 5 V supply and a single PNP output stage was developed. The oscillator and driver circuit shown in Figure 1b was optimized for this application.

Harmonic Colpitts for 3rd and 5th Overtone Operation

Overtone operation using this circuit configuration is straightforward and reliable. The principle variation to the circuit shown in Figure 1 is that the feedback path is modified to enhance feedback from the output to the input at the desired overtone frequency. In fact, in practice it is not necessary to employ anything other than a crude approximation to ensure reliable operation. Referring to Figure 4, an inductor L is placed in parallel with C_2 so that the approximately resonant frequency of the combination is given by:

$$(f_f \times f_n)^{0.5}$$

Where f_f is the fundamental frequency of the crystal and f_n is the frequency of the desired overtone. The capacitor in series with the inductor L serves to provide a DC block. Its reactance at the fundamental frequency needs to be low so that the low reactance of L provides a low impedance path for the fundamental fre-



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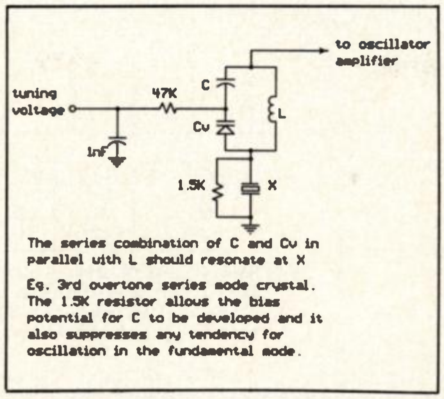


Figure 3. Colpitts circuit

quency and hence, in combination with the capacitive potentiometric divider provided by C_1, produce little feedback at the unwanted fundamental frequency.

A convenient practical characteristic of this circuit configuration is that the resonant frequency of the feedback network is not at all critical and a wide frequency range can be accommodated before unwanted modes of oscillation occur.

7th Overtone Crystal Oscillator

The circuit configuration shown in Figure 4 works reliably with crystals cut for their third and fifth overtones and has been tested up to about 90 MHz. However, the configuration is not recommended for seventh and ninth overtone operation. Seventh and ninth overtone crystals are sometimes used for local oscillators in VHF receivers, microwave frequency synthesizers and the like. In such applications they can be required to oscillate up to about 200 MHz. In the author's experience, however, although the Darlington configuration will work using seventh overtone and 150 MHz, it will only do so if the crystal has a low ESR and lead lengths are kept short. The circuit shown in Figure 5 has proved to be a very reliable and trouble free circuit configuration suitable for third, fifth, seventh and ninth overtone operation.

Feedback is again provided by C_1 and the resonant tuned circuit comprises the parallel combination of C_2 and L. The tapped inductor, at 108 MHz for example, can be self supporting and approximately 6 turns of 10 mm diameter airspaced wire with 22 pF resonating variable capacitor are suitable, tapped approximately half way. Separating the windings by the wire diameter allows the use of tinned copper wire so that there is no problem finding and soldering onto the required tapping point. Preformed plastic former coils are unsuitable for tapped applications because they melt under the action of the soldering iron and although the circuit is suitable for operation at lower overtones (and frequencies) the $L - C_2$ combination become larger and it is necessary to use enamel insulated wire and a supporting coil former for the inductor.

In this circuit the single FET does not provide much, if any, load isolation and the output needs to be buffered if the load is going to be in any way variable. Some care is needed in the adjustment of this oscillator configuration because if the feedback network is too far off the geometric mean frequency $(f_f \times f_n)^{0.5}$, self oscillation can occur. If the network is anywhere near correctly adjusted to the required frequency, the oscillator locks onto the crystal frequency and is then controlled by the crystal.

Frequency Multiplication using Fundamental and Harmonic Colpitts

The oscillators described are all aperiodic in the sense that no tuned circuits are employed. However, multiples of the crystal oscillation frequency can be selected by tuning the output collector (with a parallel tuned circuit) to the desired harmonic (Figure 1). This configuration can provide sufficient local oscillator injection for MOSFET based mixers when using 3rd overtone crystals, thus avoiding the need to employ separate multiplier stages. Some pulling of the crystal frequency may be experienced and the impedance inverting Colpitts arrangement employing an inductor in series with the crystal may be required to shift the operating frequency of the crystal sufficiently.

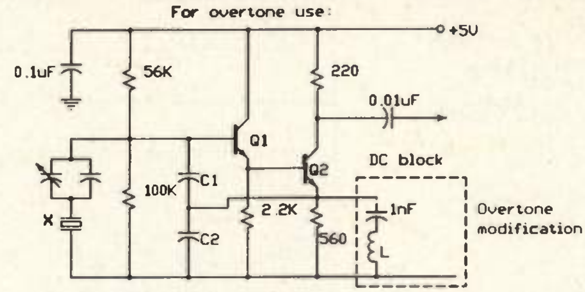
As mentioned in Part 1, the designer must bear in mind that in addition to multiplying frequency drift by the frequency multiplication factor (N), the phase noise on the sidebands of the fundamental oscillator is also multiplied by 20 log(N). It is worth noting from the systems viewpoint that the inverse process can be a powerful adjunct to improving reciprocal mixing problems since dividing the frequency source improves the phase noise of the sidebands by the same 20 log(N) factor.

Pierce Harmonic Configuration

According to Matthys (ref. 5), the Pierce circuit configuration shown in Figure 6 operates well at 100 MHz (although not constructed and tested).

Recommendations

The Colpitts fundamental and harmonic oscillator configurations described work



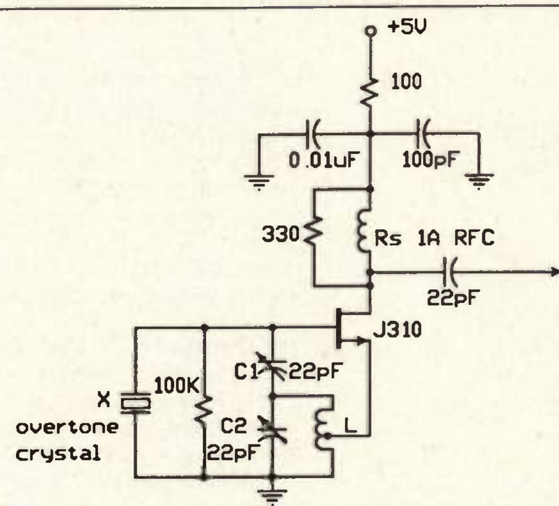
Frequency X	C1(pF)	C2(pF)
3-6MHz	560	470
6-15MHz	560	220
15-30MHz	220	100

Q1 and Q2 can be 2N706, 2N2369, 2N5179, ZTX320, 2N918, BF200, BF180, BF181, BFQ31(600MHz)

Note: L1 and C2 should resonate at approx. the geometric mean frequency of the desired overtone and the fundamental output frequency.

ie. $f_g = (F_{fundamental} \times F_{overtone})^{1/2}$

Figure 4. Colpitts oscillator for overtone use.



From 50 to 90 MHz, inductor L can conveniently be an RFC(radiospares 1 amp) with the windings removed one turn at a time until operation is found to be reliable. The oscillator free runs until it locks onto the crystal frequency as the tuned circuit (L and C2) presents sufficient impedance at the required overtone crystal.

Figure 5. 5th and 7th overtone oscillator configuration.

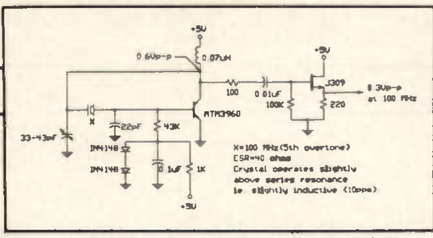


Figure 6. Pierce harmonic oscillator configuration.

reasonably well. The configuration used on overtone crystals have some deficiencies in terms of attainable frequency stability and output impedance compared to the Pierce circuit but it is easier to adapt to a wide range of frequencies.

If the requirement calls for a high stability crystal, it would be wise to order an overtone type with a high inductance value. However, do not expect such a crystal to work well in a VXO circuit. For that, a low inductance unit is required preferably operating in the fundamental mode. Low inductance crystals usually have lower working Q than high inductance units when used in VXO circuits. Therefore, care is needed to ensure the crystal keeps control of the high gain amplifier used to produce the feedback oscillator. The greater the stability of the crystal the greater its inductive component and ESR. If possible, use fundamental mode crystals for VXO and TXO applications and where stability and non-pullability are required overtone crystals are appropriate. rf

References

1. B. Parzen, *Design of Crystal and Other Harmonic Oscillators*, Wiley Books.
2. U.L. Rohde, *Design of PLL Frequency Synthesizers*, Prentice Hall.
3. The *1987 ARRL Handbook*.
4. Data Sheet, Jan Crystals, 1973.
5. R.J. Matthys, "Crystal Oscillator Circuits for VHF," *RF Design*, May 1983.
6. "Practical Circuits" Data Sheet, Euroquartz Ltd.
7. "Typical Oscillator Circuits," IQD Ltd.
8. Cathodeon Crystal Chart.
9. D.A.T.A. Book *1987 Transistors*, 57th Edition.
10. *Crystal Hybrid Oscillators/Precision Crystal Oscillators*, Crystal Catalog, CTS Knights Div.
11. R. Harrison, "A Survey of Crystal Oscillators," *Ham Radio*, March 1976.

About the Author

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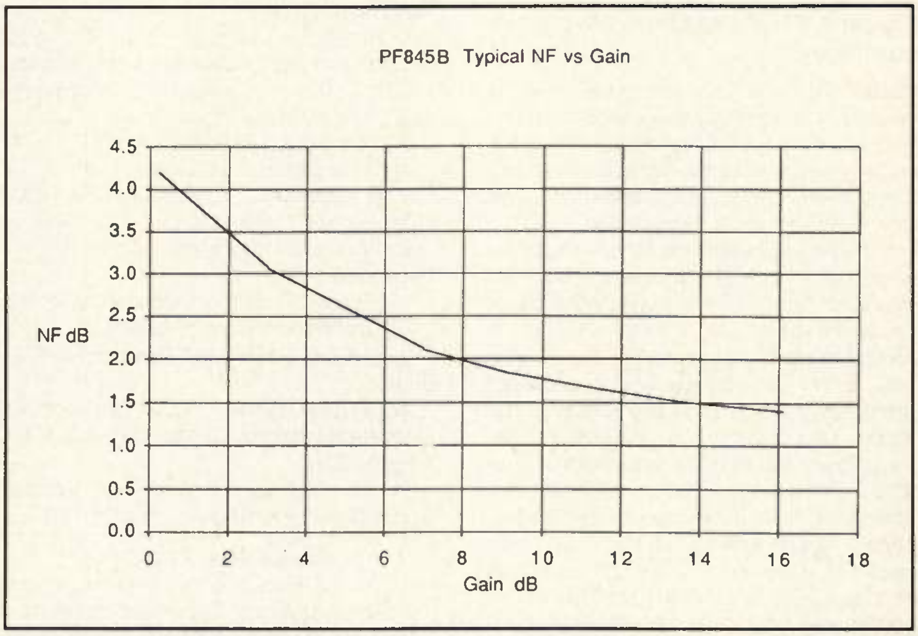
Janel Introduces a GaAs FET Amplifier

The PF845B uses two GaAs FET devices in a hybrid configuration. This is done to insure stability while providing low input and output VSWR. The device is configured in such a way that failure of a single transistor will result in a 6 dB reduction in gain although the amplifier continues to operate.

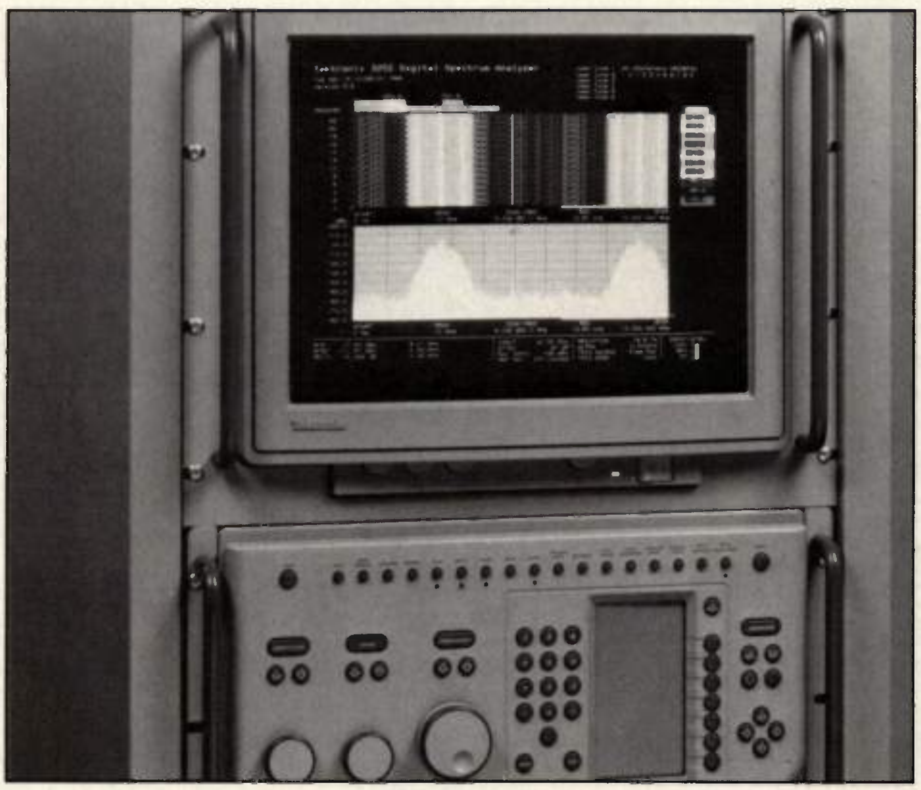
The standard frequency range is 821 to 851 MHz while any 30 MHz band between 800 to 960 MHz can be specified. Gain adjustment (at min.) is less than 7 dB and gain adjustment at the maximum is typically 16 dB. Gain flatness measured at 11 dB gain is ±0.5 dB. Also measured at 11 dB gain is noise figure which is 2.0 dB max. Third order intermodulation intercept point at the same gain is +28 dBm while 3rd order output intercept point at full gain is typically +36 dBm. Typical 1 dB compression at full gain is +24 dBm. Other specifications include a VSWR of 1.5 (at 11 dB gain), unconditional stability and impedance of 50 ohms.



The 845B has a self contained PIN attenuator that is controlled by a front panel screwdriver adjustment. The attenuator follows the amplifier to minimize the effect on noise figure as the attenuation increases. The output intermodulation intercept point decreases dB for dB with the attenuation level as does the 1 dB compression point. Note, however, that the input intercept and compression points are independent of the attenuator setting. Price for this amplifier is $505 each when purchased in quantities of 1 to 4. **Janel Laboratories, Inc., Corvallis, OR. Please circle INFO/CARD #212.**

Digital Spectrum Analyzer from Tektronix

The Tektronix 3052 has 2 MHz real-time and nearly real-time 10 MHz capabilities together with an 800-element span resolution to 1.25 Hz. It has a bank of 1024 parallel digital filters and 200 us spectral output rates in single bands to 10 MHz with continuous real-time spectral displays on bands to 2 MHz.



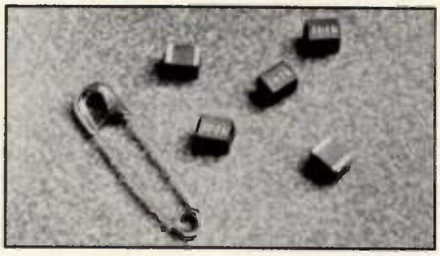
The digital spectrum analyzer is useful in various applications including communication channel fault characterization, laser testing, and frequency monitoring or surveillance. The instrument has a block capture mode where sequential spectral frames can be stored and recalled or scrolled. For example, the spectral before and after a synthesizer's frequency hop can be examined for splatter, carrier attenuation between hops and synthesizer lock-in time. Time triggers and spectral event detection offer further power for triggering captures of elusive transient occurrences.

Features of the instrument include a detachable front panel, menu driven operation, keystroke macro capability, recallable set-ups, zoom control, dual window display and processing, color monitor, and 13 frequency display spans ranging from 1 kHz to 10 MHz with total coverage of DC to 10 MHz. Display formats include amplitude-frequency, amplitude-time, phase-frequency, spectragram and waterfall. Summaries for simpler and faster assimilation of information include display updating on every Nth selectable spectral frame with additional selections for display of averages, peaks or minimum/maximum taken over N frames. Actual spectral is done with linear-phase, finite-impulse-response (FIR) filters.

The 3052 digital spectrum analyzer is $75,000, GPIB interface is $1,995, real time interface is $9,500 and color copier interface is $1,495. **Tektronix, Inc., Beaverton, OR. INFO/CARD #211.**

Shielded Chip Inductor

ICS Manufacturing introduces the CS2014 shielded chip inductor with a range of 1.0 uH to 1000 uH and a minimum Q of 50. Since the component is 100 percent ferrite, it provides greater interference protection than conventional units. Standard tolerances are 10 percent from 10 uH to 1000 uH and 20 percent below 10 uH, with 10 percent obtainable by special order. CS2014 is packaged in bulk and tape and reel and prices range



from $.50 per unit depending on quantity and inductance. The chip measures 0.199" × 0.144" × 0.125". **ICS Manufacturing, Inc., Fountain Valley, CA. Please circle INFO/CARD #209.**

Frequency Synthesizer

Model S-505 features a frequency range of 325 to 850 MHz and switching speed of 150 us. Phase measured at 400 MHz with 100 Hz offset from the carrier is −90 dBc. The device is designed to accept an external reference. When a reference of 1 MHz used, the step size for the S-505 is 2 MHz. RF output is provided by an SMA connector and power level throughout the range is 13 dBm ±1.5. Spurious signals are less than −60 dBc over the entire range. Model S-1000 has a frequency range of 800 MHz to 1200 MHz with the same performance characteristics as the S-505. Price for either unit is $950. **Z-Communications Inc., Ft. Lauderdale, FL. INFO/CARD #207.**

FET-Input Op Amps

The AD845 FET-input op amp from Analog Devices features a settling time of 350 ns to 0.01 percent into a 500 ohm/100 pF load. Total harmonic distortion (THD) below 0.0001 percent make the device suitable for driving high-speed ADCs and DSP system front ends and for high performance sample and hold circuits. Performance includes input offset voltage of 250 uV with drift of less than 5 uV/C. Noise is 94 dB max. Packaging options include plastic 8-pin DIP and hermetic cerdip. Pricing for the AD845K grade begins at $9.50 (100s). **Analog Devices, Inc., Wilmington, MA. INFO/CARD #205.**

RFI/EMI Shield

FLEXcon introduces FLEXguard, a line of flexible pressure sensitive foil/film laminates which can shield electromagnetic and radio frequency interference. It consists of a layer of foil which provides electrical conductivity for reflection and absorbtion. The foil is permanently bonded to a reinforcing substrate of polyethylene terephthalate via a heat seal adhesive and provides mechanical reinforcement, and insulation between foil and emitting circuitry. It is available in thicknesses from 0.00095" to 0.0051". **FLEXcon Company, Spencer, MA. INFO/CARD #206.**

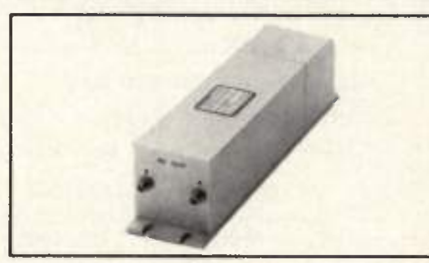
Crystal Clock Oscillator

Savoy's CMOS crystal clock oscillator product line has been expanded to include a DIP package (19.5mm × 6.8mm × 4.2mm) featuring high stability and low power. The S 2150 has a frequency range

of 62.5 kHz to 20 MHz while the S2650 has a range of 15.625 kHz to 20 MHz with rise and fall time of 5 ns(max). **Savoy Electronics, Inc., Fort Lauderdale, FL. INFO/CARD #208.**

RF Synthesizer

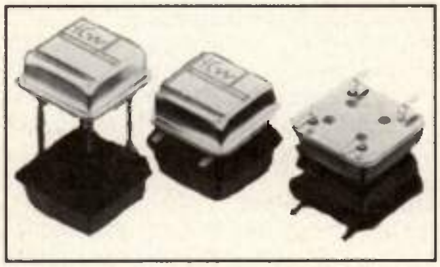
Model 26102CD consists of two independent synthesizers referenced to a 10 MHz internal TCXO. Both cover 135-185



MHz in 100 Hz steps and phase noise is −80 dBc/Hz at 10 Hz with −60 dBc spurious. Power output is 4 dBm and dimensions are 2" × 2" × 8". **Systematix, Lyndhurst, NJ. INFO/CARD #210.**

HCMOS Crystal Oscillator

Packaged in a metal hermetically sealed DIP measuring 0.5" square × 0.2" high,



the unit drives HCMOS or 2 LSTTL gates at any fixed frequency from 250 Hz to 35 MHz. Tolerance ranges from ±0.005 percent to ±0.1 percent depending on temperature range. **Connor-Winfield Corp., West Chicago, IL. INFO/CARD #204.**

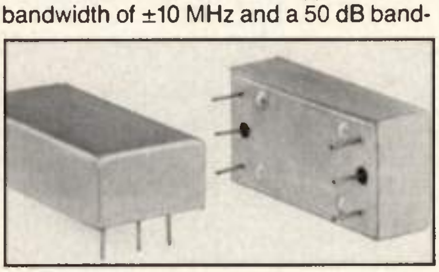
Frequency Synthesizer

The Luff Research Model SLS single-loop phase-locked frequency synthesizer covers octave bands to 1000 MHz and 500 MHz bands to 2 GHz. The units have 5 decades of frequency resolution and

can have fractional steps such as 25 kHz, 12.5 kHz and 6.25 kHz. It measures 6" × 4" × 0.8" and costs $1250. **Luff Research, Jackson Heights, NY. Please circle INFO/CARD #203.**

LC Filters

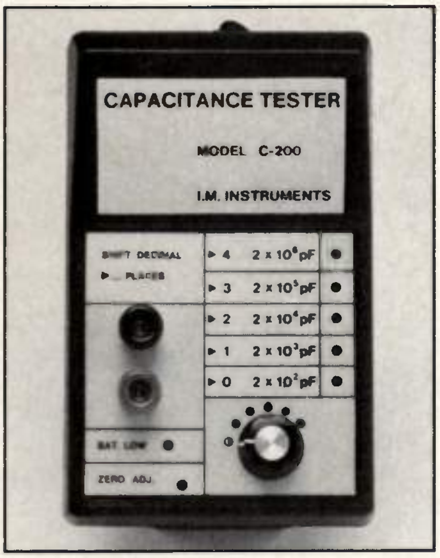
This LC filter line features a four-pole response with nominal frequency range of 150 MHz to 200 MHz. Typical 3 dB bandwidth of ±10 MHz and a 50 dB band-



width of ±60 MHz are available. Maximum insertion loss is 4 dB and load impedance is 50 ohms. **Piezo Technology, Inc., Orlando, FL. INFO/CARD #202.**

Capacitance/Inductance Measuring Devices

The C-200 is crystal controlled capacitance tester with ±0.1 percent accuracy that is intended for use with a digital



voltmeter. The instrument can measure capacitance down to 1/1000 pF with a 5½-digit voltmeter. It costs $149 and is powered with a 9 VDC battery. The L-200 is based on the same concept except that it measures inductance. Accuracy is ±1 percent and measurements as low as 1 nH can be taken. It costs $199. **I.M. Instruments, Brantford, Ontario, Canada. INFO/CARD #201.**

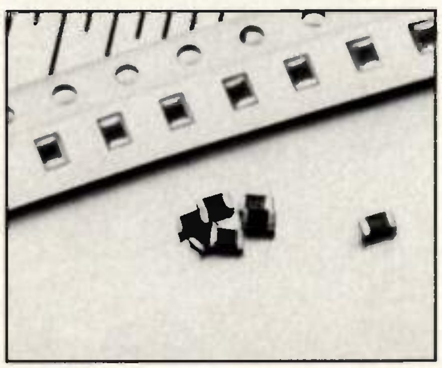
11-Port Splitter/Adder

Eleven 50 ohm sources can be interconnected with the Model 080-011. The device maintains 50 ohms in all ports. In the time domain, pulse reflections are less than 12 percent in a 70 picosecond rise time system. Bandwidth is DC to over 5 GHz and power rating is 0.611 watts. Con-

nector type is BNC female. **Bishop Instruments, Inc., Portland, ME. Please circle INFO/CARD #200.**

0.1 W Chip Resistor

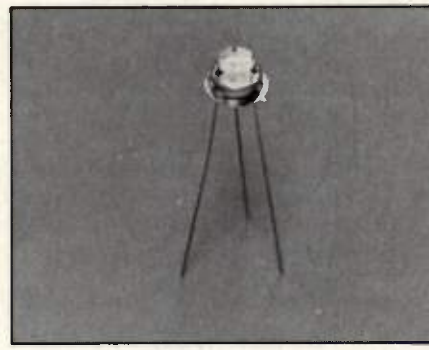
Bradford Electronics introduces a 1/10 watt thick film chip resistor. Designated the CR0805, the resistor can be ordered in a resistance range from 47 ohms to 1M ohm. Tolerances available include ±1 per-



cent (±100 PPM/C) and ±5 percent (±200 PPM/C). Dimensions are 0.079" × 0.049" × 0.018". One thousand pieces cost $19 for the 1 percent tolerance and $12 for the 5 percent tolerance. **Bradford Electronics, Inc., Bradford, PA. Please circle INFO/CARD #199.**

Quartz Crystals

Fundamental mode AT quartz resonators to 350 MHz and overtones to 500 MHz are available from IFCP. These de-



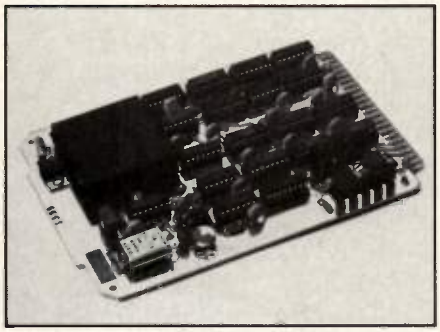
vices are designed for use in wideband filters, VCXOs and crystal oscillators. **Innovative Frequency Control Products, Inc., Plainfield, PA. INFO/CARD #198.**

Phase Noise Measurement System

The basic 2703 automates measurements to 100 kHz from carrier for sources to 500 MHz. Options include source frequency beyond 20 GHz, fourier frequency to 50 MHz, and system floor below −190 dBc/Hz at 5 MHz. A companion 5/10/20/100/500 MHz phase noise reference is also available. **Brightline Corp., Cedar Park, TX. INFO/CARD #197.**

Frequency Synthesizer

The SM-101 is a 4½ digit synthesizer which provides a TTL square wave signal into a 50 ohm load from 0.1 Hz to 16 MHz in eight decade ranges. Programming is accomplished by TTL compatible, parallel



BCD lines. Spurious is less than −60 dBc and settling time is 10 ms to within 10 percent of frequency step. Single unit price is $437. **Syntest Corporation, Marlboro, MA. INFO/CARD #196.**

Sweep/Function Generator

B & K introduces the Model 3017 which covers from 0.2 Hz to 2 MHz in seven ranges. Features include internal or external sweep/source capability with continuously adjustable sweep width to a maximum 1,000:1 ratio. Separate outputs are available for TTL/CMOS and other waveforms. Included is adjustable sweep time from 0.5 to 30 seconds with selectable linear or logarithmic operation. Sinewave distortion is less than 1 percent, with square wave symmetry better than 98 percent at 100 kHz and triangle wave linearity at 98 percent. Output level is continuously

adjustable from zero to −20 dB. It is priced at $319. **B & K - Precision, Chicago, IL. INFO/CARD #195.**

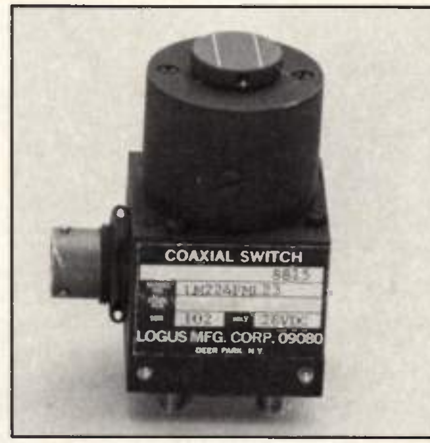
Pulse Generator

The 801P/N50 800 V pulse generator delivers 250 watts into 50 ohms with a minimum pulse width of 75 ns and maximum pulse width of 1 ms, continuously adjustable. It offers continuously variable pulse recurrence frequencies of DC to 5 MHz. Pulse rise and fall times at all fre-

quencies are less than 10 ns. The generator can be configured with an internal clock for use as a stand alone lab instrument or with TTL input for output amplitude and pulse width control for remote or ATE applications. It is available in both positive and negative polarities. **Directed Energy, Inc., Fort Collins, CO. Please circle INFO/CARD #194.**

Coax Switch

This coaxial switch (Model LMC224FML) operates at frequencies from DC to 18 GHz with insertion loss of 0.5 dB and isolation of 60 dB min. Included is one set



of C form indicator contacts, manual knob and latching operation. **Logus Manufacturing, Deer Park, NY. Please circle INFO/CARD #193.**

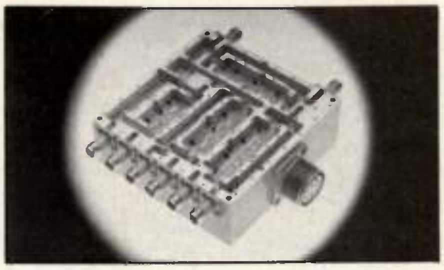
Portable FFT Spectrum Analyzer

Designated the R9211E, this portable FFT analyzer has dual channels which feature 16-bit resolution with 90 dB dynamic range and maximum input sensitivity of -140 dBV. It covers 10 mHz to 100 kHz and has a 25 to 3,200 line resolution. Input range settings are from +30 dBV to

−60 dBV in 1 dBV steps. **Advantest America, Inc., Lincolnshire, IL. Please circle INFO/CARD #192.**

Isolation Switch

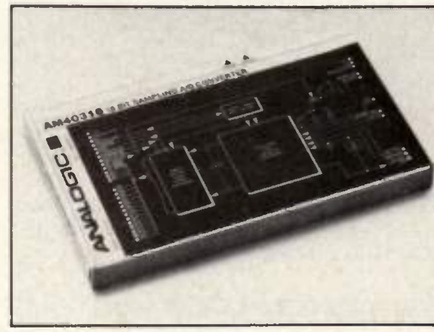
KDI/Triangle Electronics introduces a switched attenuator assembly which consists of six channels, providing calibrated attenuation levels from 2 to 60 dB over the 250 to 2000 MHz range. Internal wide-



band 6-way and 2-way power dividers are used to split signals into separate channels. It handles power levels up to +40 dBm with isolation levels exceeding 130 dB. Maximum VSWR is 1.4:1 and the assembly is TTL compatible. **KDI/Triangle Electronics, Whippany, NJ. INFO/CARD #191.**

Sampling A/D Converter

The Data Conversion Products Group of Analogic Corporation unveils the AM40316 high speed sampling A/D converter. It features 16-bit resolution and a 200 kHz sampling rate. Features include



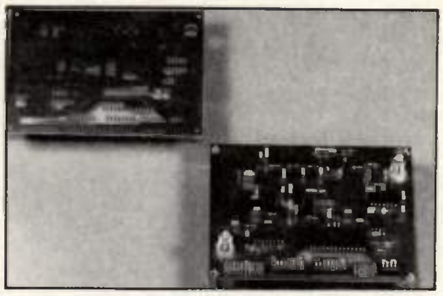
a differential non-linearity of ±0.5 LSB and −100 dB peak distortion. At 1 kHz input frequency, the device exhibits a signal to noise ratio of 88 dB, peak distortion of −100 dB and total harmonic distortion of −93 dB. **Analogic Corp., Peabody, MA. INFO/CARD #190.**

BNC and SMA Terminations

These 50 ohm terminations can be used from DC to 2 GHz (BNC) and 4.2 GHz (SMA) and have a maximum VSWR of 1.3:1. The design utilizes a male gold or silver plated connector and a MIL RCR high reliability resistor element. Dissipation is ½ watt CW and 1000 watts peak from −25 to +85 degrees C. The CT-53-BNC or SMA/M sells for $5.54 in 100-piece quantity. **Elcom Systems Inc., Boca Raton, FL. INFO/CARD #189.**

PLL Prototype Board

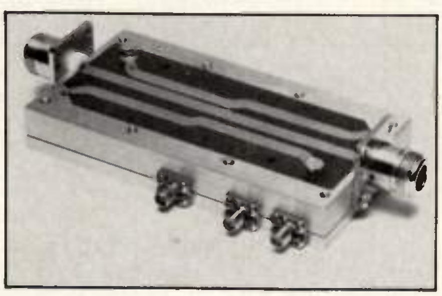
The PLL1 Quick Board serves as a basis for a 900 MHz phase lock loop synthesizer. Several PLL configurations can be implemented with user selected divide ratios, VCO, loop filter and associated components to be installed in the PLL1. It allows the designer to easily build a PLL so that parameters such as loop bandwidth, switching speed and oscillator phase noise can be optimized or to produce a low cost frequency source. The design is based on the Motorola MC145152 dual modulus, parallel interface synthesizer IC and uses common dividers and opamps. The loop filter is laid out for a



standard third order type 2 PLL. To filter unwanted reference sidebands, an active or passive low pass filter or both can be used. Frequencies are programmed with parallel data input provided by on-board dip switches. The PLL1 includes a circuit board, schematic, assembly drawing and an application note on how to build a PLL using the product. When purchased in quantities of 1 to 9, the Quick Board costs $95. **RF Prototype Systems, San Diego, CA. INFO/CARD #176.**

Tacan Coupler System

Merrimac introduces a high power subsystem designed to monitor the forward and reflected power of a Tacan radar transmitted signal. This stripline subsystem is provided with two detected outputs for each direction, one for redundancy purposes, each following the rise and



fall of the RF pulse. In addition, an RF port for direct signal monitoring and measurements in each direction is available. The subsystem is designed for input powers up to 15 kW peak, and 400 W average over the 960 to 1,215 MHz range. Coupling is within 0.2 dB and minimum directivity is 20 dB. Insertion loss is below 0.2 dB and VSWR is better than 1.06:1. This coupler sub-system measures 4.7" × 2.5" × 1.2". **Merrimac Industries, Inc., West Caldwell, NJ. INFO/CARD #175.**

Phase Locked Source

Comstron has unveiled a multiple output phase locked source that provides up to eleven high stability signal sources locked to a frequency reference. The PLS 1000 comprises a standard 5¼ inch rack chassis housing a reference distribution card and up to eleven phase locked loop source plug-in cards. Each source plug-in furnishes a locked frequency generator and output amplifier. This modular construction provides for ease of service as well as operational flexibility since new frequencies can be added or frequencies changed as the need arises. A front panel fault indicator shows if any of the sources are not locked, and each card has fault indicators for rapid fault isolation. Features include 1 kHz to 140 MHz operation. **Comstron Corporation, Melville, NY. INFO/CARD #174.**

Attenuators and Terminators

JFW introduces its thick film microstrip attenuators and terminator line. Standard products include 10 watt, 125 watt and 250 watt units. The attenuators use beryllium oxide ceramic substrates and thick film resistor inks to achieve good transfer of heat from the film area thru the substrate to the heat sink. Specifications for the A-210 series of 125 watt attenuators include frequency range of DC to 3 GHz, VSWR of 1.15:1 (DC to 1 GHz), and peak power rating of 1000 watts. The T-210 125 watt terminators have a range of DC to 3 GHz, VSWR from DC to 1 GHz is 1.15:1 and peak power of 1000 watts. **JFW Industries, Inc., Indianapolis, IN. Please circle INFO/CARD #173.**

Site Management Service

Antenna Systems announces the availability of a site management service to its base station antenna customers. The service is intended to simplify the optimum design of new antenna systems or pinpoint problems in existing ones. The company has created two computer programs from which it will generate accurate site studies, given appropriate data by the customer. One program produces precise pattern predictions allowing determination of the optimum installation parameters for side tower mounted omnidirectional antennas. The second program provides a full site intermod study when all transmit frequencies are known. **The Antenna Specialists Company, Cleveland, OH. INFO/CARD #172**

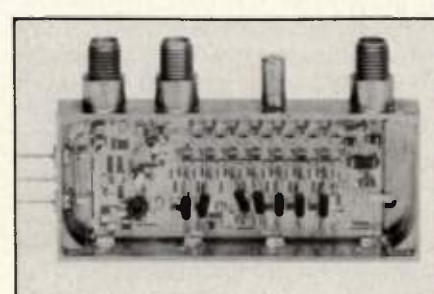
Air Core Inductors

The RL1233, RL1238 and RL1239 Series of air core inductors can handle high AC current without being driven into saturation. Available inductance values range from 0.56 uH to 33 mH and current

ratings from 1.4 amps to 22 amps. In quantities of 10,000, prices start at $.75 each. **Renco Electronics, Inc., Deer Park, NY. INFO/CARD #171.**

Log Amplifiers

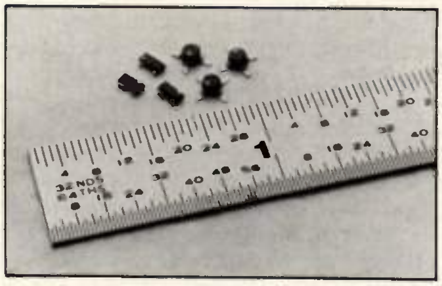
RHG Electronics introduces a line of logarithmic amplifiers designed for use in high frequency IF and frequency agile EW systems. Designated the MWL Series,



models are available with center frequencies from 1 to 2.5 GHz and operating bandwidths from 0.5 to 3.0 GHz. Log slope is 15 mV/dB and linearity is ±1 dB at 25 degrees C. **RHG Electronics Laboratory, Inc., Deer Park, NY. INFO/CARD #170.**

SMA Attenuators

These attenuators from Omni Spectra offer plug to plug, jack to jack and hex body designs. Designed in accordance with MIL-A-3933 requirements, these DC to 18 GHz designs are available in 0.5 dB steps to 10 dB, 1 dB steps to 20 dB and 30, 40, 50 and 60 dB values with a maximum VSWR of 1.35 at 18 GHz. In addition, all attenuators are available in both miniature and subminiature lengths. **M/A-COM Omni Spectra, Inc., Merrimac, NH. INFO/CARD #169.**



SMT Bipolar Transistors

The plastic packaged AT-41486 features 1.4 dB noise figure, 15 dB associated gain and 17.5 dB S21 gain at 1 GHz. The Model AT-41411 SOT-143 packaged unit has a 1.4 dB noise figure, 13 dB associated gain and 16.5 dB S21 gain at 1 GHz.

Also from Avantek is a series of 1 GHz, 5 volt, thin film cascadable amplifiers. The gain blocks are optimized for noise figures as low as 2.7 dB. Models UTO/UTC-554 and -558 cover 5 to 500 MHz while Models UTO/UTC-1054 and -1058 cover the 5 to 1000 MHz range. They are intended for 5 volt applications. Typical specifications for the UTO/UTC-554 and -558 are 29 dB gain with ±0.2 dB gain flatness, 2.7 dB noise figure, +10 and +14.5 dB output power and +21 and +23 dBm third-order intercept points respectively. Typical performance for Models UTO/UTC-1054 and −1058 are 24 dB and 24.5 dB gain with ±0.3 dB gain flatness, 3.5 and 3.7 dB noise figure, +10.5 and +13.5 dBm output power, and +21 and +23 dBm third-order intercept points, respectively. The UTO Models are housed in a TO-8 metal/glass hermetic package while the UTC Models are housed in a sealed aluminum case with SMA connectors. All models are fully cascaded and draw less than 40 mA. **Avantek, Inc., Santa Clara, CA. INFO/CARD #168.**

Software Performs Analog Circuit Analysis and Optimization

NETSIM provides the capability to perform analysis on analog circuits. Both frequency and time domain responses can be measured and plotted. Working from specified component tolerances, the program also performs Monte Carlo or tolerance/worst case analysis. Design goals can then be entered and yield estimates of a circuit made to predict the manufacturing yield of a design. It also extracts the network poles and zeros or transfer functions and performs a sensitivity analysis on the results.

NETOPT contains all the features of NETSIM while adding an optimization capability. Design goals can be specified for several different outputs of a circuit and optimization performed to adjust component values to meet specified goals. The circuit magnitude, phase or group delay may be specified for Minimax, least squares or constrained optimization. In addition the tolerance or standard deviation of the amplitude response may be specified as an optimization criteria. **RLM Research, Boulder, CO. Please circle INFO/CARD #215.**

Filter Synthesis and Analysis Program

PCFILTER designs active, lumped element passive, IIR and FIR digital, and custom switched capacitor filters, including elliptic. The analysis section performs circuit simulation, for user-file input, on arbitrary active and passive networks. The program is capable of designing lowpass, bandpass, bandstop, highpass and 90 degree phase splitters. Version 1.1 includes the ability to determine the poles and zeros of any filter from measured data. The order of the filter and transfer function can be generated using measured values of magnitude and phase response. It is tailored for IBM and compatible machines and is priced at $450. **Ellis Electronics, Inc., Vicksburg, MS. INFO/CARD #216.**

Oscillator Design Software

Circuit Busters has released a program for the design and analysis of oscillators. =OSCILLATOR= designs 16 different L-C, transmission line, SAW and quartz crystal oscillators. The program computes bias and RF component values based on user responses to program prompts. =OSCILLATOR= then writes a =SuperStar= circuit file, and =SuperStar= is used to analyze the open loop Bode response and to optimize the design parameters. The result is an optimum oscillator design which is well understood by the designer. The application frequency range is audio to approximately 2 GHz. =OSCILLATOR= also estimates the oscillator SSB phase noise, and integrates this noise over user specified baseband frequencies to derive the residual FM and PM modulation. The noise model includes the effects of Q, oscillation frequency, power level, flicker noise and varactor modulation noise.

The manual discusses non-linear topics such as starting, limiting, output power level, class-C power oscillators and harmonic content. Also considered are biasing, Q, voltage-controlled oscillators, crystal oscillator pulling and low-noise design. Case studies and tips for each oscillator type are included. The program runs on IBM PC/XT/AT/PS2 and compatible computers. DOS 2.0 or later, 512K and a parallel printer port are required. An

8087, 80287 or 80387 coprocessor is recommended and price is $495. **Circuit Busters, Inc., Stone Mountain, CA. INFO/CARD #177.**

S-Parameter Based Program

Puff is a general purpose scattering parameter based program for analyzing lumped and distributed elements and arbitrary multi-ports in a graphics environment. In the program, the user lays out microstrip and stripline circuits on the screen with cursor keys. The software can analyze circuits with transmission lines, lumped elements, coupled lines and arbitrary multi-ports. A frequency or time domain analysis can be made at any time. Puff also calculates voltage-transfer functions and allows the user to look from the outside ports into the circuit. Designing from the outside — in has the advantage that the parameters calculated are also the ones measured. The program, however, does not handle noise or nonlinear effects and does not contain an optimizer or matching routine. Puff is a public domain package and may be copied freely. **California Institute of Technology, Pasadena, CA. INFO/CARD #214.**

rf literature

Catalog Features Custom RF Cable Assemblies

This catalog describes high precision, high reliability RF transmission and delay line assemblies for EW, airframe, missile, phased array, and other applications. Complete semi-rigid cable assemblies feature SiO_2 insulation, million hour certified reliability, operation at temperatures from −300 degrees F to +1300 degrees F, operational frequency to 18 GHz and rugged hermetic connector designs. The catalog also details superiority of SiO_2 insulated cable assemblies over PFTE. **Kaman Instrumentation Corp., Colorado Springs, CO. INFO/CARD #218.**

Microwave/RF Products Handbook

K & L has updated its Microwave and RF Designer's Handbook — Microwave and RF Filters as well as the Coaxial Switches and RF Switching Matrices Handbook. The catalogs have been expanded and combined together to create a single handbook with products ranging from DC to 40 GHz. These products include all types of miniaturized bandpass, bandreject, highpass and lowpass filters as well as tunable filters, duplexers, multiplexers and subassemblies. In addition, the handbook offers a complete listing of coaxial switches and RF switching matrices to 26.5 GHz. **K & L Microwave, Inc., Salisbury, MD. INFO/CARD #188.**

Product Note Describes Measurement System

Product Note 8970B/S-3, "Noise Parameter Measurement Using the HP 8970B Noise Figure Meter and the ATN NP4 Noise Parameter Test Set," describes the operation and performance of these products from H-P and Automatic Testing and Networking, Inc. of Woburn, MA. The note includes some of the underlying theory of designing transistor networks as well as hardware descriptions. It describes numerous graphic plots and tabulations available, along with accuracy considerations. Some references are furnished. **Hewlett-Packard Company, Palo Alto, CA. INFO/CARD #219.**

Test and Measurement Instrumentation Catalog

The 1988-1989 Test and Measurement Instrumentation catalog from Wavetek Corp. contains descriptions, technical specifications, illustrations, prices and ordering information for the company's line of signal sources and measurement equipment plus related special equipment and components. The equipment categories covered include instruments on a card, WaveTest GPIB software, function and arbitrary waveform generators, pulse generators and waveform analyzers, RF signal and sweep generators, microwave signal and sweep generators, microwave scalar analyzers, microwave CW and peak power meters, precision digital multimeters, calibrators, datalogger systems, signal processing filters, signal switching systems, CATV signal level meters, CATV system analyzers, CATV system sweep and RF components. **Wavetek Corporation, San Diego, CA. INFO/CARD #178.**

Cable and Connector Selection Guide

This guide from Nemal Electronics provides specifications and photographs of connectors, wire and cables, accessories, adapters and cable assemblies. The connectors listed include BNC, miniature UHF, SMA, SMB, SMC, triaxial, twin BNC series, twinaxial, and UHF. Accessories shown include tools, cable ties, patch panels, and heat shrink tubing. Cable assemblies highlighted are RF, data, fiber optics and high voltage. **Nemal Electronics International, Inc., North Miami, FL. INFO/CARD #186.**

Components Brochure

This brochure covers isolators, circulators, and isodaptors from UHF to 24 GHz. Designs include coaxial and waveguide interfaces, narrowband and broadband ranges, for telecommunication, radar and EW application. **Harris Fairnon Components Div., Van Nuys, CA. Please circle INFO/CARD #187.**

Selector Guide and Cross Reference

This bipolar power transistor selector guide and cross reference from Motorola lists an alphanumeric cross reference between industry part numbers, Motorola direct replacement and Motorola similar replacements. From here, the user is referred to another section of the book which lists the relevant parameters. Selection by major product categories is published in the next section. The final part of this guide lists applications and selector guides. **Motorola, Inc., Phoenix, AZ. INFO/CARD #185.**

Test Equipment Product Guide

This guide contains illustrated reference information on the line of test equipment available as rentals from Leasametric. Listed are product indexes and a manufacturer's index with specifications and selection information. Products available include analyzers, meters, microwave equipment, signal sources, amplifiers and signal conditioning equipment. **Leasametric, Foster City, CA. INFO/CARD #184.**

Note Outlines Improvement for Amplifier Phase Accuracy

Precision Monolithics introduces application note AN-107, "Active Feedback Improves Amplifier Phase Accuracy", which describes a circuit design technique that significantly reduces the phase shift of a given amplifier. The technique described utilizes the matched frequency response characteristics of monolithic dual and quad op amps to reduce phase error of an amplifier by more than a decade. It shows schematics on how to achieve amplifier phase reduction by a factor or more than 50. It details circuit limitations along with design hints. In addition, a full analysis is given to support the theory behind the technique. **Precision Monolithics Inc., Santa Clara, CA. Please circle INFO/CARD #183.**

Ferrishield Snaps and Clamps Catalog

This catalog lists a line of ferrite assemblies for use with cable and wires to suppress unwanted frequencies. It uses a plastic housing which functions as a mounting clamp and protective shell. **Platec Corp., New York, NY. Please circle INFO/CARD #182.**

Frequency Synthesizer Brochure

This brochure describes Comstron's 1 us switching frequency synthesizers. The Model FS-2000's technology, switching speed and phase noise is discussed in detail. Application information covering radar; EW-ATE, simulators and RCS are described. Electrical and mechanical specifications are presented as well as both standard and custom OEM configuration guides. IEEE-488 programming examples are also included. **Comstron Corp., Melville, NY. INFO/CARD #181.**

IC Data Book

Siliconix's IC Data Book brings together updated data sheets for the company's analog switches and multiplexers, data conversion ICs, wideband/video multiplexers, special function ICs, display drivers, power conversion ICs, and mixed analog-digital ASICs. A selector chart and cross reference is included together with an applications section that provides design information.**Siliconix, Inc., Santa Clara, CA. INFO/CARD #180.**

Directional Coupler and Hybrids Brochure

Described in this brochure is a line of high power directional couplers and hybrids. The devices range is frequency from 20 MHz to 2 GHz with power levels up to 2 kW. Both electrical and mechanical specifications are included.**RF Power Components, Inc., Melville, NY. Please circle INFO/CARD #179.**

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Session Schedule for 1988 RF Expo East

Tuesday, October 25

Session A-1: SAW Devices
Chair: Dr. Emmanuel Sang, Tektronix, Inc.

- 8:30 SAW Spectrum Analyzers
  Maura Fox, Phonon Corporation
- 9:30 SAW Products: Custom Subsystems and Fully Integrated Hybrid Modules
  — R. Hays, T. O'Shea, J. Anderson and M. Lewis, SAWTEK
- 10:30 SAW Devices

Session A-2: Receiver Design
Chair: Malcolm Levy, Racal-Dana Instruments

- 8:30 Receiver Design — Simplified
  — Jerry Iseli, RF Monolithics, Inc.
- 9:30 Global Positioning System
  — Bruce Hammel, Greg Nelson and Jim Klopfenstein, Rockwell International, Collins Radio Div.
- 10:30 Optical/Acoustic Receivers
  — Richard Johnson, Crystal Technology

Session A-3: Design Techniques
Chair: Ted Dudziak, Wavetek RF Products, Inc.

- 8:30 Optimum Impedance Matching Using Minimum Number of Components
  — Donald Lanzinger, Loral Systems Group
- 9:30 Complex Signals: Their Processing and Transmission
  — Noel Boutin, University of Sherbrooke
- 10:30 Unequal Splitter Design
  — Douglas K. Linhart, Micon, Inc.

EXHIBITS OPEN — 11:00 a.m.-6:00 p.m.

Session B-1: Synthesizer Topics
Chair: Dave Badger, Wavetek RF Products Inc.

- 1:30 Optically Coupled VHF Voltage Controlled Oscillator
  — Albert Helfrick, Dowty RFL Industries, Inc.
- 2:30 Low Spurious Techniques for DDS Systems
  — Robert J. Zavrel, Jr., Digital RF Solutions
- 3:30 Direct Digital Synthesis
  — John Vendley, Wavetek RF Products, Inc.

Session B-2: Component Behavior and Analysis

- 1:30 Failure Analysis of RF Devices
  — Andrew Blackwood, Structure Probe
- 2:30 Determination of the M.T.T.F. for Pulsed Power L-Band Microwave Transistors Used in Radars and Navigation Apparatus
  — Georges Bobin, RTC, and John C. Salvey, Amperex Electronic Corporation
- 3:30 Performance of RF Components at Low Temperatures
  — Otward Mueller, General Electric Company

Session B-3: New RF Components
Chair: Gene Niemec, Merrimac Industries, Inc.

- 1:30 A 150-Watt Transistor for Class AB Power Amplifier Applications in the 460-860 MHz UHF Television Band
  — John Walsh, SGS-Thomson
- 2:30 A Silicon RF Amplifier Using a Dielectrically Isolated Monolithic Microwave Integrated Circuit (DIMMIC) Process
  — P. Bachert, M. McCombs, P. Sanders, Motorola Semiconductor Product Sector
- 3:30 Applications and Measurement of Small Value Inductors in SMT and Hybrid Circuits
  — Richard Dunlap, Micoil

Wednesday, October 26

Session C-1: Radiowave Propagation Tutorial

- 8:30-11:30 (3-hour tutorial session)
  Daniel R. Dorsey, Jr., Control Data Corporation

Session C-2: Quartz Crystal Applications
Chair: Colin Lanzl, Alpha Industries

- 8:30 Fundamentals & Stability of Crystal Resonators
  — Dr. John Vig, U.S. Army Electronics Technology & Devices Laboratory (LABCOM)
- 9:30 Crystal Filters
  — William Pond, McCoy Electronics Company
- 10:30 Practical Considerations in Specifying Hi-Stability Crystal Oscillators
  — Glenn Kurzenknabe, Piezo Crystal Company

Session C-3: Computer-Aided Design
Chair: Jack Koscinski, General Optronics Corp.

- 8:30 CAD Package for RF Applications
  — Alec Clerihew, Hazeltine Corporation
- 9:30 A Surface Acoustic Wave Filter Computer Aided Design Workstation
  — Dr. Donald Malocha, University of Central Florida
- 10:30 High-Speed Printed Circuit Board Analysis and Simulation in a Workstation Environment
  — J.N. Hall, S.H. Ardalan, M.S. Basel, R. Pomerleau, D.O. Riddle and M.B. Steer, North Carolina State University

EXHIBITS OPEN — 11:00 a.m.-6:00 p.m.

Session D-1: Elements of Antenna Theory
Chair: Gary Breed, *RF Design* magazine

- 1:30-4:30 (3-hour tutorial session)
  — Benjamin Rulf, Lockheed Electronics Company, Inc.

Session D-2: Power Amplifiers
Chair: Samuel J. Klein, Microwave Modules and Devices

- 1:30 Effects of VSWR Upon Class-E Power Amplifiers
  — Dr. Frederick H. Raab, Green Mountain Radio Research Company
- 2:30 RF Hybrid Linear Power Amplifier With Diamond Heat Sink
  — Nafiz Karabudak, Aydin Vector Division
- 3:30 Development of a Linear L-Band High Power Amplifier for Satellite Applications
  — Gillis Brassard, Spar Aerospace Limited

Session D-3: Non-Linear Circuit Simulation
Chair: Michael K. Ferrand, Microlab/FXR

- 1:30 Nonlinear Circuit Simulation for Microwave and High Speed Circuits
  — P.K.U. Wang, K.T. Lin, M. Sango and C. McGuire, EEsof Inc.
- 2:30 Simulation of Non-linear RF and Microwave Circuits
  — C.R. Chang, P.L. Heron, M.B. Steer, G.W. Rhyne, D.O. Riddle and R.S. Gyurcsik, North Carolina State University

Thursday, October 27

EXHIBITS OPEN 10:00 a.m.-2:00 p.m.

Session E-1: Mixer Tutorial

- 8:30-11:30 (3-hour tutorial session)
  — Dr. Donald Steinbrecher, Steinbrecher Corporation

Session E-2: Manufacturing-Related Topics
Chair: Lisa Boyd, McCoy Electronics

- 8:30 Special Requirements of RF Packaging
  — Rudy Sachs, ASPE, Inc.
- 9:30 An Inexpensive Silicon Monolithic Process for Microwave Low and Medium Power Circuits
  — Paul Sanders, Motorola Semiconductor Products Sector
- 10:30 Simulation of Complex PCB Layouts Including Coupled Tracks with Nonlinear Digital Device Termination
  — D. Winklestein, R. Pomerleau and M.B. Steer, Bell Northern Research

Session E-3: Transmission Line Topics
Chair: Robert C. Kane, Motorola, Inc.

- 8:30 Through Symmetric Fixture: A Two-Port S-Parameter Calibration Technique
  — J.S. Kasten, M.B. Steer and R. Pomerleau, Center for Communications and Signal Processing, North Carolina State University
- 9:30 Use of Pads and Baluns for TAHQ Alignment
  — N. Ersoz, Thomson Consumer Electronics
- 10:30 The Design of a High Reliability Electronic Step Attenuator
  — M. Da Silva and D. Whipple, Hewlett-Packard

rf expo east 88

Use the Special FREE Exhibits Pass Below

TO: RF Engineers
FROM: *RF Design* magazine
RE: RF Expo East 88

Thousands of professionals in RF engineering will converge on Philadelphia October 25-27, 1988. The reason: RF Expo East 88. This conference is targeted specifically at you and the special problems and situations you encounter daily. Note the following:

Subject: Special Courses

Since the first RF Expo East, engineers have raved about the RF Fundamentals course presented by Les Besser. 1988 promises to be no different, as once again, Les presents his extremely popular fundamentals course, RF Circuit Design Part I, October 24, 1988. And, for the first time, RF Circuit Design Part II, Advanced Topics, will be presented October 25, 1988. Both courses are sure to be highlights of the show. Another tutorial added this year is Computer Aided Filter Design, conducted by Randy Rhea of Circuit Busters, a successful software design and analysis company. This day-long tutorial in modern filter design takes place October 24, 1988 and does require pre-registration, as do both of the fundamentals courses.
Recommendation: Pre-register for all three courses on the registration card below.

Subject: Exhibiting Companies

Over 100 leading manufacturers will be on the exhibit floor, displaying the latest innovations in RF engineering technology and services. Meet with representatives of these companies to discuss your specific applications.
Recommendation: Comparison shop for components and materials you need in your work by visiting the exhibit hall.

Subject: Session Schedule

The complete session schedule is at left.
Recommendation: If you're serious about improving your design techniques and problem solving skills, attend the sessions.

RF Expo East will be an outstanding opportunity for you to improve your skills and advance your career. The registration form is below. Fill it out and mail it today.

Bottomline: Attend RF Expo East 88. Your future success depends on it.

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eturn to RF Expo East, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111 — (303) 220-0600

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September-February 1988-1989

ANOTHER EMI INCIDENT?

(See Page 3)

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COURSE TITLE / COURSE LOCATION	SAN DIEGO	CHICAGO	BOSTON	PHILDADELPHIA	PALO ALTO	ATLANTA	LAS VEGAS	DALLAS	WASHINGTON DC	LOS ANGELES	ORLANDO
GROUNDING AND SHIELDING	SEP 12-16			SEP 26-30	OCT 10-14	OCT 24-28	OCT 31-NOV 4		OCT 14-18	DEC 5-9	JAN 23-27
PRACTICAL EMI FIXES	OCT 17-21 JAN 16-20		SEP 12-16	OCT 3-7	SEP 19-23	OCT 31 NOV 4	DEC 5-9				JAN 30 FEB 3
EMC DESIGN & MEASUREMENT		SEP 12-16					OCT 3-7	NOV 7-11	DEC 12-16	FEB 6-10	
TEMPEST DESIGN & MEAS.					NOV 15-18				FEB 7-10		
TEMPEST FACILITIES DESIGN					JAN 16-20				OCT 17-21		
INTRO TO EMI/RFI/EMC	NOV 15-17										

ABOUT THE COVER: ANOTHER EMI INCIDENT?

The installation of microprocessors for controlling critical automotive functions (engine control, braking, acceleration) has dramatically increased the modern vehicle's vulnerability to interference. Even the malfunction of non-critical functions (power sun roofs and windows, hood and trunk releases) has caused property damage, injury and even death.

Although automotive travel has become safer, there are a growing number of complaints related to "unintended" acceleration as recorded by the National Highway Traffic Safety Administration. Dr. Roger L. McCarthy, P.E., of Failure Analysis Associates expects the trend to increase since the "overwhelming majority of vehicles produced since 1981 have had computer-controlled engines." Complaints of braking system failure, sometimes simultaneous with unintended acceleration, and the inability to confirm the validity of these complaints in subsequent tests make the problem difficult to investigate or substantiate. Dr. McCarthy asserts, however, that "it would be equally erroneous to dismiss all such complaints as untrue. The problems associated with detecting and reproducing all types of transient electrical phenomena are well known, and phenomena such as single event upsets, where a transient electromagnetic disturbance changes the system state, only complicate things further."

The detection and measurement of, design against, and retrofit to prevent electromagnetic interference is a science and a necessary developmental phase of any successful product—commercial, industrial or military. This catalog is your guide to the latest in theory application and pragmatic approaches to the control of electrical noise interference.

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WASHINGTON, DC Nov. 14-18, 1988	LOS ANGELES, CA Dec. 5-9, 1988	ORLANDO, FL Jan. 23-27, 1989	SAN DIEGO, CA Feb. 13-17, 1989	To register, see page 23

COURSE OUTLINE

1ST DAY

Logarithms and Applied Fourier Transforms for EMC

Review of dB and Logarithms
- Wide Ranges and Logarithms.
- Manufacturers' and Specifications Reporting Format
- Development of the dB-Log Relations
- Development of the dB-Log Tables
- Illustrative Examples
- Short Quiz and Scoring

Bode Plots and Fourier Transform with Applications
- Fourier Transforms and Bode Plots
- Time-Frequency Domain Relations
- Rectangular Pulse and (Sin x)/x Relations
- From Linear to the Logarithmic Domain
- Trapezoidal Functions and Envelope Relations
- Bode Plots of Performance Envelopes
- Brief Workshop

Fourier Series with Applications
- Distinction between Fourier Transforms and Series
- Clock, Data Line, and other Emission Pulse Trains
- Bode Plots and Harmonic Radiations
- FCC, VDE, MIL-STD-461C Compliance

2ND DAY

Grounding, Power Conditioning and PCB Control

EMI/EMC Terms and Definitions
- Introduction to EMI/EMC
- Nuisance and Catastrophic EMI
- Terms, Definitions and Classifications

Grounding: Reasons and Conflicts
- Safety, Shock Hazard, and Fire Prevention
- Facility Grounding Requirements
- Leakage Currents and Control
- Lightning Hazard Control
- Building Grounding Grids, Plates, Rods

Bonding
- Bonding Materials & Corrosion Control
- Bonding Straps and Jumpers
- Bonding Hardware and Techniques

Power Mains Coupling and Its Control
- Switching Regulator Noise Control
- Isolation and Faraday Iso Transformers
- Power-Line Filters
- Motor-Generator/Alternator Sets
- Power Conditioners
- Uninterruptable Power Supplies (UPS)

Common Ground-Impedance Coupling
- Single and Multipoint Grounds
- Impedance of Ground Planes, Conductors and Straps
- Illustrative Examples

EMI Control in Printed Circuit Boards
- Analog and Logic Families
- Impedance of PCB Wiring
- Regulated d-c Power Distribution
- Single and Multilayer Boards
- Design and Layout of PCBs

Class Group Problem: VDT and PCB Design
- Single-Layer Board Design in a Box
- Computing to Determine if FCC/VDE/MIL Compliant
- How to Fix the Three EMI Failures?
- EMI Fixes and Option Evaluation
- Solution Critique and Post Mortem

Computer Design and "What-If" Options/Solutions
- CAD Program for Solution of PCB Design—#5300
- Same Design as Previous Session
- Single-Layer to Multi Layer Design
- DIP to Surface-Mounted Design
- General External Case Design
- Option Evaluation

3RD DAY

Shielding, Ambients and Common-Impedance Control

Open Session for Student Questions and Answers

Shielding Effectiveness
- Near and Far Fields
- Plane Waves and E- and H-fields
- Reflection and Absorption Loss
- Shielding Effectiveness Design Graphs

Metals and Coatings
- Magnetic and Non-Magnetic Metals
- Sheet and Foil Materials
- Metalized Plastics and Coatings
- Conductive Paints and Sprays, ARC Sprays, Dippings, Depositions and Overcoats
- Composites; Flakes, Powder, Fibers

Aperture Leakage and Shielding Integrity
- Slot and Aperture Leakages
- Seams and Bonds
- Screens and Wire Meshes
- Sub-Apertures and Hexagonal Cells
- Compartments and EMC Components
- EMC Electrical Gasketing

Shielding Design Methodology and Procedure
- Defining Shielding Effectiveness Needs
- SE Performance Work Sheets
- Box Skin and Aperture Design
- Shielding Design Flow Diagram

Class Group Problem: Shielded Box Design
- Shielded Box Need with Three Apertures
- Review of Manual Design Forms
- Design of Box Shielding Skin
- Predicting Leakage from Aperture Types
- Designing EMI-Suppressed Leakages
- Review of Results and Critique

Computer Design and "What-If" Options/Solutions
- CAD Program for Solution of Box Design—#5500
- Start with Design as Previous Session
- Design of a Metalized Plastic Box
- Computing of Aperture Leakages
- EMI Fixing of All Aperture Leakages
- Option Evaluation
- Optimization in Design

Cable-to-Cable Coupling: Crosstalk
- Capacitive, Inductive, and Composite Coupling
- Hardening Techniques against Crosstalk
- Rules for Using Design Charts and Graphs

4TH DAY

Common and Differential-Mode and Ground-Loop Control

Open Session for Student Questions and Answers

Field-to-Loop, Common-Mode Coupling (CMC)
- Cable-Equipment-Ground-Loop Area
- Quantitative CMC Relations
- Loop Area and CMC Reduction Methods
- Prediction Techniques and Reduction Procedures

Ground-Loop Coupling (GLC) Control
- Quantitative GLC Relations (Unbalanced Circuits)
- GLC Relations (Balanced Circuits)
- Increasing GLC Impedance and Floating
- The Ground Inductor Role in Floating
- Float Box Inside Box Case
- Balanced Line Drivers and Receivers
- Optical Isolators and Fiber Optic Links
- Isolation Transformers and Ferrites
- EMI Prediction and Reduction Techniques

Differential-Mode Coupling (DMC) and Control
- Balanced Lines
- Electric and Magnetic Coupling
- Twisted-Wire Pairs and Groups
- Cable Shields and Grounding Criteria
- Coaxial Lines and transfer Impedance
- Double-Shield, Triax, Semi-Rigid Lines
- EMI Prediction and Reduction Techniques
- Illustrative Examples

Class Group Problem: Interconnected System Design
- Broadcast EMI to Interconnected Equipments
- Prediction Methodology and Procedures
- Strategy for Problem Solution
- Solution for Multi Noise Sources, Multi-Victims and Multi-Frequencies

Computer Design and "What-If" Options/Solutions
- CAD Program for Solution of Interconnect—#5220
- Same Design as Previous Session
- Design of an EMI-Suppressed System
- Performance of Analog and Logic Victims
- Balanced and Coaxial Cables
- Try Out "What-If" Options for Fixes
- Option Evaluation
- Optimization in Design

*5TH DAY

EMI Problem-Solving Workshop

You must attend the first four days in order to attend the group workshop.

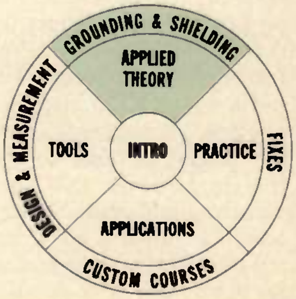
Open Session for Student Questions and Answers

Review of ESD, Lightning and EMP Transients
- How to Develop Spectral Density Threats
- Applications to ESD, Lightning and EMP

Workshop Groups
- Each Student Gets Free Copy of "EMI Control Methodology and Procedures" textbook.
- Class Is Divided into Working Groups
- EMI Workshop Problems Are Assigned

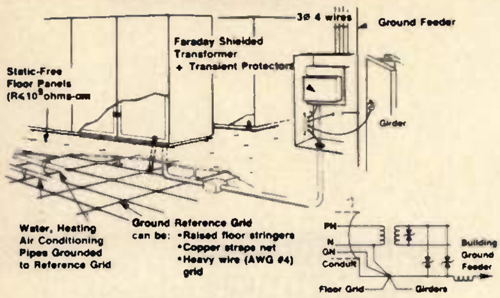
Groups Work on Workshop EMI Problems
- Start to Solve Problems
- Use Computers to Try Out "What-Ifs"
- Use Computers to Confirm Manual Solutions
- Some Workshop Problems Include:
  - Transmitter (Three Sources) EMI to Analog System
  - Lightning to Analog System
  - EMP to Digital System
  - Terminal Design to Meet FCC/VDE Regulations
  - Computer Room Crosstalk and Transient Control
  - Equipment ESD Performance and Control
  - Microprocessor-Based Instrument Design
  - Shielded Box Design to Meet Designated Threats

Problem Solution Presentation:
- First Group Leader Presents Problem
- Leader Discusses Strategy
- Leader Presents Solution
- Leader Gives Rationale
- Class Critiques Leader's Presentation
- Instructor Critiques Leader and Class
- Repeat above for All Group Leaders and Problems



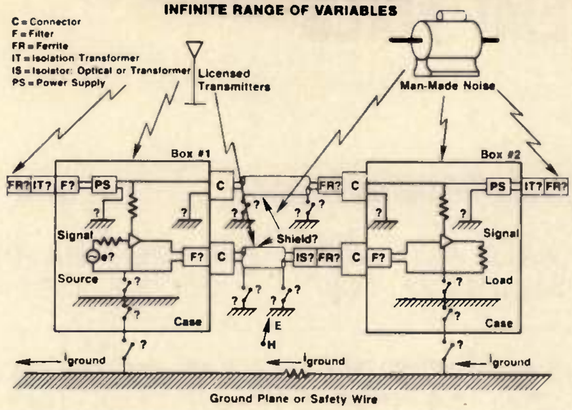
 This seminar is also available for "in-house" presentation at your facility. (see page 14).

LARGE EDP INSTALLATION SHOWING POWERING AND GROUNDING

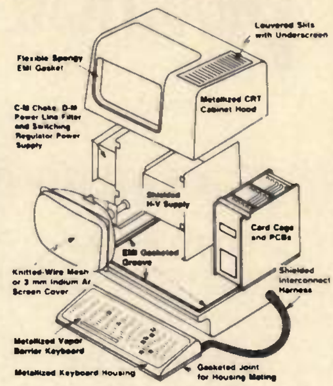


- Inter-frames and cabinet-to-grid bonds should have <1mΩ resistance
- Ground reference grid intersects welded or bonded with <1mΩ
- Power conduit supplements but *does not* substitute for ground wire. Conduit frequently bonded to ground grid.

A TWO-BOX EQUIPMENT EMC SITUATION—500,000,000 COMBINATIONS ☆—MANY WITH AN INFINITE RANGE OF VARIABLES



EMI CONTROL MEASURES IN VDT's (Solution)



BENEFITS YOU TAKE HOME

KEY BENEFITS OF ATTENDING:

- Learn when to ground and when not to ground.
- Get the art, science and tools of EMI control.
- Learn how to satisfy conflicts between Safety and EMI control.
- Stop product "homing pigeons".
- Reduce installation time and costs.
- Become your company's EMC focal point.
- Reduce susceptibility to power-line disturbances.
- Learn how to design for compliance.
- Reduce product costs by reducing unnecessary EMC components.
- Learn EMI Control Methodology & Procedures not attainable elsewhere.
- Become effective in applying dB and Fourier envelope problem solutions
- Learn the basics of spectrum analysis.

BENEFITS OF WORKSHOP

- Apply theory to real-world problems to solidify methodology and procedure understanding.

WHO SHOULD ATTEND

Design and systems engineers, interfacing and field installation engineers and fix/retrofit engineers will benefit the most from this course. 15 percent of our students are senior technicians and 20 percent have masters or doctorate degrees, so we recommend it for all levels.

YOU TAKE THESE VALUABLE TOOLS HOME WITH YOU

You will receive the handbooks *Shielding Design Methodology and Procedures* written by Don White (an $86 value), *Grounding for the Control of EMI* by Hugh Denny (a $68 value), a large binder of illustrations, graphs and tables and an addendum of pertinent material. If you attend the optional workshop, the *EMI Control Methodology and Procedures* manual by Don White and Michel Mardiguian is also provided (a $375 value). The materials alone cover the cost of the workshop.

NEW HANDS ON TRAINING WITH LAPTOP COMPUTERS AND EMC SOFTWARE

Laptop computers will be demonstrated during the course. They will also be available for loan in the evenings to take back to your hotel room. Using these computers, you will gain valuable hands-on experience with a variety of EMC computer-based problem solving and design software programs. You will learn how to solve your interference problems in a fraction of the time it would take using manual computations and trial and error.

To register, phone 703-347-0030

TRAINING REVIEW DISK

As soon as we receive your registration for the Grounding and Shielding course we'll send you an ICT Training Review Program Disk. The programs on the disk are a comprehensive review of the basic engineering concepts you'll be using in the Grounding & Shielding course. Specifically it offers a review of decibels, logarithms, Fourier series and transforms. Also included is a brief 15-question interactive quiz on the basic EMI principals which will be covered in the course. You can run the programs on any IBM (or compatible) with color graphics. To ensure that you receive the disk, please make sure your registration is received at least three weeks in advance of the course date. This information makes the course more pragmatically oriented by maximizing the understanding of the basics, before the detailed problem solving begins.

PRACTICAL EMI FIXES

NEW! TWICE AS MANY FIXES!

FOUR DAYS — $1,335 • FIFTH-DAY WORKSHOP — $360*

BOSTON, MA Sept. 12-16, 1988	PALO ALTO, CA Sept. 19-23, 1988	PHILADELPHIA, PA Oct. 3-7, 1988	SAN DIEGO, CA Oct. 17-21, 1988
ATLANTA, GA Oct. 31-Nov. 4, 1988	LAS VEGAS, NV Dec. 5-9, 1988	SAN DIEGO, CA Jan. 16-20, 1989	ORLANDO, FL Jan. 30-Feb. 3, 1989

COURSE OUTLINE

1ST DAY (Starts at 11 am)

EMI BASICS
- What is EMI?
- EMI Victims
- EMI Sources
- EMI Coupling Paths
- EMI Ground Currents
- Coupling Path Road Map

EMI UNITS
- Decibels
- Time Domain Units
- Frequency Domain Units
- Time Domain to Frequency Domain Transformations
- Broadband and Narrowband Units

EMI MEASUREMENTS
- Time Domain Measurements
- Frequency Domain Measurements
- Antennas and Sensors
- Current Probes

EMI FIXES THEORY
- Victims
- Sources
- Coupling Paths
  - Conducted EMI
  - Radiated EMI
  - The Field to Wire Transition
  - Ground Loops

EMI FIX SELECTION FLOWCHART
- Victim Identification
- Access Point Selection
- Coupling Path Identification
- Frequency Domain Worksheet
- Fix Selection Worksheet
- Fix Installation and Evaluation
- Iterating to a Solution
- Example Application

THE EMI FIX CATALOG
- **Introduction to the Catalog**
  - Catalog Layout
  - Fix Classification Guidelines
  - Fix Application Guidelines

2ND DAY (Starts at 9 am)

Conducted EMI Fixes
- Fix #1 Signal Filters
- Fix #2 Power Line Filters
- Fix #3 Ferrites
- Fix #4 Ferrite Loaded Cables
- Fix #5 Signal Isolation Transformers
- Fix #6 Power Isolation Transformers
- Fix #7 Faraday Shielded Transformers
- Fix #8 Balun Transformers

Conducted Transient Fixes
- Fix #9 Spark Gaps
- Fix #10 Gas Tubes
- Fix #11 MOVs
- Fix #12 Zener Diodes
- Fix #13 Transorbs
- Fix #14 Transient Snubbers
- Fix #15 Transient Plates

Other Conducted Fixes
- Fix #16 Motor Generators
- Fix #17 Uninterruptable Power Supplies
- Fix #18 Dedicated Power Supplies
- Fix #19 Controlling Stray Capacitance

Ground Loop Fixes
- Fix #20 Increasing Circuit Impedance
- Fix #21 Floating Circuits
- Fix #22 Inductor in Safety Ground
- Fix #23 Optical Isolators
- Fix #24 Fiber Optics
- Fix #25 Balanced Circuits

Common Impedance Fixes
- Fix #26 Reduce Ground Currents
- Fix #27 Divert Ground Currents
- Fix #28 Single Point Grounds
- Fix #29 Reducing Common Impedance

3RD DAY

Field to Cable Fixes
- Fix #30 Reducing Loop Area
- Fix #31 Reducing Circuit Currents
- Fix #32 Reduce Signal Frequencies
- Fix #33 Reduce Signal Rise Times
- Fix #34 Increase Distance

Differential Mode Field to Cable Fixes
- Fix #35 Twisting Wires
- Fix #36 Shield Wires
- Fix #37 Place Cables in Conduit
- Fix #38 Use Coaxial Cables
- Fix #39 Terminating Cable Shields

Cross Talk Fixes
- Fix #40 Increase between Pair Spacing
- Fix #41 Reduce in Pair Spacing
- Fix #42 Change Circuit Impedance
- Fix #43 Reduce Signal Currents
- Fix #44 Reverse Coupling Direction
- Fix #45 Reduce Parallel Cable Distance

EMI Shielding Fixes Using:
- Fix #46 Sheet Metals
- Fix #47 Permeable Metals
- Fix #48 Metal Foils
- Fix #49 Wire Screens
- Fix #50 Conductive Plastics
- Fix #51 Conductive Coatings
- Fix #52 Conductive Paints
- Fix #53 Building Grids

EMI Shielding Enclosures
- Fix #54 Equipment Cases
- Fix #55 Racks and Cabinets
- Fix #56 Shielded Rooms
- Fix #57 Double Shielded Rooms
- Fix #58 Shielded Buildings
- Fix #59 Shielded PCBs

4TH DAY

Shielding Aperature Control
- Fix #60 Controlling Aperature Size
- Fix #61 Fingerstock
- Fix #62 EMI Gaskets
- Fix #63 Conductive Tapes
- Fix #64 Conductive Windows
- Fix #65 Honeycombs
- Fix #66 Waveguide Beyond Cutoff
- Fix #67 Dirty Box Shielding
- Fix #68 Shielded Connectors and Backshells

Victim Hardening
- Fix #69 Reduce Bandwidth
- Fix #70 Reduce Sensitivity
- Fix #71 Emininate Audio Rectification
- Fix #72 Error Handling Software
- Fix #73 Error Handling Hardware
- Fix #74 Digitize Signals

Source Modification Fixes
- Fix #75 Harmonic Filtering
- Fix #76 Reduce Rise Time
- Fix #77 Time Domain Multiplexing
- Fix #78 Signal Blanking
- Fix #79 Soft Start Switches
- Fix #80 Zero Crossing Switches

Fix Installation Guidelines
- Location
- Mounting
- Cable Routing
- Shield Terminations
- Shield Integrity
- Ground Connections

*5TH DAY WORKSHOP Must Attend First 4 Days

Putting Theory into Practice
- How to Determine that EMI Is the Problem
- What to Do When Equipment Fails
- Diagnostic Procedures in the Lab
- Diagnostic Procedures in the Field

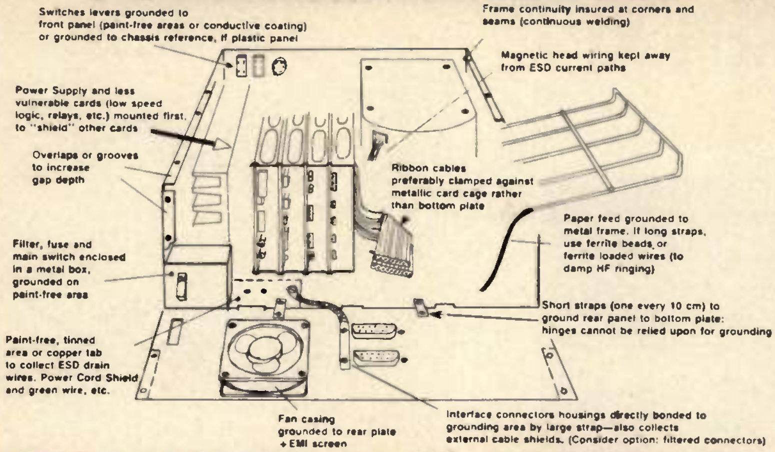
How Do You Measure EMI?
- Diagnostic Measurements
- Diagnostic Equipment
- Compliance Verification

Fixes First Aid Kit
- A Collection of Parts and Pieces for Practical EMI Control

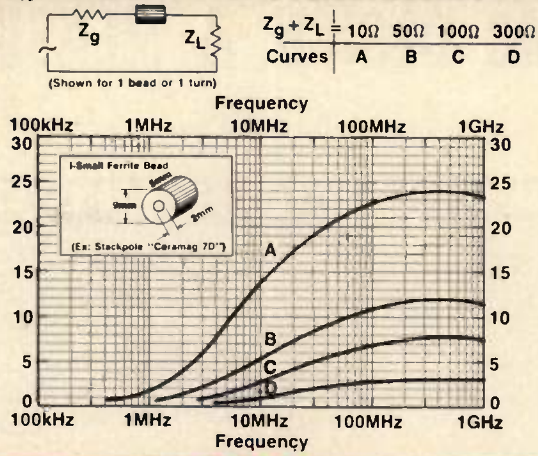
Where Do I Go for Help?
- Publications
- Government Agencies
- Professional Societies
- Standards and Publications

Workshop
- **4 Practical Examples of Fix Applications**

EXAMPLE SHOWING ESD PROTECTION MEASURES



TYPICAL INSERTION LOSS OF FERRITE BEADS ON WIRE



BENEFITS YOU TAKE HOME

KEY BENEFITS OF ATTENDING

New for 1988. We've doubled the number of fix techniques to over 80. And all fixes are now grouped by coupling path in a new convenient catalog style. Plus we've added the new EMI FIX SELECTION FLOWCHART® and the FIX INSTALLATION GUIDELINES® to augment the instructional information.

You will master how to tell if a problem is an interference situation and, given that it is, how to diagnose the nature of the problem and how to determine what fixes will work. Plus, you will gain the ability to select and apply the most cost-effective approach to fixing interference problems.

The fourth-day workshop is highly recommended in order to help you assimilate and apply the material presented.

WHO SHOULD ATTEND

Anyone who has experienced or is going to experience (everyone else) an electromagnetic interference problem and has unsuccessfully tried to fix it using "rules of thumb" will find this course invaluable.

This seminar is also available for "In-House" presentation at your facility (see page 14).

YOU TAKE THESE VALUABLE TOOLS HOME WITH YOU

Attendees receive a bound course notebook containing notes, graphs, example application of the fixes, sample calculations, and the Fix Selection Flowchart® and Fixes Catalog. In addition, each student will receive *Vol. 3 EMI Control Methods and Techniques* (a $129 value) as a personal technical reference.

COMMENTS

"Student reaction to this new course tells us we have achieved our objective. Typical student comments have been:

"Emphasis on the practical as advertised."

"The course organized and cataloged many fixes which we need to do."

"Comprehensive coverage of possible fix strategies."

"Excellent step-by-step presentation of fixes."

"Excellent approach to enable proper evaluation of problems and solutions to these difficulties."

"Related EMI Fixes to the real world."

"Covered multitude of subjects in detail to get me on right track."

"Organization and presentation of fixes were excellent, most useful seminar I have ever attended.""

To register, phone 703-347-0030

COURSE OBJECTIVES

- To learn to understand the basic EMI problem
- To define the basic terms and concepts used in the EMI world
- To develop a mental picture of the EMI path
- To develop a simple step by step procedure for selecting the "BEST" fix
- To catalog EMI Fixes in practical terms to show:
  - —What each fix is
  - —How it works
  - —When to use it
  - —When it won't help
  - —How to install the fix

The fifth day workshop adds the practical guidance necessary for success:

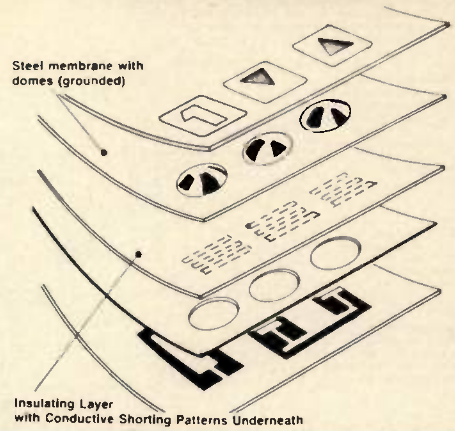
- How do you measure and identify EMI
- How do you show that the problem has really been fixed
- Where do you go for help

And introduces you to the "FIXES FIRST AID KIT" which collects the parts and pieces necessary for practical on-site applications.

The workshop gives you the chance to apply the Fixes Flowchart and Fixes Catalog to real world problems. Solving these example problems will test your skill in applying the techniques learned in the classroom.

EMC DESIGN & MEASUREMENT

MEMBRANE KEYBOARD SHOWING OPTION FOR EMI AND ESD SHIELDING



FIVE DAYS: $1,695 (or) DAYS 1-3 ON TOOLS: $1,195

CHICAGO, IL Sept. 12-16, 1988	LAS VEGAS, NV Oct. 3-7, 1988	DALLAS, TX Nov. 7-11, 1988
WASHINGTON, DC Dec. 12-16, 1988	ANAHEIM CA February 6-10, 1989	

COURSE OUTLINE

To Register See Page 23

1ST DAY-TOOLS

Fundamental EMC Design Tools

Introduction
Basic EMC Design Tools:
Basic EMI Mathematics
- Review of Decibels
- Introduction to "Eureka" Equation
- Solving Software

Fourier Transform Techniques
- Time Domain to Frequency Domain Transform

Directory of the EMC Community
- Government Regulations and Standards
- Industry Community and Organizations

Design Practice and Techniques
- EMI Design Methods
- Establishing EMC in the Design

Design Tools:
Victim Susceptibility Characteristics
- Digital Logic Susceptibility
- Analog Circuit Susceptibility

Culprit Source Emission Characteristics
- Terms and Definitions

Ground Philosophy
- Shock Hazard Control
- Fire Prevention
- Lightning Hazard Control
- EMI Grounding Considerations

EMI Ground Control Techniques
- Ground Schemes
- Single Point Ground
- Multipoint Ground
- Bonding

2ND DAY-TOOLS

EMI Coupling Path Design Tools

Coupling Path Calculations
- Coupling Path Definition
- Coupling Path Effects
- Coupling Path Control Techniques

Design Tools:
Ground Impedance Noise Control
- Calculate Ground Impedance
- Isolate Ground Currents

Common Mode Cable Pick-Up
- Field To Loop Reception
- Loop Area Control

Ground Loop Noise Control
- Controlling Ground Loop Currents
- Calculate EMI from GLC
- Use of Ferrites for EMI Control
- Use of Balanced Circuits

Differential Mode Noise Control
- Caclulating DMC
- EMI Control Techniques:
- Twisting Wires
- Shielding Cables
- Coaxial Lines

Cross Talk Control
- Calculating Capacitive Coupling
- Calculating Inductive Coupling
- EMI Reduction Techniques

Radiated Emission Control
- Mathematical Model of Radiated Emissions
- Model Limitations
- EMI Reduction Techniques

Conducted Noise Control

3RD DAY-TOOLS

EMI Control Tools

EMI Control Using Shielding
- Maxwell's Equations
- Wave Impedance Effects
- Reflection and Absorption Losses
- Calculating Shielding Effectiveness

Design Tools:
Shielding Materials
- Metal Cases
- Foils
- Composites
- Spray Coatings and Paints

Shielding Integrity
- Aperature Leakage Prediction
- Aperature Leakage Control
- Joints and Seams
- Gaskets
- Aperature Treatments

Shielded Case Design Practice
- Design Methology
- Component Layout
- Aperature Design

EMI Control Using Components
Design Tools:
EMI Filters
- Filter Types, Construction, and Performance
- Filter Selection Guidelines
- Filter Performance Calculations
- Filter Mounting Considerations
- Filter Performance Evaluation

Transient Suppression
- Transient Signal Characteristics
- Transient Suppression Selection Matrix
- Circuit Considerations for Transient Suppressors

PCB Design and Layout
Component Layout Guidelines

4TH DAY-MEASUREMENTS

Radiated Measurement Tools

Radiated Measurement Practices
- Developing a Test Plan
- Enforcing Test Methods
- Evaluating Test Results

Radiated Measurement Tools:
Spectrum Analyzers and Receivers
- Sensitivity and Bandwidth
- Broad and Narrowband Emissions
- Detector Functions

Antenna Basics
- Antenna Factors
- Proximity Effects
- Reflection Effects

Emission Measurement Antennas
- Dipoles and Biconicals
- Conical Log Periodics
- Probes, Rods, and Loops

Test Sites and Chambers
- Open Field Test Sites
- Shielded Enclosures
- Anechoic Chambers

Measurement Error Control
Regulation Compliance, FCC, VDE
- CISPR Recommendations and Publications
- FCC Rules and Regulations
- VDE and FTZ Regulations

Industrial Susceptibility Standards
Military Emission Measurements
- RE01 Magnetic Fields
- RE02 Electric Fields

Military Susceptibility Measurements
- RS02 Magnetic Fields
- RS03 Electric Fields
- RS04 Tests

5TH DAY-MEASUREMENTS

Conducted Measurement Tools

Conducted Measurement Practices
- Developing a Test Plan
- Enforcing Test Methods
- Evaluating Test Results

Conducted Measurement Tools:
Conducted EMI Sensors
- Current Probes
- Absorping Clamps
- Line Impedance Stabilization Networks
- Voltage Probes

Power Line Monitoring
- Monitor Characteristics
- Monitor Setup

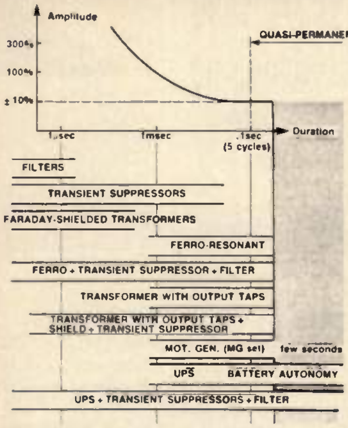
Transient Measurement
- Transient Waveforms
- Recorder Specifications

Conducted Emission Measurement Methods
- FCC Conducted Noise Measurements
- VDE Conducted Noise Measurements
- CE01 and CE03 Power Leads
- CE02 and CE04 Interconnecting Leads
- CE07 Conducted Transients

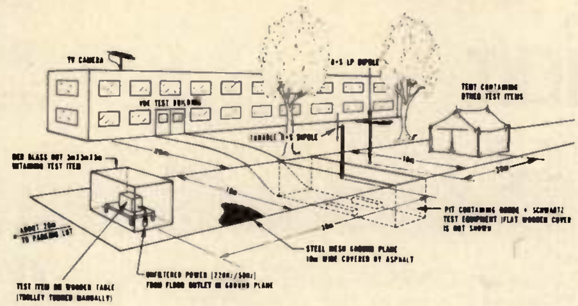
Conducted Susceptibility Measurement Methods
- Industrial Susceptibility Tests
- CS01/CS02 Power Lines
- CS03 Intermodulation
- CS09 Common Mode Injection

Diagnostic Measurement Techniques
- Diagnostic Test Strategy
- Diagnostic Test Flowchart

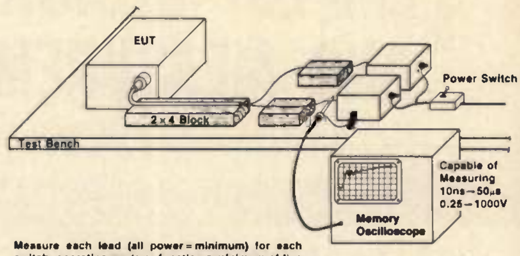
ENVELOPE OF POWER LINE DISTURBANCES AND SUMMARY OF VIABLE SOLUTIONS



VDE FIELD TEST SITE AT OFFENBACH



METHOD CE07.1 CONDUCTED EMISSION, SPIKES, TIME DOMAIN



Measure each lead (all power = minimum) for each switch, operating mode or function a minimum of five times, and report maximum.

On/Off shall be measured.
On AC power lines switching timed to occur at peak and zero crossing.

BENEFITS YOU TAKE HOME

KEY BENEFITS OF ATTENDING

An effective Engineer uses the best tools available to assist him in doing his job. This new course will provide you with a working knowledge of the fundamental tools used by the *Design Engineer* to prevent EMI from occurring.

In addition to the *Design Tools*, an effective Engineer also must be able to measure the performance of his product. The *Measurement Tools* provide you with the techniques and practices necessary to make successful EMI measurements.

New for 1988. You will use computers with equation solving software to speed up your problem solving process. Each student receives special templates for EMI situations.

The objective of this course is for you to master these tools through a format which allows you to use them immediately to solve your interference design and measurement questions.

WHO SHOULD ATTEND

All practicing professionals who need a comprehensive, practical, detailed methodology of the tools needed to solve EMI problems.

YOU TAKE THESE VALUABLE TOOLS HOME WITH YOU

You will receive a bound course notebook containing notes, graphs, sample calculations and case studies for each tool covered.

You will also receive *EMI Control Methodology and Procedures* by Donald R.J. White and Michel Mardiguian and *Shielding Design Methodology and Procedures* written by Donald R.J. White. (Included course materials total over $500.)

HOW THESE TOOLS WILL HELP YOU

The course notes which you will receive are designed to become a ready reference guide which you can use to provide step-by-step procedures for applying these tools as the need arises. Each tool is packaged as a complete stand-alone unit which facilitates its easy, quick application to your situations.

Having a library of ready-to-use tools to apply to interference situations will allow you to put the proper EMI control into your design rather than apply band-aid fixes later.

Measurement of interference has a reputation of being nearly impossible. These measurement tools will provide you the techniques and procedures required to make effective measurements.

To register, see page 23 or phone 703 347-0030

COURSE FORMAT

- The Basic Theory for that Tool
- How It Works
- When to Use It
- Step-by-Step Procedures for Using the Tool
- A Math Model for Predicting Benefits of Using the Tool
- A Computer Model for Visualizing Effects of Variables
- A Detailed Case Study Showing Proper Use of the Tool

This seminar is also available for "In-House" presentation at your facility. **(see page 14).**

TEMPEST DESIGN, AND MEASUREMENT

NSA ACCEPTED

PALO ALTO, CA
Nov. 15-18, 1988

WASHINGTON, DC
Feb. 7-10, 1989

FOUR DAYS—$1,485

To register see page 23

KEY BENEFITS OF ATTENDING

This course teaches the means of getting and keeping compliance with NACSEM 5100, assuring a listing for your company's product on the Preferred Product List.

You will learn the terminology and understand the definitions pertinent to TEMPEST Engineering. Special emphasis is given to the design and test requirements, mathematical relationships of TEMPEST signals and instrumentation parameters and special emissions sensors and measuring instruments.

You will learn how to detect compromising emanations, how to identify, classify and quantify TEMPEST emissions. TEMPEST control is covered from the design stage.

This seminar is also available for "In-House" presentation at your facility (see page 14).

ELIGIBILITY

This course is available to United States government agencies, industrial firms having a contractural need for TEMPEST information and participants in the Industrial TEMPEST Program (ITP).

Participants MUST be U.S. citizens, have a current U.S. SECRET clearance and establish a proper need to know. Requirements must be verified and be on file at ICT prior to the start of the course.

WHO SHOULD ATTEND

Engineers who design equipment to meet TEMPEST requirements; plan, conduct and report TEMPEST testing; or supervisors of such effort will derive the maximum benefit from attending this course.

YOU TAKE THESE VALUABLE TOOLS HOME WITH YOU

You will receive *Electromagnetic Shielding Materials and Performance* by Don White and *Interference Control in Computers* and *Microprocessor-Based Equipment* by Michel Mardiguian (together a $104 value)

COURSE OUTLINE

1ST DAY

Introduction to TEMPEST and TEMPEST Requirements

Introductory Session
- Course Introduction
- Instructor Introduction
- Student Introduction
- Local Logistical Arrangements
- Security Announcements
- Review of Handout Materials

TEMPEST Basic Definitions
- Fundamental TEMPEST Concepts
- Fourier Envelope Transforms and their Applications

Fundamental RED/BLACK Isolation Concepts
- RED/BLACK Definitions
- RED/BLACK Isolation
  - Interfaces
  - Lines
  - Areas

History of TEMPEST and TEMPEST Requirements
- NAG Family
- FED-STD-222
- NACSEM and NACSIM Documents
  - NACSEM 5100A
  - NACSEM 5109

Current Equipment Level TEMPEST Requirements
- Overview of NACSIM 5100A Requirements
  - Types of Measurements
  - Application of Measurements
  - TEMPEST Manifestations
  - Signal Classification

Other TEMPEST Requirements
- Facility TEMPEST Requirements
- Analysis Requirements
- Other TEMPEST Requirements

Contractural Implications
- Security: Personnel and Facility
- Document Classification, DD254
- The RFQ/RFP/IFB
- Procuring Activity vs. Ft. Meade

The Industrial TEMPEST Program
- History
- Current Administration

Current TEMPEST Policy
- Structure of the Sponsoring Agency
- PPL Qualification
- Certified TEMPEST Testers and Engineers

TEMPEST Engineering
- Responsibilities of a TEMPEST Engineer
- Interrelation of TEMPEST Activities with Physical Security
- The TEMPEST Control Plan

Structure of TEMPEST Testing Requirements

2ND DAY

TEMPEST Test Planning and Execution

Overview of NACSIM 5100A
- RED/BLACK Limits

Overview of NACSEM 5109

Basic Testing Parameters

TEMPEST Testing
- **Test Planning**
  - Test Planning Criteria
  - Equipment Analysis
  - Testing Parameters
- **Test Design and Instrumentation**
  - Starting Frequencies
  - Stopping Frequencies
  - Required Bandwidths
- **Test Preparation**
  - Test Facilities
  - Testing Documentation
  - Test Execution
  - Test Equipment
  - Test Setups
  - Measurement Error
- **Qualification Testing**
- **Production Testing**
- **TEMPEST Performance Warranties**
- **Test Planning Example**

3RD DAY

TEMPEST Signal Propagation, Analysis and Development of TEMPEST Design Requirements

TEMPEST Signal Propagation
- Signal Source Characterization

TEMPEST Signal Propagation
- Radiated Emissions
  - Differential Mode Radiated Emissions
  - DM to CM Conversion
  - Ground Loop Coupling
  - Common Mode Radiation
- **Conducted Emissions**
  - Direct Signal Emanations
  - Power Supply Emanations

Development of TEMPEST Design Requirements
- Derivation of Design Requirements
- Case Shielding Design Requirements
- Conducted Emissions Design Requirements
  - Signal Ports
  - Power Ports

4TH DAY

TEMPEST Design for Equipment, Retrofit of Existing Equipment

TEMPEST Design for Equipment Shielding
- EM Theory as Applied to EM Shielding
  - EM Emanations from a Source
  - Near Field and Far Fields
  - E- and H- Fields and Plane Waves
- Basic Material Shielding
  - Reflection Loss Shielding
  - Absorption Loss Shielding
  - Combined Shielding
  - EM Shield Selection Theory
- Shield Penetrations
  - Slits, Slots, Holes/Apertures Leakage Control
  - Compartments and Gaskets
  - Shielded Equipments, Racks and Consoles

Filtering

Power Supply Isolation
- Switching Regulator Power Supplies
  - Input Filtering
  - Output Ripple Filtering
- Linear Regulator Supplies

Cable Bundle Design

Grounding
- Reasons for Grounding
- Grounding Approaches
  - Single Point Grounds
  - Multi Point Grounds
  - Single Reference Grounds
- Bonding
  - Connections
  - Corrosion Control

Retrofit of Existing Equipment
- Analysis vs. Evaluation Measurement
- Source Suppression
- Encapsulation

Instructor Led Participative Design Exercise

Course Summary

TEMPEST FACILITIES DESIGN, INSTALLATION AND OPERATION

NSA ACCEPTED

Day 1-Overview of Facility Requirements—$360* **Day 5-Optional Problem Solving Session—$360****

WASHINGTON, DC
Oct. 17-21, 1988

PALO ALTO, CA
Jan. 16-20, 1989

DAYS 2-4-MAIN TEMPEST COURSE—$1,195

To register see page 23

KEY BENEFITS OF ATTENDING

This course addresses TEMPEST compliance at the building or facility level.

You will master how to meet TEMPEST requirements via recommendations of NACSIM 5203 and NACSEM 5204 as well as pertinent sections of NACSIM 5100A. Techniques for integrating technical and physical security requirements are included. In addition to TEMPEST at the facility level, methods of handling power mains, signal lines, telephones, fire-protection sprinklers, lighting, air conditioning, and the like, are covered.

This seminar is also available for "In-House" presentation at your facility (see page 14).

ELIGIBILITY

This course is available to United States government agencies, industrial firms having a contractural need for TEMPEST information and participants in the Industrial TEMPEST Program (ITP).

Participants MUST be U.S. citizens, have a current U.S. SECRET clearance and establish a proper need to know. Requirements must be verified and on file at ICT prior to start of course.

WHO SHOULD ATTEND

Building architects and engineers (A&E), facility engineers, building contractors, managers and industrial engineers and technicians will find this course to be a must if they have TEMPEST requirements at the facility level to be met in design, installation, operation, maintenance or retrofit stages. This course is based in part on official U.S. government TEMPEST publications, but it is not sponsored or endorsed by the U.S. Government. Interference Control Technologies is solely responsible for its content.

YOU TAKE THESE VALUABLE TOOLS HOME WITH YOU

You will receive two extensive technical reference books totaling $104. They are *Electromagnetic Shielding Materials and Performance* by Don White and *Grounding for the Control of EMI* by Hugh W. Denny.

COURSE OUTLINE

*1ST DAY *NEW!*

Overview of Facility Requirements (Optional)

An optional one day discussion of the issues involved in satisfying TEMPEST requirements at the facility level, geared to the needs of facilities project managers and security officers who must deal with TEMPEST issues. Stripped of the technical detail, this presentation concentrates on the issues in a conceptual manner. Attendees learn the essentials of TEMPEST technology and current policy allowing their intelligent participation in the decision-making, resource-allocation process.

Attendees of the full course can be registered for this option FREE, if they are accompanied by their management and/or security personnel. For all others, the cost is $360 for the one day. All attendees of this presentation will receive a binder containing all unclassified material presented. **Attendees for this presentation must preregister and eligibility requirements still apply.**

Management/Security Overview Option

Optional One Day Overview of TEMPEST Facility Requirements and Means of Satisfaction

Morning Session
TEMPEST Engineering Basics
- Description of the TEMPEST Problem
- Basic TEMPEST Concepts
- RED/BLACK Technology

TEMPEST Facility Requirements
- Sources of TEMPEST Requirements
- DD254 for TEMPEST Requirements Implementation

Satisfaction of TEMPEST Facility Requirements
- Options for Satisfying TEMPEST Requirements
- TEMPEST Engineering - Physical Security Interactions

Afternoon Session
- RED/BLACK Engineering Guidelines
- Qualified vs. Non-Qualified Equipments
- MIL-STD-188C vs. Non 188C Equipments

Zoning Approach
NACSIM 5100A PPL Equipment
- What PPL Means
- Manufacturing Requirements
  - Certification Maintenance
  - Long Term Quality Issues
  - Maintenance Support

The Shielded Enclosure Option
- Shielded Enclosure Requirements
- Shielded Enclosure Performance
- Shielded Enclosure Maintenance/Operations

Review and Summary

2ND DAY

Introduction to TEMPEST Engineering, Facility TEMPEST Requirements, TEMPEST Signal Propagation, TEMPEST Engineering for Facilities and Basic RED/BLACK Concepts

Introductory Session
- Course Introduction
- Instructor Introduction
- Student Introduction
- Security Announcements/Briefing
- Local Logistical Arrangements

TEMPEST Engineering Basics
- Definition of TEMPEST Phenomena
- Example of the TEMPEST Problem

Facility TEMPEST Requirements
- Historical Application of TEMPEST Requirements
- Sources of TEMPEST Facility Requirements
- Structure of TEMPEST Facility Requirements

Satisfying TEMPEST Facility Requirements
- Options Available
- Methods of Selecting Options
- Developing Optimum Choice Strategies

TEMPEST Signal Propagation
- Signal Sources

RED/BLACK Engineering Concepts
- Basic Definitions
- Concept Application

Class Problem - RED/BLACK Definition

3RD DAY

Overview of NACSIM 5203 Recommendations, Building and Equipment Zoning Concepts, Preferred Products List Equipments Usage

Overview of NACSEM 5203 Guidelines
- Document Structure
- Approved Equipment Installation
- Non Compliant Equipment Installation
- Other Areas of Concern

Building and Equipment Zoning Concepts
- Building Zoning
- Equipment Zoning

Acquisition and Use of Preferred Product List Equipment(s)
- The Industrial TEMPEST Program
- NACSIM 5100A Qualification
- The Preferred Products List
- Manufacturer Support for the PPL Items

Class Problem - Facility Requirements Satisfaction

4TH DAY

Review of Basic Shielding Theory, NACSEM 5204 Requirements, General Facility TEMPEST Issues, TEMPEST Facility Design, Course Review and Summary

Basic Shielding Theory
- EM Propagation for Shielding
- Material Inherent Shielding Performance
  - Reflection Loss
  - Absorption Loss
    - Combined Losses
- Cable Shielding
  - Cable Shield Performance
  - Schulkenoff Shielding
  - Installation Factors
  - Cable Shield Grounding

NACSEM 5204 Requirements
- Shielded Enclosure Performance Concepts
- Typical Shielded Enclosure Structure
- Shielded Enclosure Grounding

Shielded Enclosures
- Basic Shielded Enclosure Design Concepts and Approaches
- Shielded Enclosure Requirements
- Shielded Enclosure Performance
- Shielded Enclosure Installation
- Shielded Enclosure Penetrations
- Unique Problems
- Shielded Enclosure Performance Measurement
- Enclosure Operations
- Enclosure Maintenance

General Facility TEMPEST Issues
- TEMPEST Engineering Interactions with Physical Security
  - Physical Security Requirements
- Grounding
- Facility Planning, TEMPEST Issues
  - General Facility Planning vs. TEMPEST Facility Planning
  - Special Requirements from TEMPEST Issues

Class Problem - Strategies for Optimum Choices in Satisfying Facility Requirements

**5TH DAY

Optional, Problem Solving Workshop

Description of the Problem Solving Sesssion
Description of the Problems
- No. 1 - Building Grounding System
- No. 2 - New Facility Planning
- No. 3 - Existing Facility Conversion
- No. 4 - Local Area Network
- No. 5 - Shielded Enclosure Damage Assessment
- No. 6 - Shielded Enclosure Systems Interfacing

Problem Solving Session - Problems 1, 2, and 3
Student Presentations and Commentary
Problem Solving Session - Problems 4, 5 and 6
Student Presentations and Commentary
Course Summary

AN INTRODUCTION TO EMI/RFI/EMC

SAN DIEGO, CA
Nov. 15-17, 1988

THREE DAYS—$1,095

To register see page 23

KEY BENEFITS OF ATTENDING

When you take our introductory course on EMI/RFI/EMC, you will gain an overall EMC awareness and learn about sources of EMI. You will also develop an understanding of coupling mechanisms, learn about device susceptibility and gain knowledge about the EMC community. In order to obtain an overview of EMC rules, regulations and standards, as well as to develop an understanding of EMC design and control, this course is a must.

WHO SHOULD ATTEND

This is our most popular course for participants who have very little knowledge about EMI and its control. This includes relatively new engineers who have had little exposure to interference problems or those who are being retrained to develop new disciplines for new applications. These candidates should take this course before attending more specific ICT courses such as Grounding and Shielding or EMC Design and Measurement for the Control of EMI, or before courses with specific applications are taken.

YOU TAKE THESE VALUABLE TOOLS HOME WITH YOU

You will receive a binder of notes and illustrations pertinent to the course and a hardbound volume to complement your EMC library—*Vol. 3, EMI Control Methods and Techniques* (a $129 value).

This course is also available for "In-House" presentation at your facility (see page 14).

COURSE OUTLINE

1ST DAY

Overview of EMI/EMC—Intersystem Interference

Broad Aspects of Electromagnetic Interference
- Examples of Electromagnetic Interference
  - Nuisance/Hazardous Interference Episode
- The Frequency Spectrum—EM Ambients
- Elements of an Interference Episode
  - Source
  - Coupling Media
  - Receptor
- Hazards of Electromagnetic Radiation

Definition of Interference & Compatibility Terms
- Units and Conversion Factors
  - Narrowband and Broadband
  - Radiated and Conducted
  - Emission and Susceptibility
- Instrument Antennas and Conduction Probes

Quantifying Electromagnetic Interference
- Intersystem (Antenna-to-Antenna) Interference
- Intrasystem (Back-Door) Interference
- Ideal and Actual Environments
- Sources of Interference
  - Functional
  - Incidental
  - Natural
- Propagation and Coupling
- Action on Receptors—Susceptibility

Examples of Intersystem Interference
- Case Histories of Intersystem Interference
- Definitions of Systems
- Examples of Systems—Military and Industrial
- Typical Modes of Systems Interactions

Quantification of Intersystem Interference
- Elements of Interference
  - Antenna Patterns
  - Transmitter Profiles
  - Propagation
  - Receiver Responses
- Summary of Elements
- Short Form Prediction Sheet

2ND DAY

Intrasystem Concepts

Examples of Intrasystem (Non-Antenna) Coupling Modes
- Equipment Emissions and Susceptibility
- Common-Mode Pickup
- Common-Mode Coupling
- Reduction of Common-Mode (CM) Coupling
- Differential Mode Pickup
- Reduction of Differential-Mode (DM) Pickup
- Other Coupling Modes

The Importance of Grounding for Achieving EMC
- Reasons for Grounding
  - Safety
  - Lightning Control
  - EMC
- Grounding Schemes
  - Single-Point/Multipoint Grounding
- Shield Grounding
- Bonding

The Importance of Shielding
- Shielding Effectiveness
  - Reflection
  - Absorption

The EMC Community
- World Organizations
- Government Agencies
  - Industrial
  - Commercial
  - Governmental
- Professional Organizations

EMC Program Objectives and Organization
- EMC Function in Organization
- EMC Cost Considerations
- EMC Management Considerations

3RD DAY

EMC Specifications, Measurements

EMC Specifications
- Rationale for EMC Specifications
- Review of Specifications
  - MIL-Stds
  - FCC Rules
  - IEC/CISPR/VDE

Structure of Typical Specifications
- MIL-STD-461/2 & Notices
- FCC Rules & Regulations

Other EMC Related Specifications
- MIL-STD-704
- MIL-STD-449
- MIL-STD-469
- MIL-E-6051D

EMC Testing
- Open Field Testing
- Shielded Enclosure Testing & Test Procedures
- Test Failures and Equipment Failures
- Antennas and Conduction Probes
- Receivers and Spectrum Analyzers
- Signal Generators and Power Amplifiers
- Susceptibility Test Antennas and Exciters
- Conducted and Radiated Testing

EMC Test Cost and Planning
- Application of EMC Specifications to Equipment
- EMC Test Summary Diagram
- EMC Test Matrix
- Cost of Performing Tests

Review/Class Discussion/Summary

QUALIFIED INSTRUCTORS WHO WORK FOR YOU

The topics presented in this brochure have been mastered by the Interference Control Technologies (ICT) staff of professional engineers and associates. Collectively they represent approximately 500 years of combined experience in the fields of EMI and EMC, telecommunications, computers and related disciplines. This is a **partial** listing of our instructors.

Donald R.J. White, president of Interference Control Technologies, holds BSEE and MSEE degrees from the University of Maryland. He lectures and consults in the United States and abroad on electromagnetic compatibility and related topics and has written several books and many papers. He has also held positions in government and large and small industry. He is a past national chairman of the IEEE Professional Group on EMC and past chairman of EMC EXPO.

Martin Green, received his BSEE degree from London University. He is currently the manager of Interference Control Technologies European Sales Efforts. Prior to joining ICT, he served as the Electronics Group International Sales Support Manager for the Raychem Corporation based in Swindon, England. His particular area of interest is in cabling and grounding systems and he has provided much consultative advice to the electronics companies throughout Europe and the Americas on this subject.

Dr. William G. Duff holds BSEE, MSEE, and DSc degrees. He is the manager of the Advanced Systems Technology Department of Atlantic Research Corporation. Dr. Duff is active in projects relating to math modeling techniques for EMC prediction and analysis. He has authored or co-authored a number of technical publications, including *Mobile Communications* and *EMI Prediction and Analysis Techniques*, published by Interference Control Technologies. Dr. Duff is a fellow of the IEEE and is active in the group on EMC.

Ronald W. Brewer, EMC engineering manager for Instrument Specialties Company, Inc., received his BSEE from the University of Michigan. He has over 19 years of experience in electromagnetic/TEMPEST engineering and closely related disciplines. His diverse experience includes project-level design and evaluation of various systems including telecommunications, navigation, radar, EDP and related equipment to meet EMC specifications such as MIL-STD-461, NACSEM/NACSIM 5100A and various FCC rules and regulations.

Dr. J.L. Norman Violette holds a BSEE from Rensselaer Polytechnic Institute, an MBA from Auburn University, and a PhD (EE) from North Carolina State University. He has performed research in applied electromagnetic theory and developed computer models for the impedance of obstacles in waveguides and electromagnetic wave propagation. His experience includes C^3I and related fields. He is an independent consulting engineer, an active instructor in Interference Control Technologies EMI-EMC courses and a contributor to Interference Control Technologies EMI-EMC publications.

Ralph Morrison is a senior engineer with over 30 years of experience in engineering and engineering management. He has a BS in Physics from California Institute of Technology and a MSEE from University of Southern California. Besides being author of two technical books and numerous articles for various trade journals, including EMC Technology, Mr. Morrison has developed or participated in the development of seven registered patents. He is founder of Dynamics Instrumentation Co. and is owner of Instrum, a manufacturing and consulting firm.

Kenn Atkinson is Director of Training at Interference Control Technologies. He has 15 years of experience in high power RF circuits and interference control including management of a Navy database tracking interference onboard Navy ships, design of medical electronics, and design of high power radio frequency generators and transmitters. He is a registered Professional Engineer holding a bachelor's degree in Physics from Brigham Young University, a Master of Engineering Administration from the University of Utah and is currently completing a Doctor of Science in Artificial Intelligence.

Richard T. (Dick) Ford was formerly assistant director of the Navy's Shipboard Electromagnetic Compatibility Improvement Program (SEMCIP). He holds a BSEE from Northeastern University and is a graduate of the Northeast School of Radio and Television Broadcasting with postgraduate work at Virginia Polytechnic Institute. He has served as special assistant for military affairs to U.S. Senator Orrin Hatch.


Donald R.J. White


Martin Green


Dr. William G. Duff


Ronald W. Brewer


Dr. J.L. Norman Violette


Ralph Morrison


Kenn Atkinson


Richard T. (Dick) Ford

ICT IN-HOUSE TRAINING SEMINARS TAILORED TO YOUR NEEDS

SELECT FROM 22 SEMINARS OR ASK US TO DESIGN ONE FOR YOU

ICT's expert faculty and training seminars are available to you at your facility, and at your convenience. You can select a seminar from many existing ICT seminars, or we can combine several existing seminar subjects to develop a new seminar, or we can specifically design a seminar to perfectly suit your needs.

SPECIFIC TRAINING FOR SPECIFIC APPLICATIONS

All seminars are developed and taught by seasoned ICT instructors who are practicing experts in their field and in the art of communications. ICT In-House Training features comprehensive, two- to five-day short seminars on interference control covering all the disciplines within the electronics, computer, telecommunications, and allied industries. Our training is dedicated to providing practical, state-of-the-art effective education for the advancement of your engineers and technicians while offering you significant savings of time and money.

TRAIN MORE PEOPLE AT A LOWER COST, AND CHOOSE THE TIME AND PLACE

If you have 10 or more people to train, our in-house training can save you 30% or more by eliminating costly travel time and expenses. You can plan your Interference Control or Tempest training to fit with the schedule of your people while we arrange all the details of planning, developing, and teaching your seminar. The value of ICT's In-House Training can best be measured in the savings gained from recognizing and solving interference problems in the design and test stages where costs are inexpensive and by ensuring that you will be in compliance with government or military standards and regulations before you start production.

STANDARD, TAILORED, OR CUSTOMIZED SEMINARS

Over the years we have helped hundreds of companies get the most out of their in-house training seminar dollars. The procedure that we use has been carefully designed to speed the process and make it easy for you.

We are experts in this process, and for 18 years have helped people to define their in-house training needs. Listed next are ICT's standard in-house training seminars. Together we may find that one of these existing seminars fits your needs . . . or we may recommend combining parts of several existing seminars to tailor a new seminar . . . or it may be best to create a custom design seminar. Our one objective is to provide the specific in-house seminar best suited to solve your needs while saving you time and money.

YOU'RE IN GOOD COMPANY WHEN YOU CHOOSE ICT IN-HOUSE TRAINING

We have trained 34,000 engineers, scientists, managers, and technicians from over 1,300 companies in 49 countries around the world. Collectively we have over 500 years of work experience, and we are dedicated to creating in-house training courses that provide specific "real-life" solutions to your interference problems. Below is a partial list of companies we have served.

AAI Corporation
Abbott Labs
Aerospace Corp.
Aerospatial
Allen Bradley
Allied Chemical Corp.
Altoflex
Argo Systems
AT&T
Atomic Energy of Canada
AVCO
Beech Aircraft Co.
Canadair
Caterpillar Inc.
Cern
Commercial Bank of Mexico
Communications Canada
Consolidated Controls
Control Data Corp.
Cornell-Dublier Elec. Corp.
C&P Telephone Co.
Crown Controls
Crypto AG
Dayton T. Brown Co.
Digital Equipment Corp.
Digital Switch Corporation
Dow Jones & Co.
E-Systems, Inc.
Eastman Kodak Corp.
Eaton Corporation
EG&G, Inc.
E.I. DuPont Co.
Electro-Metric Service Co.
Emerson Electric
Ericsson
E.S. Dassault
Federal Electric Co.
Ford Aerospace Corporation
Ford Motor Co.
Garrett Turbine
General Motors
Genisco Technology Co.
Georgia Inst. of Tech.
Georgia Power Co.
Goodyear Corp.
Gould, Inc.
Gretag
Grumman Aerospace Corp.
GTE Sylvania
GTE Automatic Electric
GTE Information Systems
Hazeltime Corporation
Hewlett-Packard Co.
Homes Narver Co.
Honeywell, Inc.
Hughes Aircraft Co.
Hydro-Quebec, Ltd.
IBM
Israel Aircraft Industries
ITT
Jet Propulsion Lab
John Fluke Manufacturing Co.
Johnson Controls Corp.
Lawrence Livermore Laboratories
Lear Siegler
Lorain Products
Marconi Underwater Systems
3M Electronic Products
Martin Marietta Corp.
McDonald Dettwiler
Micom Systems
Microtel
Mitre Corporation
Monsanto Company
Motorola
NASA
National Bureau of Standards
National Defense Headquarters
National Institute of Health
National Security Agency
National Weather Service
New Mexico University
Nixdorf Computer AG
Northrup Ventura
Philips Information Systems
Royal Canadian Mounted Police
Royal Danish Air Force
Saab Motors
Schneider Services
Siemens Albis AG
Simmonds Precision, Inc.
Singer Company
Singer Link Co.
Sintra
Southwest Research Institute
Sperry Rand Corporation
Sperry Univac Corp.
State of Illinois
Storage Technology Corp.
Sun Oil Company
Swedish Telecommunications Administration
Systematics General Corp.
Telebras
Teledyne Ryan Aerospace Corp.
Toshiba
Tracor
Union Carbide
University of New Mexico
U.S. Air Force—Divisions Worldwide
U.S. Army—Divisions Worldwide
U.S. Coast Guard
U.S. Department of State
U.S. Navy
Whirlpool Corporation

LIST OF STANDARD IN-HOUSE SEMINARS

Below is a listing of some of our most popular courses. The first six courses are listed in detail in the first 12 pages of this catalog. The remainder are briefly described. Because of space, some courses are listed by title only. For more information, call us and we will send you a detailed syllabus.

(1) **Practical EMI Fixes** (see page 6)
(2) **Groundingand Shielding** (see page 4)
(3) **TEMPEST Facilities** (see page 11)
(4) **TEMPEST Design, Control & Testing** (see page 10)
(5) **Intro to EMI/RFI/EMC** (see page 12)
(12) **EMC Design and Measurement for the Control of EMI** (see page 8)

(8) Digital EMC
Four Days

You will learn to incorporate protection from hostile electromagnetic ambient, including braodcast transmissions, lightning and ESD events. You will also learn to control the conducted and radiated emanations from digital equipments.

Course outline includes, *Basic EMI Concepts, International EMC Trends, National-Level Interference, MIL-STD-461/462, Comparison of Emission Limits, Classification of EMI Problems, Radiated Emission Model, Conducted Emission Model, EMC Basics of Grounding, Equipment and System EMI Problems, Electromagnetic Ambients, Common Impedance Coupling, Radiated Susceptibility Model, Cable-to-Cable Coupling, Power Mains Coupling, Transient Suppression, Shielding Concepts, Shielding Effectiveness, EM Environment, Transmission Line Characteristics, PCB Power Distribution, Conductor Inductance, Power Distribution & Decoupling, PCB Layout Guidelines, Electrostatic Discharge, EMC Testing, Test Areas & Shielded Enclosures, Receivers, FCC/VDE Emission Measurements, Commercial EMC Susceptibility Measurements.*

(6) Electrostatic Discharge Control
Three Days

This course is a must for most engineers. In contrast to the traditional "passive" approach where EMI is considered to be an unavoidable plague, this course gives an aggresive, preventive strategy against the EMI threat. You will learn how to perform ESD test compliance, how to apply ESD diagnostic failure strategies and test procedures, how to fix and retrofix an ESD failure and how to design out ESD weakness from the start.

Course outline includes, *ESD Scenarios, ESD Parameters, Industrial/Commercial ESD Standards, ESD Control at IC and PCB Assembly Level, ESD Testing, ESD Diagnostic and Failure Isolation, Avoiding ESD Entry Paths, ESD Fixes at the Functional Level, ESD Fixes at the Box Level, ESD Field Fixes and Retrofit.*

(10) Power Conditioning
Three Days

This course examines internal and external noise sources, e.g., switched mode power supplies and lightning, which contribute to power line noise; and provides proven solutions for each interference source. Attendees will recieve a full appreciation of the power problem, the latest in reduction techniques and monitoring concepts to achieve electromagnetic compatibility. The course covers the latest techniques for identifying power line noise sources, as well as the most cost effective design

procedures and retrofit efforts to eliminate EMI problems. Topics in both susceptibility prevention as well as emission control are covered extensively.

Course outline includes, *System Layout: Commercial vs. Military, System Grounding, System Level EMI Sources, System Transients, Commercial Standards, Military Standards, System Level EMC, Safety Margins, Introduction to EMI Hardware Solutions, System EMI Hardware Solutions, Switched-Mode Power Supplies, EMI Modeling and Analysis Methods for Switching Converters, Input Filter Considerations in Switching Regulators, Internal EMI Sources and EMC Design Techniques, Shielding Techniques, Filter Requirements for Specification Compliance, Filter Performance and Applications, Matching Filter Type to EMI Source, Insertion Loss Characteristics, Filter Effects at Power Frequency, Filter Design, Filter Components, Filter Specifications, Power Line Monitoring.*

(21) Electrical Noise Control in Local Area Networks
Three Days

Electrical noise and interference are the most common cause of interruption of service and loss of performance for Local Area Networks. Key considerations in designing, purchasing and operation of Local Area Networks are based on the performance in a real world environment filled with interference and noise problems. This course indentifies the strengths and weaknesses of the major LAN systems, and provides the background and training necessary to keep your LAN operating at peak effectiveness.

The effective design, proper installation and efficient operation of a Local Area Network mandates controlling electronic interference and noise. This intensive course identifies those areas of a LAN susceptible to interference and noise and gives simple, effective solutions to avoid LAN performance degradation and failure.

Course outline includes, *Basic Terms and Concepts, Comparison of LAN Performance with and without Interference and Noise, Noise Impacts on Wide Area Network Interfaces, Cable, Wiring and Installation to Prevent Problems, Common Interference Problems, Diagnostics, Measurement of Interference, Fixes, Case Study and Workshop.*

(22) Architectural EMC Design
Three Days

This course abolishes myths and establishes a rationale and describes standards for interference control for buildings and their contents. Anyone involved with a complex facility such as, building contractors, architects, industrial engineers, construction personnel, power and telephone engineers and plant managers should attend this course. Also electrical/electronic technicians and engineers, tasked with design of special facilities, installation, fix and/or retrofit of equipment and systems will find this new course to be a must.

Course outline includes, *Course Overview, Developing the Need for Building EMC, Building Ground Systems, Field Ambients, Conducted Ambients, Power Mains Transient Control, Telephone and Other Signal Lines, Internal Sources Requiring Special Attention, Special Rooms Requiring Quality Service, Building Control of Other Environmental Threats, Integrating EMC into the Specifications, Course Summary.*

More Interference Control Courses

(7) **EMP/SGEMP Design & Testing for Survivability**
(9) **ESD Component Handling Techniques**
(11) **EMC for Mechanical Packaging Engineers**
(13) **MIL-STD-461/462 System Level EMI Testing**
(14) **Mobile Communications**
(15) **Grounds & Shields in Instrumentation**
(16) **EMC and Project Management**
(17) **EMI Control in Motor Vehicles**
(18) **EMI Control in Weapon Systems/ Military Vehicles**
(19) **Essentials of EMI/EMC**
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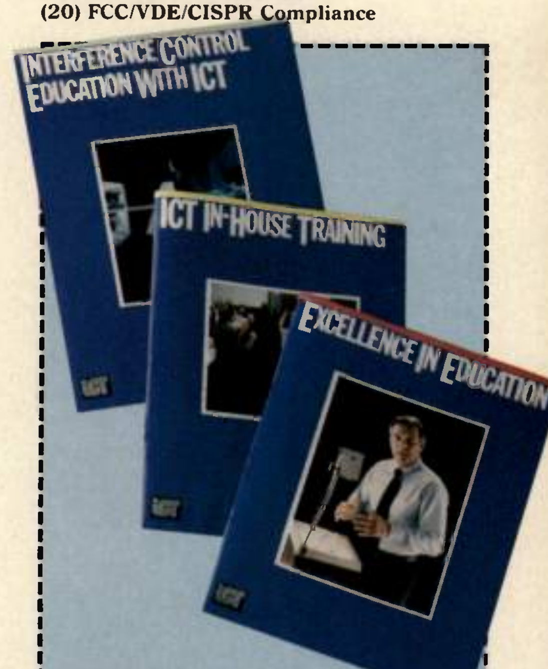

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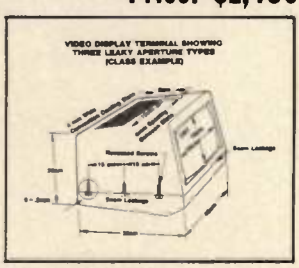
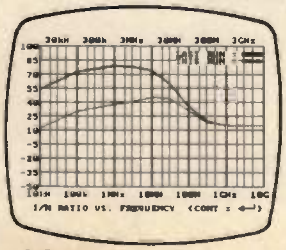
The software calculates box shielding performance from 10 kHz to 10 GHz and tells if your electronics are adequately protected. As your design changes, it can be re-evaluated in minutes. Design leakages are identified along with help-fix flags.

Run the program several times for any design and get different EMC solutions. Then, select the best design based on other than EMI considerations, such as cost, weight, reliability and maintainability.

Price: $1,450





BOX-LEVEL RADIATED EMISSION CONTROL—PROGRAM #5300, REV 2.1

Control emission from your single-layer or multi-layer boards and from your enclosure housing. Evaluate your trial design to meet FCC, VDE, MIL-STD-461C, or other emission regulation you select.

See the impact of different logic families, number of chip carriers, board dimensions, ribbon cable and 20 other parameters on radiation control. Then try out "what if" scenarios along with the enclosure design to get spec compliance.

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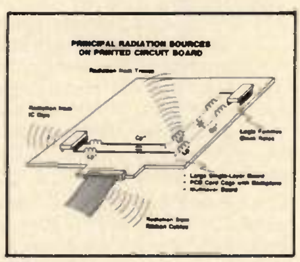
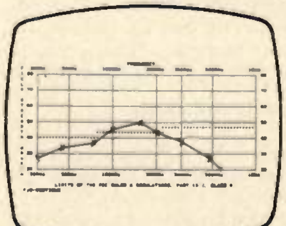




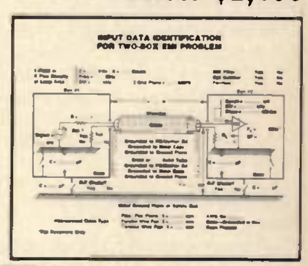
BOX-TO-BOX RADIATED EMI SUSCEPTIBILITY CONTROL—PROGRAM #5220, VER 3.0

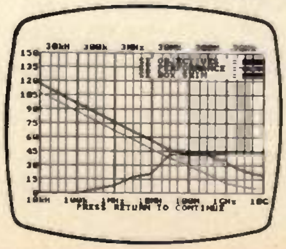
Interconnecting cables act like antennas for EMI. Together with various box grounding schemes, they are the first places that an EMC expert looks for EMI problems.

Program #5220 addresses these together with common and differential mode, and ground-loop coupling reduction. The help-fix menu covers these and topics of victim analog devices, logic families, balanced and unbalanced circuits, coaxial and wire-pair cables and their shields, filters and 25 other parameters.

The software is used to organize and simplify this otherwise complicated design problem from 10 kHz to 10 GHz. In minutes, you can now design cables, and associated networks that protect against combinations of SAE/CBEMA/SAMA/MIL-STD-461 ambients, CE transmitters, lightning, EMP or any other EMI threat you specify. Use the "what-if" scenario to see quick results and to obtain different solutions for best choice.

Price: $2,450





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Interfaces and related cables are among the most notorious receptors and emitters of electromagnetic interference (EMI). This book provides practicing engineers, technicians and students with a coherent approach to controlling interference in cables and device interfaces. The book progresses from an introduction of the interface domain through basic transmission line principles, terminal and peripheral interfaces, functional aspects of bus interfaces, etc. Basic building blocks of data acquisition systems in the industrial environment, related EMI tests, optoelectronic systems, noise in local area networks and, RF and microwave EMI problems and solutions are detailed.

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EMI Control Methodology and Procedures

by Donald R. J. White and Michel Mardiguian

If you could have but one reference book for understanding and controlling electromagnetic interference, this is it. Dr. William G. Duff, past president of the IEEE EMC Society, calls it the "best workbook for controlling interference available. No library should be without one."

EMI Control Methodology and Procedures covers all aspects of EMI control from predicting problems to effecting solutions. The format of this popular book is logical and easy to follow. It emphasizes the practical application of principles. Nearly all material is new and does not appear in other published literature.

Ten chapters cover 120 topics, interference control from A to Z. Illustrated with hundreds of pictures, charts, graphs and tables, it is a cornerstone work in EMC.

Fourth Edition $375

Interference Control in Computers and Microprocessor-Based Equipment

by Michel Mardiguian

EMI control takes on new significance with the computer and its building block, the microprocessor. Like vibration, acoustics and climatic conditions, EMI is a big part of the environment. It strongly affects the performance of such equipment. By understanding the nature of EMI, you can learn to cope with it and avoid costly rework, extra effort and retrofit.

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Lightning and Lightning Protection

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Lightning destroys. High voltages and heavy currents can surge through all types of lines to disrupt systems, damage programs and memories or burn out equipment. *Lightning and Lightning Protection* provides the technical information you need for effective design and protection of equipment, systems, facilities and personnel.

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Grounding for the Control of EMI

by Hugh W. Denny

An EMI expert covers one of the key areas of EMI control. This handbook emphasizes practical application instead of complicated mathematics and detailed theory. Use the information for day-to-day applications in design, construction and use of electronic equipment and systems.

This book covers the various rules for grounding networks, describes basic principles of operation and presents a set of preferred design practices. Subjects include topics like electromagnetic environments, ground circuit behavior and ground network configurations.

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Comprehensive definitions of Electromagnetic Compatibility (EMC) and how interference manifests itself are covered in detail. This handbook addresses national and international EMI regulatory control and support agencies, committees, associations and organizations, and their respective EMI control standards, specifications, test plans, reports and certification. It also covers results of numerous other surveys, test plans and EMI control procedures and reports from sources throughout the EMI community.

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Volume 2 EMI Test Methods and Procedures

by Donald R.J. White

Fundamentals and practical application how-to-do-its of test methods and procedures required in the control of EMI are emphasized in this text. It includes detailed descriptions of basic terms; a comprehensive survey of EMI instruments, calibration factors and measurement concepts; preparation of test specimens, including excitation and loading; conducted and radiated emissions and susceptibility test procedures for MIL-STD-462 and other EMI-MIL-STD tests; and instrument measurements error analysis and ambient site surveys.

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Volume 3 EMI Control Methods and Techniques

by Donald R.J. White

This handbook focuses on sources of EMI and receptors. Emphasis is placed upon prediction and control and design of grounding and bonding; shielding, cabling, wiring and harnessing; connectors, fittings and gasketing; filters, filtering and suppression devices; packaging; and applications for control of radiation hazard.

668 Pages 431 Illus. ~~$129~~ $64

Volume 4 EMI Test Instrumentation and Systems

by Donald R.J. White

Volume 4 stresses some of the most vital aspects of engineering for the control of EMI test instrumentation and test environment. This includes testing in open-field and shielded enclosures (including anechoic chambers); EMI emission and susceptibility antennas; EMI conducted sensors and susceptibility injectors; EMI test instruments, including automatic EMI systems and test instruments of the future; receivers and spectrum analyzers and signal and susceptibility testing sensors.

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Volume 5 EMI Prediction and Analysis Techniques

by Dr. William G. Duff and Donald R.J. White

This is a comprehensive introduction to EMC analysis including technical (and practical) application of prediction techniques, spectrum use, survey of prediction, analysis of models and methods (both theoretical and empirical) on transmitters, receivers and antennas, and propagation and performance degradation criteria. Applications cover natural environmental noise models plus man-made emitters and receptors including radar, voice, data communications, navigation and telemetry.

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Volume 6 EMI Specifications, Standards, and Regulations

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Fundamentals of Electromagnetic Compatibility

As the introductory text, this volume is an overview of the EMC field and explains principles upon which later volumes elaborate. Early chapters provide common EMC terms and definitions and illustrate basic EMI problems and solutions. Subsequent chapters cover EMC in telecommunication and other electronic systems, principles of grounding and bonding, shielding, filter applications, standards and rules and regulations. The book also provides data on EMI control and test plans, and measurement procedures $90

Volume 2
Grounding and Bonding

This volume clarifies the difference between earth grounds, safety green-wire connections, zero-volt analog and logic references and other concepts that fall under the grounding umbrella. Safety versus fault detection and correction issues are addressed, along with the principles of and rationale for power grounding, ground-related EMI, cable shield grounding, architectural grounding and test and maintenance procedures. Various bonding techniques are explored, including welding, brazing, soldering, screw-type fasteners, and corrosion control. $125

Volume 3
Electromagnetic Shielding

This is the complete guide to EMI shielding materials and methods from small enclosures to buildings and vehicles. It begins with shielding theory, including field theory, wave impedance, metal impedance and shielding effectiveness (SE). Extensive information on achieving skin shields by conductive paint, spraying, dipping, deposition and composites are presented. Also covered are methods for determining SE requirements, SE of box structures, evaluation and control of aperture leakages and shielding design and retrofit. $135

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EMC in Components and Devices

A good design for EMC begins at the component level. Introductory material covers EMC performance of components and essential EMI mechanisms. The book then discusses EMC characteristics of resistors, capacitors and inductors; insulators and conductors; analog and logic devices; power electric components; transformers, solenoids, relays and other magnetic components; electromechanical and luminescent devices; transient suppressors and optoelectronics. Information is also provided on PCB layout techniques, backplanes and motherboards and design for ESD tolerance. $85

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Interference in baseband and carrier band telecommunication systems may be forecasted and analyzed to determine if it meets user objectives. Following an introduction to telecommunication system EMC, the reader is presented with a comprehensive analysis of transmitter, receiver and antenna EMC considerations; propogation paths and modes; and performance models for EMC assessment. EMI control methods are discussed, and a survey of EMC analysis computer software is included. $95

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Organized similar to Volume 11, this book provides information on and reproductions of supporting military standards relating to connectors, cables, filters, etc. Specific MIL standards and specifications include MIL-E-5400T, MIL-C-13909C, MIL-F-15733F, MIL-C-26482G, MIL-STD-1377, MIL-STD-1385A, MIL-STD-1399B, MIL-STD-1512, MIL-C-85485A, MIL-C-83723D, MIL-C-24308B, and many others. $65

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Electromagnetic fields radiated by natural and man-made sources can have adverse effects on electrical and electronic systems. These effects can range from noise on communication lines to personnel hazards.

This book will help you deal quantitatively with the coupling of electromagnetic fields to transmission lines. It contains effective techniques to solve coupling problems. The author gives readers a method for solving nonuniform electromagnetic field problems without restricting the solutions to plane waves.

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1986 $75
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Electromagnetic Shielding Materials and Performance

by Donald R. J. White

One of the major problems in selecting and using materials for EMI shielding is the prevalence of misleading or inaccurate data. Manufacturers' literature regarding the impedance of the fields (E, H or plane waves) is often unreliable. It clarifies and quantifies these points in real-life applications. This book starts with shielding effectiveness versus frequency as a function of shield metal. The discussions and data go beyond homogeneous metals.

The appendices are perhaps the most important of all materials presented. They contain 42 pages of design shielding effectiveness graphs for several metals whose thicknesses range from 2.54 nm to 2.54 cm. The design graphs cover source-to-metal distance ranging from 10 cm to 10 km for both near- and far-field calculations and associated frequencies.

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This 3 1/2" × 6 1/2" (9 cm × 17 cm) EMC primer, entitled, "Essentials of EMI/EMC and Electrical-Noise Suppression," fits in your shirt pocket for ready reference. Packed with charts, tables, graphs and illustrative examples, this 24-page "mini-reference" covers a surprising number of EMC/EMI related topics.

24 Pages $5

Fiber Optics and Optical Isolators

by Dr. C.J. Georgopoulos

The emerging field of fiber optics presents new challanges for effective EMI control. This handbook covers the design of circuits using optical isolators, equipment interfaces and systems using fiber optics. It offers new perspectives on EMC problem solving.

Fiber Optics and Optical Isolators shows you how optical coupling can provide many solutions. It covers optical sources, detectors and couplers and their capabilities, limitations and applications. Other subjects include selection criteria, standardization, wavelength multiplexing and survey with projected uses and market trends.

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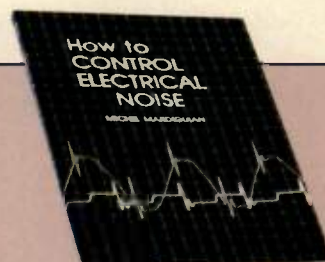

How to Control Electrical Noise

by Michel Mardiguian

How to Control Electrical Noise addresses the subject in clear, uncomplicated terms. It emphasizes practical understanding and control techniques. Profusely illustrated, it covers subjects from EMI sources to troubleshooting. Also included are topics like the first barrier against radiated EMI and how to maintain box shielding with covers.

87 Pages 52 Illustrations $19

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Shielding Design Methodology and Procedures

by Donald R. J. White

Here is the step-by-step approach to shielding against EMI during the design process. This new publication helps you predict shielding requirements and analyze the effectiveness of proposed measures. You can increase effectiveness with this book's logical, practical approach before constructing the first piece of hardware. The system is reliable and effective for box, case, cabinet and enclosure designs.

Shielding Design Methodology and Procedures fills a significant need in literature for a systemized approach to shielding design. This book also addresses design and retrofit stages with dozens of examples illustrating its applications. Use it to select boxes with optimized skin shielding and well-secured apertures.

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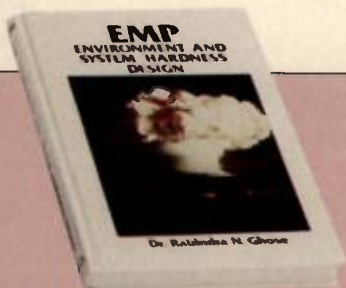

EMP Environment and System Hardness Design

by Rabindra N. Ghose

Understanding EMP is the first step in protecting systems against the effects of nuclear EMP. This handbook details the EMP problem and ways of avoiding its adverse effects. System designers, managers and users concerned about EMP and looking for ways to harden a system against it will benefit.

EMP Environment and System Hardness Design presents EMP characteristics, coupling mode and system interaction as well as ways to decrease your systems' vulnerability. It discusses various hardness concepts and methods of assuring hardness. Included are steps for forming standards and specifications for system hardness during its acquisition phase and life cycle. This important book contains EMP hardness-assurance management concepts. It covers simulation of EMP environments for system hardness testing, test concepts, instrumentation, sensors and test facilities.

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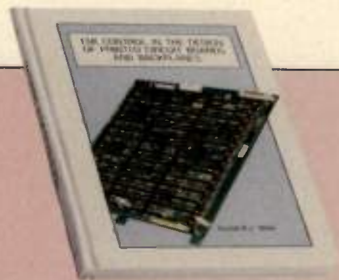

EMI Control in the Design of Printed Circuit Boards and Backplanes

by Donald R.J. White

PCB designers are having to meet new and rigid specifications, such as standards by the FCC and VDE and regulations like MIL-STD-461B. This book is a single, comprehensive source of information in this increasingly important and expanding field.

EMI Control in the Design of PCBs and Backplanes covers analog, digital, discrete and integrated circuits. It emphasizes backplanes, backplane interconnects and input-output (I/O) devices from buses to peripherals. For example, it covers the performance data for filters, shields and other interference components presented by their manufacturers as amplitude versus frequency. This is important for PCB designers, who must work in both the frequency and traditional time domains.

The appendix addresses development and applications of the time-frequency domain transform. Illustrations and tables are abundant and illuminate key points about the real-world discussions.

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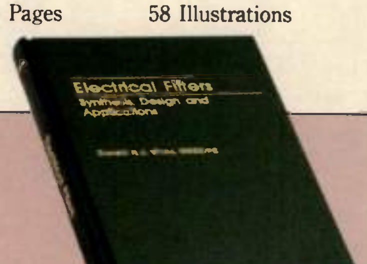

Electrical Filters

by Donald R.J. White

This basic manual covers the types and uses of filters and filter systems in modern electrical and electronic circuitry. It helps you properly select and design filters, eliminating problems, redesigns and expenses.

Electrical Filters opens with a survey of the different types of electrical filters. It includes modern network synthesis and response functions of the Butterworth, Chebyshev and other types of filters. Of special value is a step-by-step approach to the design of low-pass, high-pass, band-pass and band-rejection filters using low-pass prototypes and frequency and impedance scaling. The text also covers physical realizability due to finite Q-factors of components and their parasitics.

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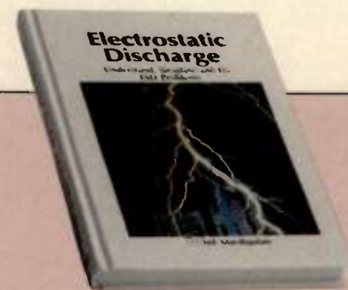

Electrostatic Discharge—Understand, Simulate and Fix ESD Problems

by Michel Mardiguian

The subtle and difficult-to-predict problem of electrostatic discharge can cause serious problems with delicate systems, instrumentation and data storage banks. This new book gives you a thorough understanding of the physics and parameters involved. It contains typical scenarios and statistical aspects. It allows personnel involved with ESD to devise reasonable ESD criteria and avoid costly and time-consuming redesign and retrofit work.

This is one of the few books on the market that includes the complete mechanics of personnel and furniture ESD. Learn how to predict ESD-induced noise in PCBs and cables. The text also includes existing specifications, simulators, available options and detailed test procedures.

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☐ Payment Enclosed ☐ Please Bill: ☐ Me ☐ Company
☐ Purchase Order and/or Payment to follow. P.O. # ____________________

☐ VISA ☐ MasterCard Card # ____________________ Exp. Date ___/___/___ Signature ____________________

TRAINING COURSE REGISTRATION

Please register me for the course checked below on:

____________________ *held in* ____________________
course date *course city*

☐ Grounding and Shielding (page 4)
☐ Practical EMI Fixes (page 6)
☐ EMC Design and Measurement (page 8)
☐ TEMPEST Design, Control and Testing (page 10)
☐ TEMPEST Facilities Design (page 11)
☐ Intro to EMI/RFI/EMC (page 12)

STUDENT FEES & DISCOUNTS

***Discounts**—Please check the ONE discount you wish to use—see discount section.

☐ Past student discount (10% of student fee): ____________________

Enter past course and date: ____________________

☐ Multiple student discount: ____________________

Student Fee $____________________
Early Bird $(____________________)
*Discount $(____________________)
Total Due $____________________

ACCOMMODATIONS

A block of rooms is reserved at a special rate at the course hotel. To receive this rate, you must make reservations at least three weeks prior to the course start date. After that, there is no guarantee that rooms will be available. Also, you must mention that you are attending an Interference Control Technologies training course to get reduced rates. Call early and make reservations.

CANCELLATIONS/CREDITS

You may cancel up to three weeks before a course and receive 100% credit toward another course or a full refund. A 20% cancellation fee is charged for all no-shows and cancellations made less than three weeks before the course start date.

IN-HOUSE TRAINING

☐ Please mail me your Free In-House Training Course kit. (If responding by mail please give address above.)

HANDBOOK ORDER SECTION All Orders Are Shipped FREE via UPS Ground Service.

Title	Price	Qty.	Total
EMI Control Methodology	$375		
EMI Control in Computers	58		
Grounding	68		
Coupling of Elect. Fields	41		
Lightning Protection	49		
Electrical Filters	47		
1986 EMC EXPO Record	95		
1987 EMC EXPO Record	95		
1988 EMC EXPO Record	95		
EM Shielding	46		
Electrical Noise Control	19		
Fiber Optics	38		

THE NEW SOURCE	Pre	Pub	Qty.	Total
Vol. 1-Fund of EMC	P	90		
Vol. 2-Grounding & Bond.	P	125		
Vol. 3-EM Shielding	108	135		
Vol 5—EMC in Comp. & Dev.	P	85		
Vol 7—EMC in Telecomm.	P	95		
Vol 9—US Com. Standards	P	70		
Vol 10—Europ. Com. Stand.	56	70		
Vol 11—Princ. Mil. Stand.	P	75		
Vol 12—Support. Mil. Stand.	P	65		
EMP Hardness Design		49		
Design of PCB's		32		
Electrostatic Discharge		69		

Title	Pre	Pub	Qty.	Total
Shielding Design		86		
Cables and Interfaces		59		
Aerospace Lightning		69		
Pocket EMC Primer		5		
Vol. 1-Noise & Specs.		34		
Vol. 2-Test Methods		49		
Vol. 3-EMI Control Methods		64		
Vol. 4-EMI Test Instru.		47		
Vol. 5-EMI Prediction		57		
Vol. 6-EMI Specifications		42		
20% Discount/Past Students			—	
Total Amount				$

EMC SOFTWARE

☐ Yes! Please mail me the computer program(s) indicated below. I have indicated method of payment and listed address above.

Program Number & Identification	Price	Qty.	Total
Program 5220 . . . Box-to-Box Radiated Susceptibility Control	$2,450		
Program 5300 . . . Box Level Radiated Emission Control	$950		
Program 5500 . . . Design of Shielded Boxes	$1,450		
Total			$

EMI FIX-IT KIT

☐ Yes! Please send me the EMI Fix-It Kit for $950 which includes shipping and handling. I understand orders will begin shipping October 1st, 1988. I have indicated payment type above.

EMC TECHNOLOGY

☐ FREE 1-Year Subscription to **EMC Technology** Magazine. Please send me a qualification card.

EMC EXPO '89

Please send me information on attending or exhibiting at the 4th annual EMC Exposition and Conference to be held in Washington, D.C., August 1-3, 1989. I am interested in:
☐ Attending ☐ Exhibiting

COMBAT ELECTRICAL NOISE & INTERFERENCE

AUGUST 1988 THROUGH FEBRUARY 1989 SCHEDULED SEMINARS

COURSE TITLE / COURSE LOCATION	SAN DIEGO	CHICAGO	BOSTON	PHILADELPHIA	PALO ALTO	ATLANTA	LAS VEGAS	DALLAS	WASHINGTON DC	LOS ANGELES	ORLANDO
GROUNDING AND SHIELDING	SEP 12-16			SEP 26-30	OCT 10-14	OCT 24-28	OCT 31-NOV 4		OCT 14-18	DEC 5-9	JAN 23-27
PRACTICAL EMI FIXES	OCT 17-21 JAN 16-20		SEP 12-16	OCT 3-7	SEP 19-23	OCT 31 NOV 4	DEC 5-9				JAN 30 FEB 3
EMC DESIGN & MEASUREMENT		SEP 12-16					OCT 3-7	NOV 7-11	DEC 12-16	FEB 6-10	
TEMPEST DESIGN & MEAS.					NOV 15-18				FEB 7-10		
TEMPEST FACILITIES DESIGN					JAN 16-20				OCT 17-21		
INTRO TO EMI/RFI/EMC	NOV 15-17										


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EMC Software
Page 16


EMI Fix-It Kit
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