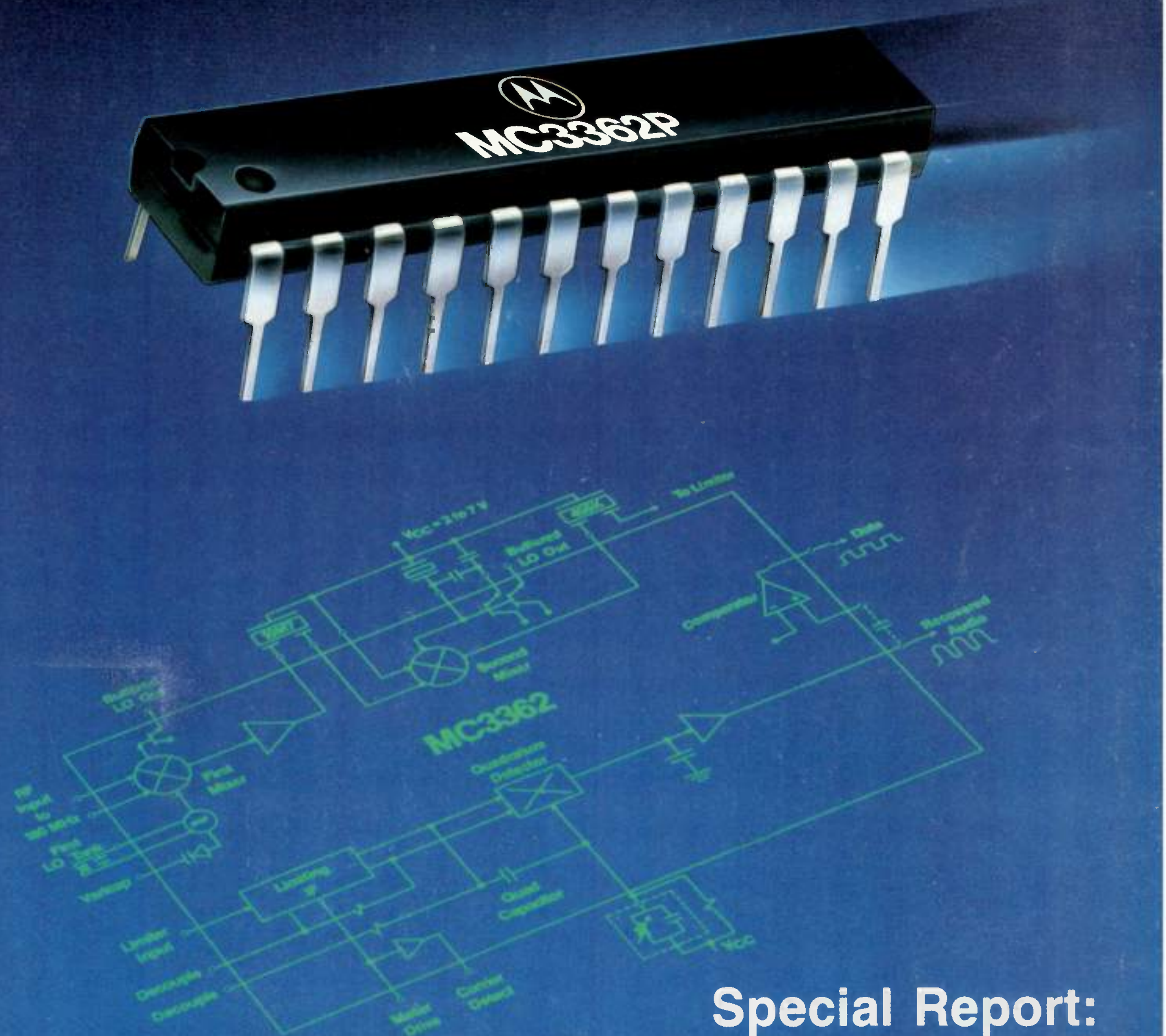
rf design
ideas for engineers
January 1987



Special Report: RF in Scientific Research

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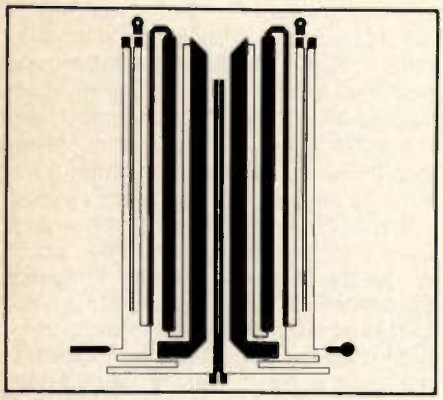
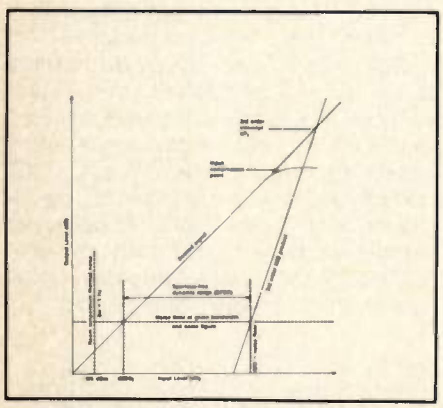
Page 36 — Special Report



Page 52 — Microstrip Filters



Page 65 — Receiver Dynamic Range

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***rf* editorial**

Research: For Knowledge or Technology?

By Gary A. Breed
Editor

Scientific research was born 2500 years ago, with the idea that Man can actually go out and look for the secrets of Nature. The first man to realize that discovery need not be accidental was named Thales, a thinker of Phoenician descent living on the Mediterranean island of Miletus.

By 585 B.C. Thales had made a name for himself. Through his studies he was then able to predict an eclipse, certainly a big deal back then. He had solved a few other knotty problems, too, such as getting an army across a river that was too deep to ford. Mostly, though, Thales spent his time trying to figure out how the world around him operated.

If we consider Thales as the first "scientist" then we need to hear another tale about him: Money to support research was scarce in 585 B.C., too, and Thales was constantly chided for his poverty. So he decided to do something about it. His studies of weather patterns indicated that a good growing season was likely, so he went out and bought options on all the olive presses on Miletus. When the big crop came in, he made a killing on the market! Then he went back to his studies.

Pure Science vs. Applied Science

Even in the dawn of scientific research, the differences between *pure science* and *applied science* were pointed out to Thales. The arguments haven't changed in 2500 years. With tough competition for the finances to support research, battles are constantly waged between those who see the pursuit of knowledge as the only important role, and those who insist that research have a practical outcome.

I'd like to make just one point: In the long view of history, *neither* approach has any monopoly on effectiveness or results. Applied science, in the efforts to develop radar in World War II, led to fundamental discoveries about the nature of wave propagation. The study of prime numbers in mathematics, once a seemingly useless theoretical exercise, has given us a virtually perfect data encryption system.

The battle for dollars will go on, sometimes with the argument that either "pure" or "practical" is the better way. Whatever the arguments, we just have to make our best judgment on the short-term and long-term values of the research efforts competing for support. Getting rid of the artificial labels of "pure" and "applied" is the first step toward making even-handed decisions. Pure science eventually gets applied, and applied science usually discovers some basic principles.

Our Special Report (page 36) takes a look at some of the research efforts where RF plays a central role. Some of these efforts might be called pure science, some considered applied science, but at the bottom line they are all fascinating explorations of Nature intended to satisfy our insatiable curiosity and then use that knowledge to give us a little more control over our life on earth (and beyond).

rf viewpoint

The Right Place at the Right Time: RF Technology Expo 87

By Keith Aldrich
Publisher

If you're an RF engineer at this time in history, there seems to be little question that the "right place" for you, come February 11 to 13, is at the Disneyland Hotel in Anaheim, Calif., attending RF Technology Expo 87. No matter how busy you are in your job. No matter if the expense is a bit of a strain on the budget. No matter what else might be going on at that time.

Recent research shows that if you're among one half of our readers you've been working in RF less than six years — even though you've been a working engineer for 12 years — and several thousand of you have gotten into RF work within the past year. You're part of a great influx into this technology, occasioned by a worldwide boom in RF applications. Your newness is no disgrace, but with the technology itself changing as fast as it is, there's no question you've got a real challenge in trying to keep up. Perhaps you owe it to your company and to yourself to take a break and get better at what you're doing.

Or, let's say you're among the other half of our readers — those who've been working in RF more than six years. To you, RF Technology Expo is a homecoming: a sign that your time has come. For years you labored in relative obscurity, and even some disdain, in a world where digital technology reigned supreme. No more. Our research shows that 90 percent of our readers rate RF work as "desirable" or "extremely desirable." And of course among the readers are many who used to *be* those digital engineers . . . *or still are.*

Therein lies the real importance of attending RF Technology Expo, even for the most experienced RF veteran. The times, they are a-changin'. Most RF systems now employ digital as well as RF techniques. They combine lumped element with distributed circuit techniques. Discretes give way to hybrids which give way to monolithic chips. "Seat of the pants" design gives way to precise characterization and computer aided design. The RF engineering veteran, if he isn't careful, might well become the RF dinosaur.

RF Technology Expo, in its brief two-year history, has already developed a reputation for offering technical sessions of great practical value to engineers involved in these transitions — whether they are developing radio-controlled toys or sophisticated jamming systems. It is not a conference for scientists, theorists, lobbyists, or businessmen. It does have a practical business side, however, in bringing engineers together with manufacturers of RF devices. This year more than 120 exhibitors, using more than 200 booth spaces, will be showing the latest and best of the components, instruments, subsystems and design aids now available to RF engineers.

In this issue you'll find a complete, digested guide to the technical program, as well as advertisements from many of the exhibitors, advising you of their booth numbers at RF Technology Expo 87, February 11-13 at the Disneyland Hotel. Careful study of this material will convince you of the rather bold statement at the outset of this piece: that if you're an RF engineer *that* place is the *right* place for you to be at *that* time. You'll even find a registration card on page 48 to make sure you follow through and act on your conviction.

See you in Anaheim.

rf design

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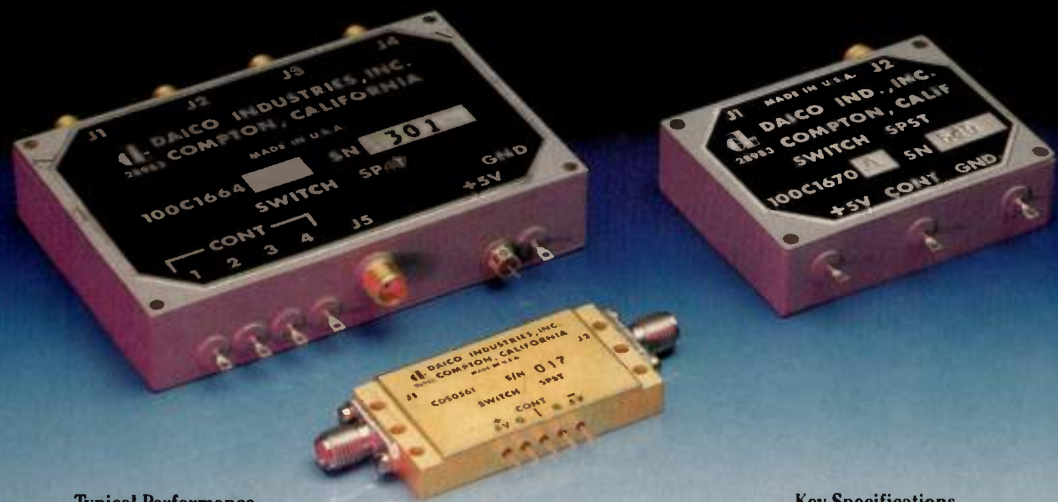

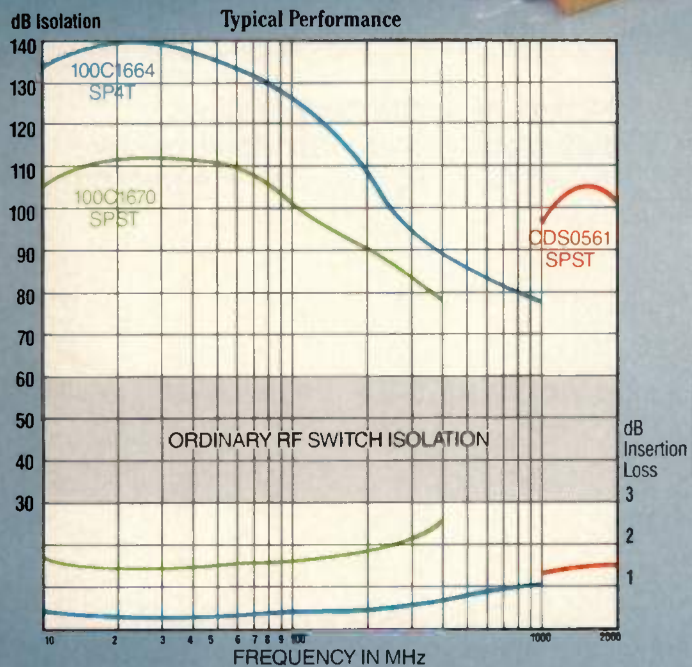

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Control Configuration	1 LINE TTL	1 LINE TTL	4 LINE TTL	—	Logic
Switching Transients	155	10	600	mV	Peak Value
Transition Time	4	2	—	ns	90%/10% or 10%/90% RF
Switching Speed	17	33	400	ns	50% TTL to 10%/90% RF
Insertion Loss	1.5	1.5	—	dB	—
	—	—	0.7	dB	20 - 350MHz
	—	—	1.0	dB	350 - 600MHz
Isolation	106	100	—	dB	—
	—	—	105	dB	20 - 200MHz
	—	—	85	dB	200 - 600MHz
VSWR	1.15 / 1	1.2 / 1	1.1 / 1	—	—
Termination VSWR	1.5 / 1	1.2 / 1	1.1 / 1	—	—
RF Power,	+13.5	+12	+24	dBm	0.1 dB Compression
Operate Max.	—	—	+30	dBm	No Damage
Operating Frequency	1700 - 1900	10 - 100	20 - 600	MHz	—
Operating Temperature	−55 - +125	−55 - +85	−55 - +85	°C	TA

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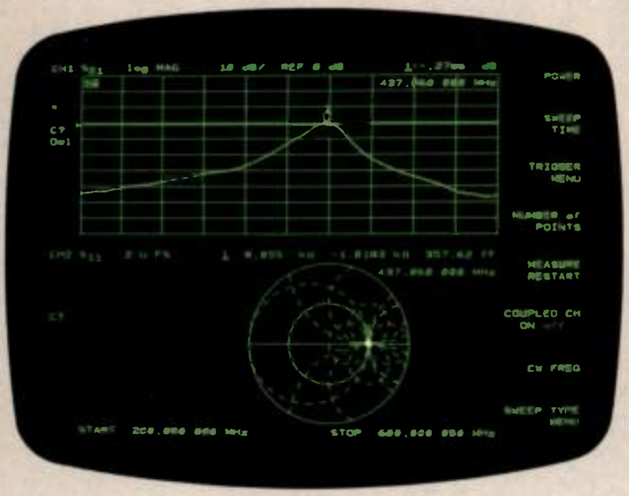

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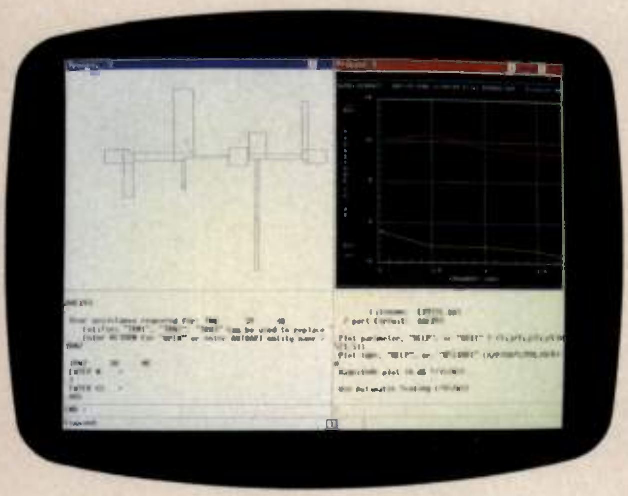

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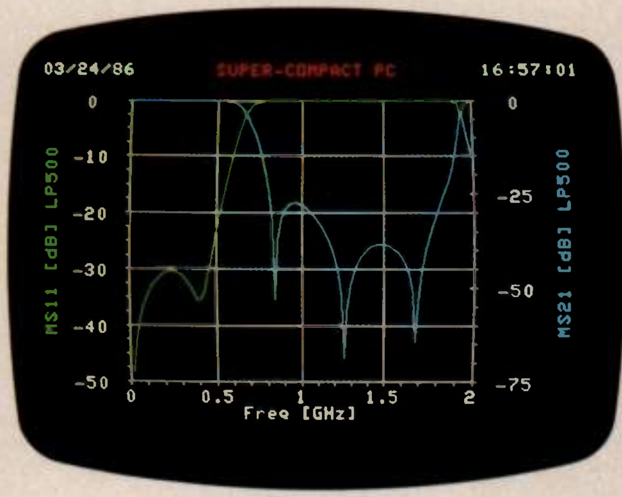

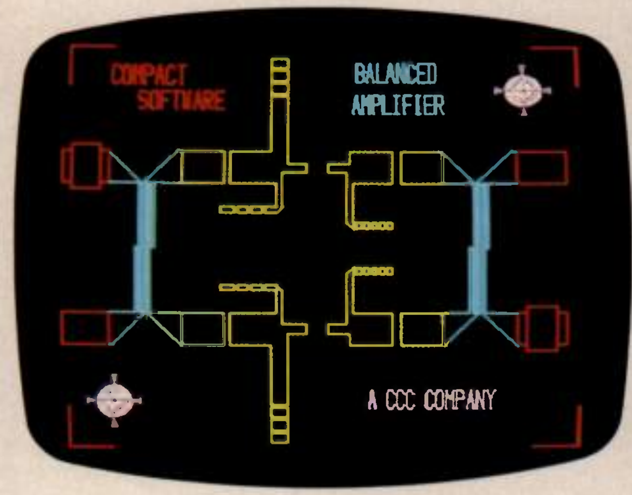

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rf letters

Letters should be addressed to: Editor, *RF Design*, 6530 S. Yosemite St., Englewood, CO 80111.

"Ladder Network Analysis" Notes

Editor:

I would like to thank all the readers who have written recently about my article, "A Ladder Network Analysis Program," Nov. 1986, p. 68. Be sure to watch future issues for more! I would like to remind those who have ordered the software disk or the program listing that the IBM version is designed to be used with the Color Graphics Adapter (CGA) card, or equivalent, in order to obtain the high-resolution screen plots. Also, the IBM program, GRAPHICS.COM, is required in order to print the screen plot to an EPSON graphics, or compatible, printer.

In addition, I would like to point out some minor typos that crept into the figures.

Page 68, Table 1: For model types 12 through 16; the "3EI0" is really "3E10," i.e., the number 30,000,000,000.

Page 69, Figure 1: The letters within the matrix should read;

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} \text{ not } \begin{bmatrix} A & C \\ B & D \end{bmatrix}$$

Page 69, Figure 2: The fourth formula should read;

"then: $$\begin{bmatrix} V_{1A} \\ I_{1A} \end{bmatrix} = \begin{bmatrix} A_A B_A \\ C_A D_A \end{bmatrix} \begin{bmatrix} A_B B_B \\ C_B D_B \end{bmatrix} \begin{bmatrix} V_{2B} \\ I_{2B} \end{bmatrix}."$$

Page 76, Figure 4(a): Add a 170 pF capacitor from the junction of the 0.1 uF capacitor and the 18.7 nH inductor to ground as shown in Figure 4(b). Add a 95.3 pF capacitor from the junction of the 0.1 uF capacitor and the 32.7 nH inductor to ground as shown in Figure 5(a).

Please note that although the program is copyrighted, I would like to encourage readers to modify the BASIC code in order to make improvements. Let me know of any major improvements or changes so that I might be able to share these with the rest of the readers.

Lastly, I failed to acknowledge, in the original article, the help of James Sesters, who kindly provided the superior graphics routine. Thank you, Jim!

Ken Wyatt
Woodland Park, Colorado

More Shielding Discussion

Editor:

Can you stand another letter on the April 1986 article "Composite EMI/RFI Shielding" and the ensuing letters about it?

Both letters about the article point out a confusing, misleading graph of shielding effectiveness which perpetuates or strengthens the myth that the FCC requires a certain level of shielding for products that fall under its rules! The fact is that the FCC does *not* require any shielding of any electronic device! The FCC requires that *unauthorized RF emissions be kept below the regulatory limits!* Shielding is only one of several ways to accomplish the needed suppression of unauthorized emissions.

The last letter (Curilla, September 1986) mentions the ASTM ES7-83 gold-filmed calibration sample. This sample is about 4.5 nm thick and has a shielding effectiveness of 32 dB ±3 dB. A one-atom thick gold-film would only have about 19 dB shielding effectiveness (Is this "substantial?"), while if it were at least one skin-depth thick the gold-film would have a

(Continued on page 24)

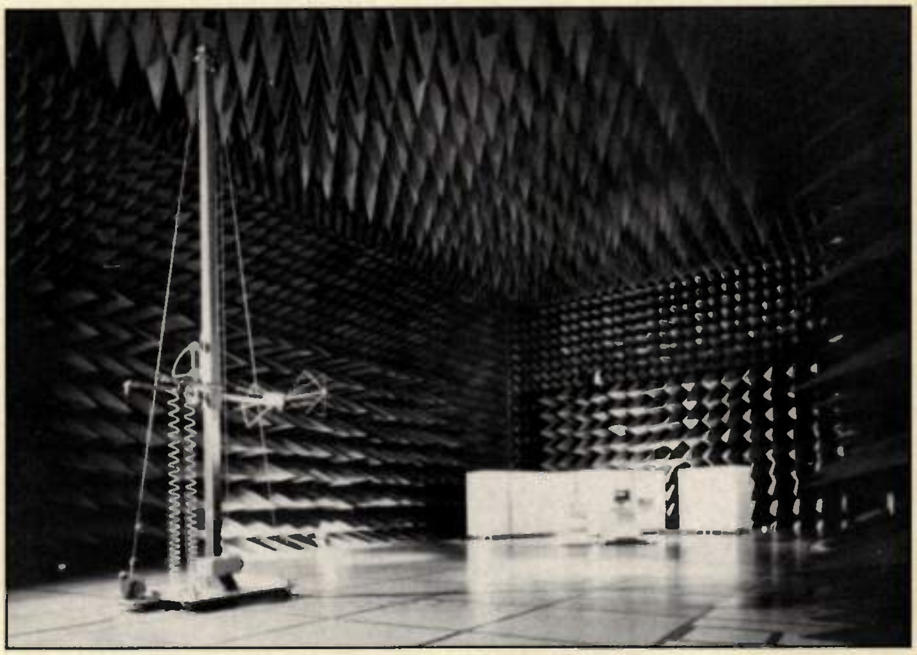
FCC Recognition for Foreign Test Data Opens U.S. Doors

A huge anechoic test chamber near Mt. Fuji in Japan has become the first overseas facility to have its site attenuation data recognized by the FCC as equivalent to open-field data, according to Keene Ray Proof, Norwalk, Conn., the company which engineered and built the chamber for Fujitsu Ltd.

"Such FCC recognition should come as good news to overseas electronic manufacturers aiming at the U.S. market," says Brian Lawrence, vice president of Keene Ray Proof. "It means that the FCC will almost certainly accept data direct from overseas manufacturers if recorded in a properly designed chamber."

The test chamber is part of Fujitsu's new EMC and Acoustics Laboratory at its Numazu facility. It is designed to perform RF emissions testing for Fujitsu's line of personal and commercial computers in the 30 to 1,000 MHz range. The chamber has a shielding integrity of more than 100 dB attenuation up to 10 GHz, and has proven suitable to accommodate measurements in accordance with FCC rules, Section 15.38, Part 15 J.

Measuring 86 by 46 by 36 feet, with a 26-foot diameter, seven-ton capacity turntable, the $2 million test chamber easily accommodates Fujitsu's large FACOM supercomputer system at test range lengths up to 10 meters. Chamber walls, floor and ceiling are constructed from modular panels. Walls are supported by structural steel for the seismic requirements of the region. Lining the interior are foam rubber pyramids ranging four to eight feet in length, impregnated to absorb RF and microwave energy.



Fujitsu's anechoic chamber has been FCC-recognized.

"There's a great deal of global interest in meticulous testing for FCC compliance among manufacturers of electronic devices today," says Lawrence. "This can be attributed to the FCC's current crackdown on companies doing doubtful emissions testing. There are currently fewer than 10 anechoic test chambers whose data has been accepted without reservation by the FCC."

RF Business Briefs

K&L Microwave, Inc., Salisbury, Mass., has acquired all assets of Communication Techniques, Inc. (CTI), Whippany, N.Y. Founded in 1973, CTI manufactures a variety of high performance RF and microwave signal sources and synthesizers. It will function as a wholly owned subsidiary of K&L.

TRW Electronic Components Group, El Segundo, Calif., has formed TRW Semiconductor Products Division to consolidate the European operations of LSI Products and Optoelectronics and RF Devices Divisions. The Semiconductor Products Division is expected to strengthen the group's position in Europe by bringing together manufacturing, marketing and sales operations of its active component product lines into a single organization.

Adams-Russell Electronics, Inc., Burlington, Mass., has signed a letter of intent with SDI, Inc., Billerica, Mass., agreeing to acquire all assets of SDI. SDI is a fast-growing maker of diodes, switches, limiters and subassemblies. It will function as a wholly-owned but separate subsidiary of Adams-Russell when the transaction is completed.

Varian Beverly Solid State Operations Division, Beverly, Mass., has been renamed Varian RF Subsystems Division. The division is part of the Solid State Microwave Division, headquartered in Santa Clara, Calif., and manufactures phase detectors, direction-finding subsystems and synthesizers for EW applications.

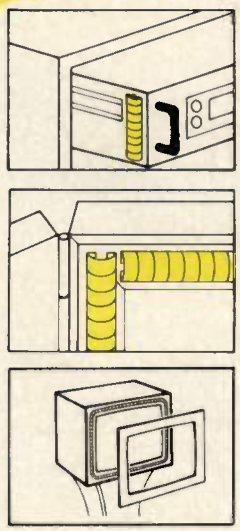
Systron Donner Corp., Concord, Calif., has executed a memorandum of understanding with Austron, Inc., Austin, Tex., to pursue negotiations for Austron's purchase of Systron Donner's Instrument Division based upon approval of both boards of directors. Systron Donner's Instrument Division is a maker of RF and microwave synthesizers, sweepers, microwave counters and power supplies. Austron produces instruments and systems for the precise measurement of time and frequency.

The U.S. Army Signal Warfare Laboratory

Want to save $10,000?

Heat is on computer manufacturers to comply with FCC emission standards. At stake are amounts of electromagnetic radiation that disrupt communications. Recent FCC test showed that half of 29 models examined failed to meet limits. Agency plans to ask Justice to crack down on offenders with fines of $10,000 for those who fail to comply, and that includes fixing machines already sold.

— as reported by Research Institute of America



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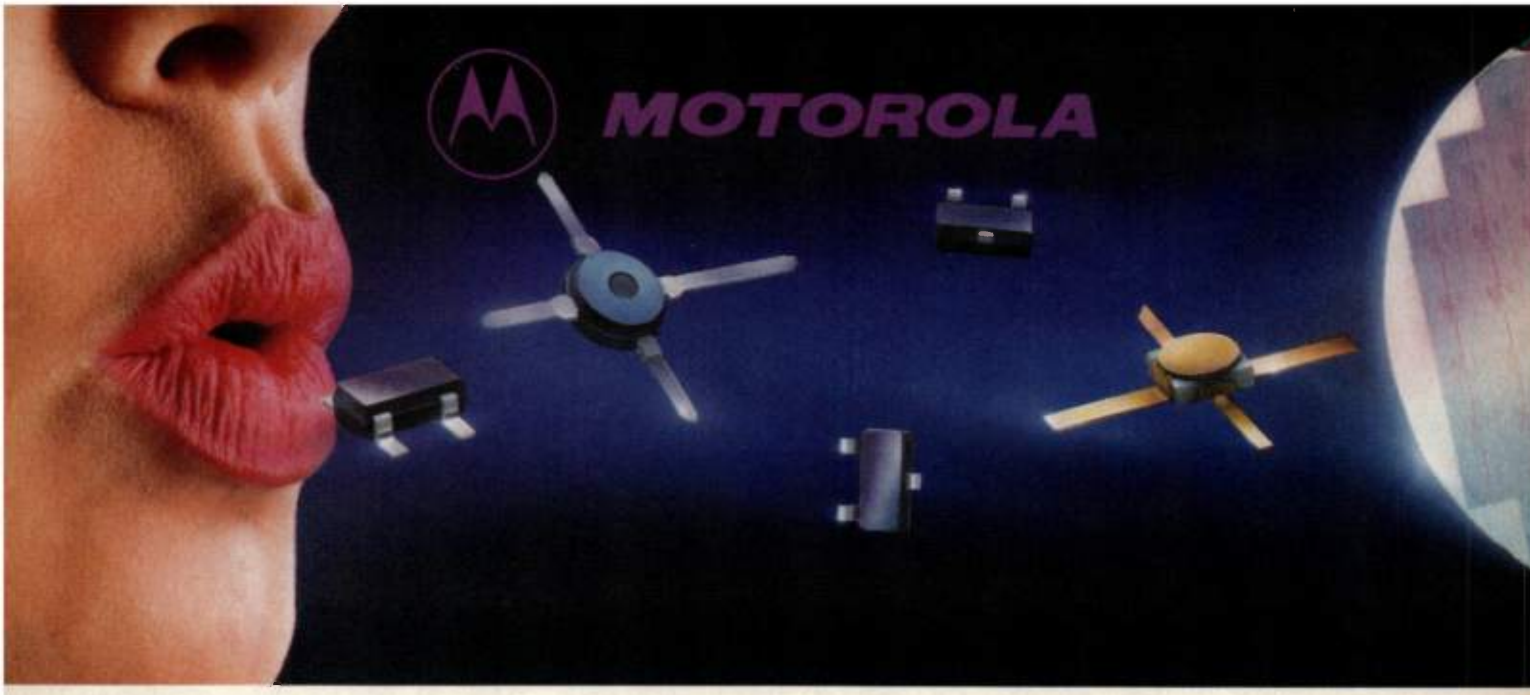
at Vint Hill Farms, Warrenton, Va., has awarded a $1,027,394 contract to American Electronic Laboratories, Inc. for antenna research and development. AEL will develop a specialized antenna system for a moving vehicle utilizing techniques developed by the company's Antenna Division. AEL has been awarded an $18.2 million contract by the Dalmo Victor Division of Singer Co., Belmont, Calif., to produce antennas and receivers for the U.S. Army's AN/APR-39A radar warning receiver system.

TRW Inc. and American Shizuki Corporation, a wholly-owned subsidiary of Shizuki Electric Co., Inc., a Japanese-based electronics company, announced today that they have signed an agreement for the sale of TRW's Capacitor Division for an undisclosed price. Under terms of the agreement, American Shizuki will buy all of TRW's capacitor operations. The Capacitor Division is headquartered in Ogallala, Nebraska, and operates manufacturing facilities there, in Guadalajara, Mexico, and in Taiwan. The division currently employs 980 people. The sale is expected to be completed by the end of December.

The board of directors of Itel Corporation and Anixter Bros, Inc. approved the acquisition of Anixter Bros. By Itel in a transaction valued at over $5 million. Itel has agreed to pay $14 per share in cash for all Anixter common shares. Anixter currently has 36.4 million shares outstanding. Itel, a Chicago-based corporation, has annual revenues of $300 million and operates businesses in the cargo container, rail, and marine dredging industries. Anixter Bros., Inc., also headquartered in the Chicago area, has annual revenues of approximately $650 million. It is a leading supply specialist for wire and cable and other products used in telecommunications, data communications, and cable TV industries.

India's Ministry of Defense has awarded Ericsson an order worth approximately $21.5 million for radio relay equipment that is similar to the type used by the Swedish military. Ulf Mimer, manager of Ericsson's Radio Systems' Defense Communications Division, notes, "Ericson has worked a long time on increasing its market share in nonaligned countries, so the Indian contract may be considered a breakthrough for our company." Ericsson Radio Systems is a supplier of defense communications equipment, including command, control and communications systems, radar systems, tactical communications networks and encryption equipment. The company is also a major supplier of mobile telephone systems, paging systems, avionics, satellite antennas and land mobile radio equipment.

TRW Resistive Products Division, Boone, N.C., has been acquired by Crystalate Holdings plc. The division will operate as IRC, Inc., a U.S.-based, wholly owned subsidiary of Crystalate, a U.K.-based, publicly traded holding company.



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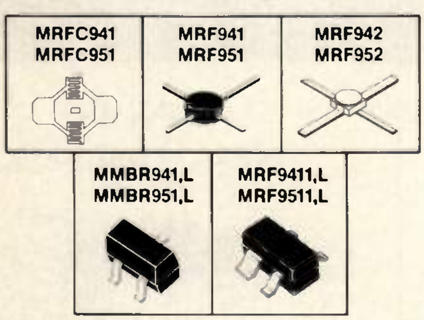
Particularly if you're designing portables or land-mobile radio where signals come in weak most of the time. Because you can't get those signals through noisy, low-quality front ends that put up their own sound barriers.

Motorola now provides small-signal amplifiers that are not only kissed by noise figure specs as low as 1.2 dB, but are offered in a variety of packages, plus chips, for optimum applications flexibility.



High-frequency whispers.

Rated at 15, 30, 50 or 100 mA I_C collector currents, the MRF-/MMBR- family provides a totality of choice in four different package styles, including plastic Macro-X and soon-to-be-registered 70- and 100-mil ceramic types, including SOT-23/SOT-143 with tape and reel packaging options, plus unpackaged chips.

We even plan to offer the ceramics in Hi-Rel versions.

And listen to these best-in-industry performance specs: 1.2 dB and 1.7 dB noise figures at one and two gigahertz levels for the higher-current versions and 1.2, 1.7 and 2.8 dB NF at one, two and four gigahertz frequencies for the lower-current types.

The 1.2 micron die geometries are all of gold top-metal construction with fully-implanted base and emitter structures with silicon nitride passivation for optimum reliability.

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- Package: 1.5 x .8 x .25 inches
- Output: 1 volt RMS
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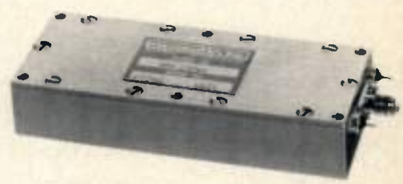
INFO/CARD 68

μ-NOISE NMA 2200 Series

- Package: 3.75 x 1.5 x .7 inches
- Output: +13dBm
- Upper Freq. Limit: 100KHz to 300MHz
- Output VSWR: 1.2 to 1

INFO/CARD 69

μ-NOISE NMA 2300 Series



- Package: 3.75 x 1.5 x .7 inches
- Output: 3 Watts Peak
- Upper Freq. Limit: 100KHz to 300MHz

INFO/CARD 70

Come see us at the RF Technology Expo, Booth #552

Chicago Commuter Trains Provide Cellular Phones

Cellular telephone service is being provided to passengers on 34 daily commuter trains in the Chicago area for a 90-day trial period ending January 31. The trial tests passenger use of the phones throughout the 5,500 square mile area covered by Ameritech Cellular Service. Rates during the trial are 95 cents per minute for calls to local area codes, and $1.45 per minute for long distance calls. The experiment represents the first use of cellular phone service for passengers on any U.S. train system.

Boeing Woos U.K. AWACS Contract, Joins With Racal-Tacticom for Saudi Project

Boeing Company has announced a joint agreement with Racal-Tacticom of the U.K. to develop a tactical radio production facility in Saudi Arabia. The project could add as much as $500 million in tactical radio sales in the Middle East in the next several years. The Saudi project is part of a deal made by Boeing which involves the creation of a technology center in Saudi Arabia, not just sales of hardware.

Perhaps more important is Boeing's choice of a British company as a partner. The U.K. Ministry of Defense is expected to decide on an early-warning aircraft contract in the near future, with Boeing's AWACS and Britain's own Nimrod (General Electric Co. plc.) the primary competitors. Boeing has offered a 130 percent offset to the U.K. which would mean that Boeing would spend 13 dollars in the U.K. for every ten dollars of the AWACS contract.

Boeing's primary subcontractor, Westinghouse's Electronic Warfare Division, has joined in the effort to impress the Britons, with both companies making agreements with Racal, Plessey and Ferranti for offset contracts if Boeing should be the successful AWACS supplier.

Report Claims Pacific Basin to be Fastest Growing Telecommunications Market

The recent launch of two Aussat satellites over the South Pacific has resulted in two-thirds of the capacity being booked within one month of operation. A report from Benn Electronics Publications asserts that there will be a fast-growing demand for TVRO and data communications equipment in the Pacific Basin, and that a third Aussat will add even more momentum to the trend.

The B-MAC transmission standard has been chosen for the Aussat system, allowing data handling for transmission to specific subscribers. With this addressable system, the possibility exists for downloading computer software, video games, music and educational courses to individual households.

The various nations in the Pacific Basin, including Australia, New Zealand and several island nations have indicated that they will use the satellite system for internal communications needs. Others have scheduled trials to evaluate such applications. Benn projects a $140 million per year market for TVRO equipment alone.

FAME!!!

Well, among your engineering peers, anyway . . .
for seven winners in the 2nd annual . . .

RF DESIGN AWARDS CONTEST

You've got an original circuit design. Something truly novel. Here's your chance for real recognition . . . and a chance to win a first-class RF instrument or design program . . . just for sharing your ingenuity with your peers . . . in *RF Design's* second annual Design Awards Contest.

The Grand Prize winning design will be featured in the July issue of *RF Design,* with a picture of the winner on the cover . . . along with his or her brand new HP Spectrum Analyzer (grand prize shown at right). Other prize winning designs may also be published in future issues of *RF Design* . . . and the runner-up prizes will be awarded to their winners in July, promptly after judging is completed. Seven winners in all will be chosen. Why shouldn't you be one of them?

The official entry rules and judging criteria are listed below. Don't miss out on your chance at fame and fortune.

Deadline for entries: March 31, 1987
Mail entries to: RF Design Contest
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111

JUDGING CRITERIA

1. **Originality:** The purpose of the contest is to reward engineers for their unique design contributions. Each design will be evaluated according to its similarity to work by others, unusual application of a device or technique, and other judgments of its contribution to the advancement of the engineering craft.

2. **Engineering:** Engineering is the application of technology to solve a problem or meet a design goal. Entrants should clearly identify how their circuit was created in response to such a need. Judges will evaluate performance, practicality, reproducibility and economy.

3. **Documentation:** Communicating ideas to others is the business of *RF Design* and a necessary part of good engineering. Each entry will be judged on its description, analysis and graphical material. Each circuit should have a complete list of components, explanation of functions, and a summary of performance and test data.

Entry Rules

1. Entries shall be RF circuits containing no more than 6 single active devices (tubes or transistors), or 4 integrated circuits, or be passive circuits of comparable complexity.

2. The circuit must have an obvious RF function and operate in the below-2 GHz frequency range.

3. Circuits must be the original work of the entrant.

4. If developed as part of the entrant's employment, entries must have the employer's approval for submission.

5. Components used must be generally available, not obsolete or proprietary.

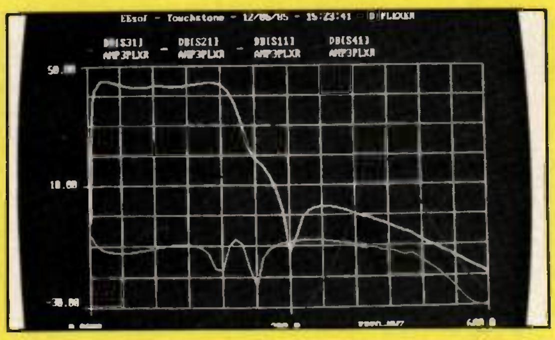
6. Submission of an entry implies permission for *RF Design* to publish the material. If published, the entrant will receive the normal per-page author's honorarium.

7. Deadline for entries: **March 31, 1987.**

FORTUNE!!!

Well, in engineering terms, anyway . . .
Here are prizes for winning designs . . .

Grand Prize Winner receives the Hewlett-Packard 8590A Portable Spectrum Analyzer, featured on the cover of November *RF Design*!



One Runner-up receives a copy of EEsof's Touchstone/RF, the popular circuit design software for RF engineers.

One Runner-up receives Bird Electronics' Model 4421 RF Power Meter, featured on the cover of December *RF Design!*

Four Honorable Mentions receive a copy of Superstar from Circuit Busters — Easy to use circuit design software, an honorable prize for four deserving contest winners!

rf design

shielding effectiveness of about 100 dB at 30 MHz, increasing as $\sqrt{f}$ above 30 MHz. This is for plane-wave shielding, while other, various values would exist for the electric or magnetic fields from electrically nearby sources. To adequately discuss these shielding design issues would take many more pages.

Edwin L. Bronaugh
Director — Research & Development
Electro-Metrics
Amsterdam, New York

Author Will Provide Programs

Editor:

Response to my VHF Propagation manuscript (Aug. '86 *RF Design* and May '86 *Communications*) has been rewarding. To date I have mailed 25 Commodore and 102 IBM programs to interested readers. Several readers have asked about something similar covering the Land Mobile frequencies from 30 to 50 MHz. I recently wrote a program for ground wave propagation covering 3.5 to 50 MHz, and I will furnish it on disk (specify C64 or IBM format) for $8.00.

I now have a version of my Smith Chart program which runs on PC-DOS or MS-DOS 2.0 or higher using BASICA. I will also supply it on disk for $8.00.

For anyone interested, I will supply a disk with the latest updated versions of all 3 programs (Smith Chart impedance matching, VHF- and HF-Propagation) for $15.00. Specify IBM or Commodore format.

Lynn A. Gerig
R.R. #1
Monroeville, Indiana 46773

Errata

"Constant Impedance Bandpass and Diplexer Filters," November 1986, *RF Design,* contained an error in the HP-41 program on page 99. Line 173 should read, "ARCL IND 28" and Line 174 should read "FS?C 2."

"An Eight-Stage Log Amplifier," in the same issue, requires a few corrections. In Figure 2 on page 84, the vertical axis label should be "Normalized Output Voltage (V_O/V_{OL})." On the same chart, the lower amplifier stage should have a label of "1" to indicate a gain of unity. Figure 3 (p. 85) horizontal axis should be labeled "Normalized Input Voltage (A V_{IN}/V_{OL})" and the vertical axis "Normalized Output Voltage V_O/V_{OL})." Figure 10b (p. 87) should have a vertical axis label of "Phase Shift (Degrees)."

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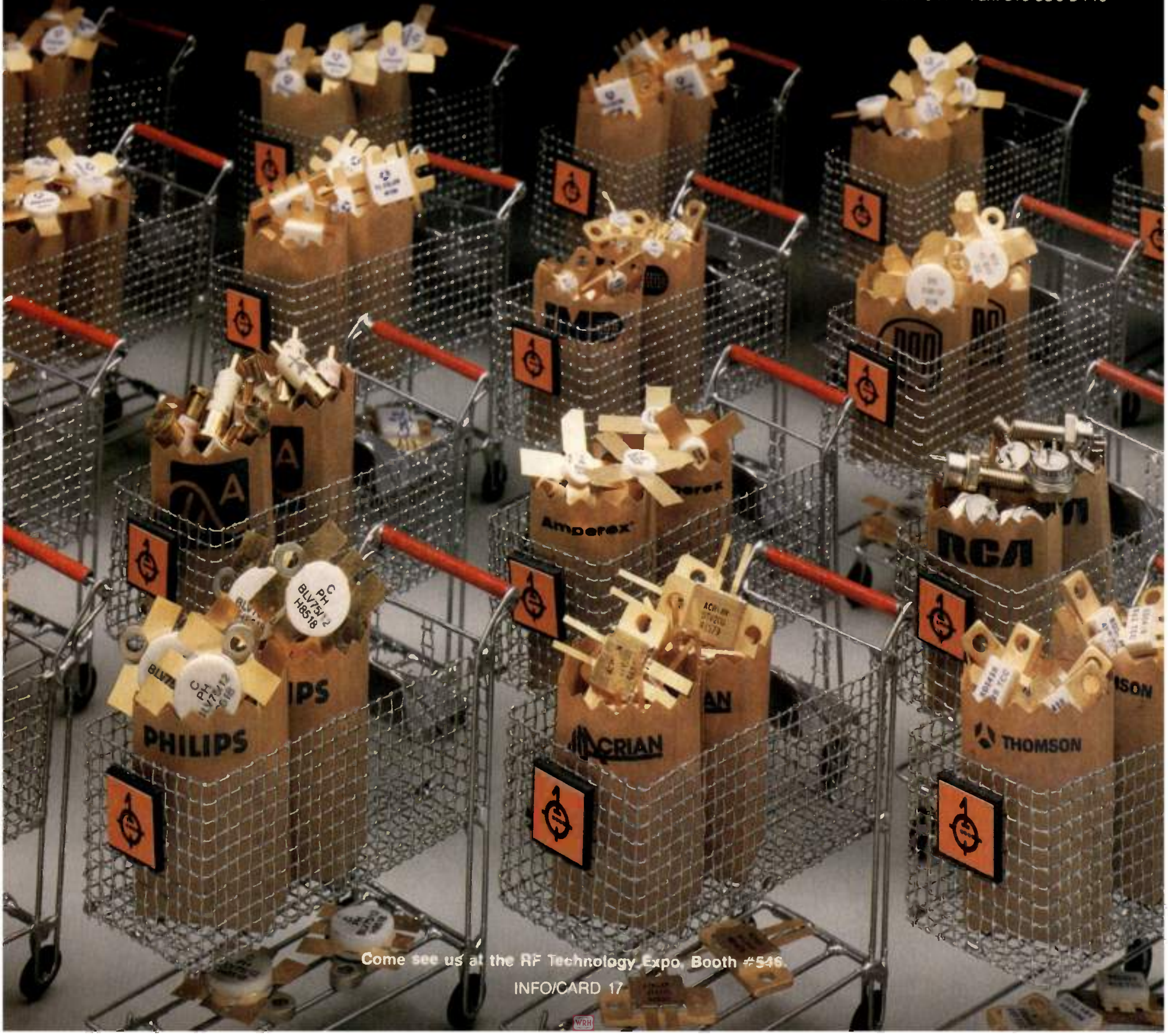

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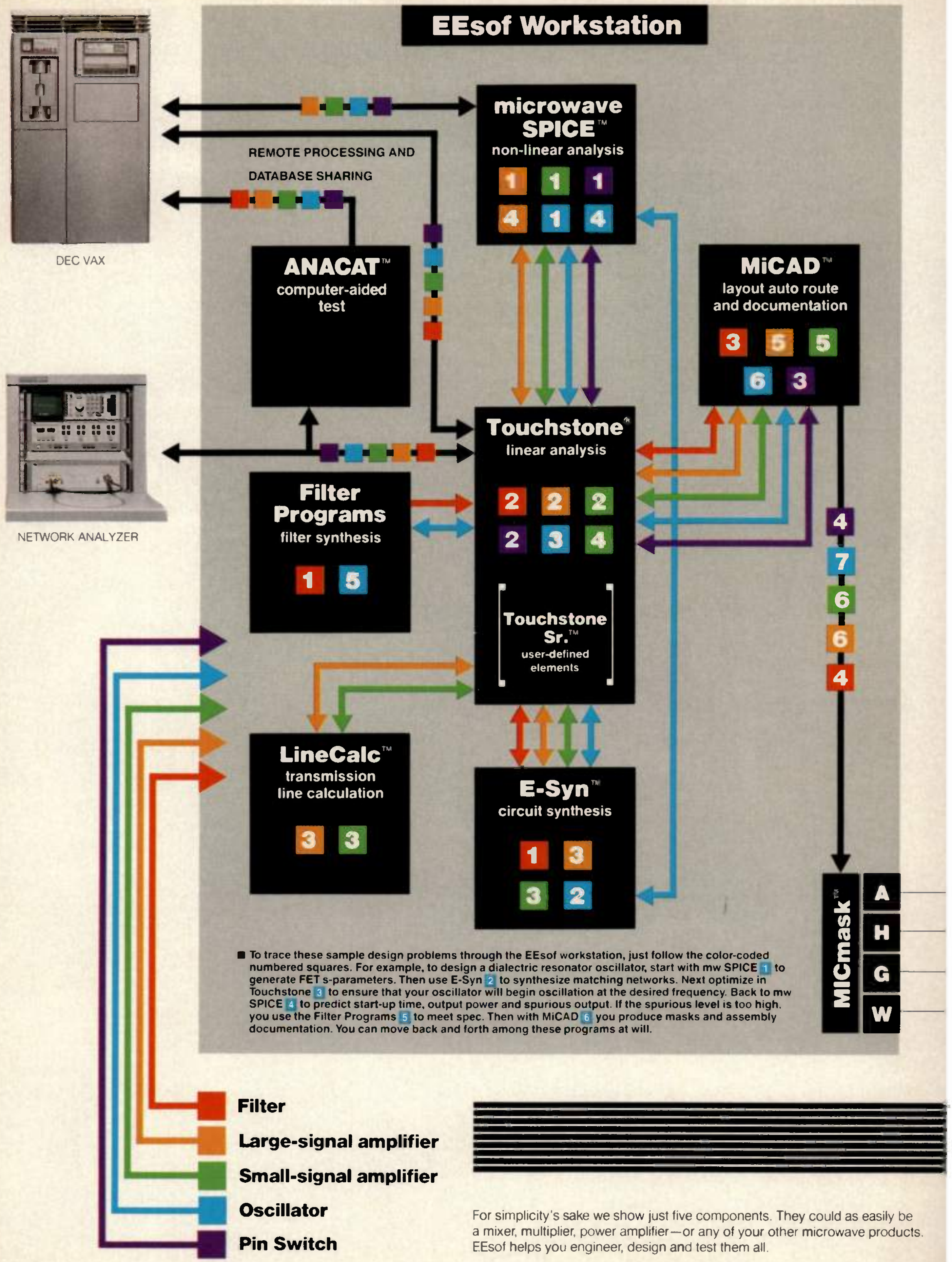
INFO/CARD 17



■ To trace these sample design problems through the EEsof workstation, just follow the color-coded numbered squares. For example, to design a dialectric resonator oscillator, start with mw SPICE 1 to generate FET s-parameters. Then use E-Syn 2 to synthesize matching networks. Next optimize in Touchstone 3 to ensure that your oscillator will begin oscillation at the desired frequency. Back to mw SPICE 4 to predict start-up time, output power and spurious output. If the spurious level is too high, you use the Filter Programs 5 to meet spec. Then with MiCAD 6 you produce masks and assembly documentation. You can move back and forth among these programs at will.

For simplicity's sake we show just five components. They could as easily be a mixer, multiplier, power amplifier—or any of your other microwave products. EEsof helps you engineer, design and test them all.

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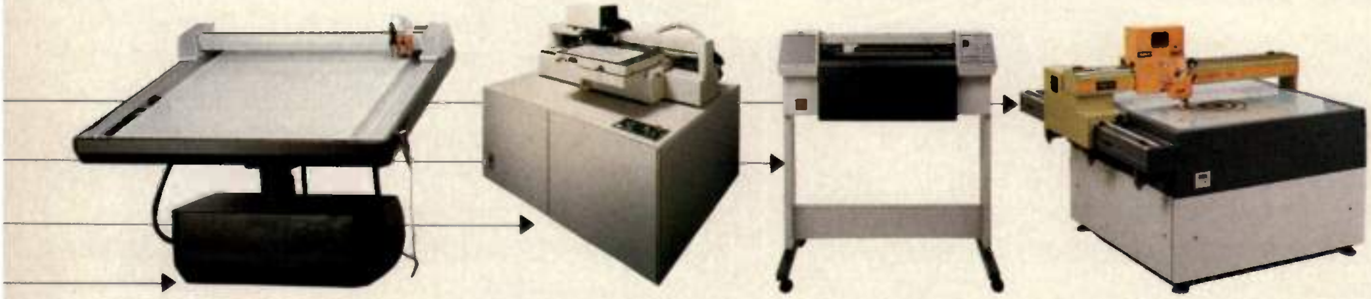

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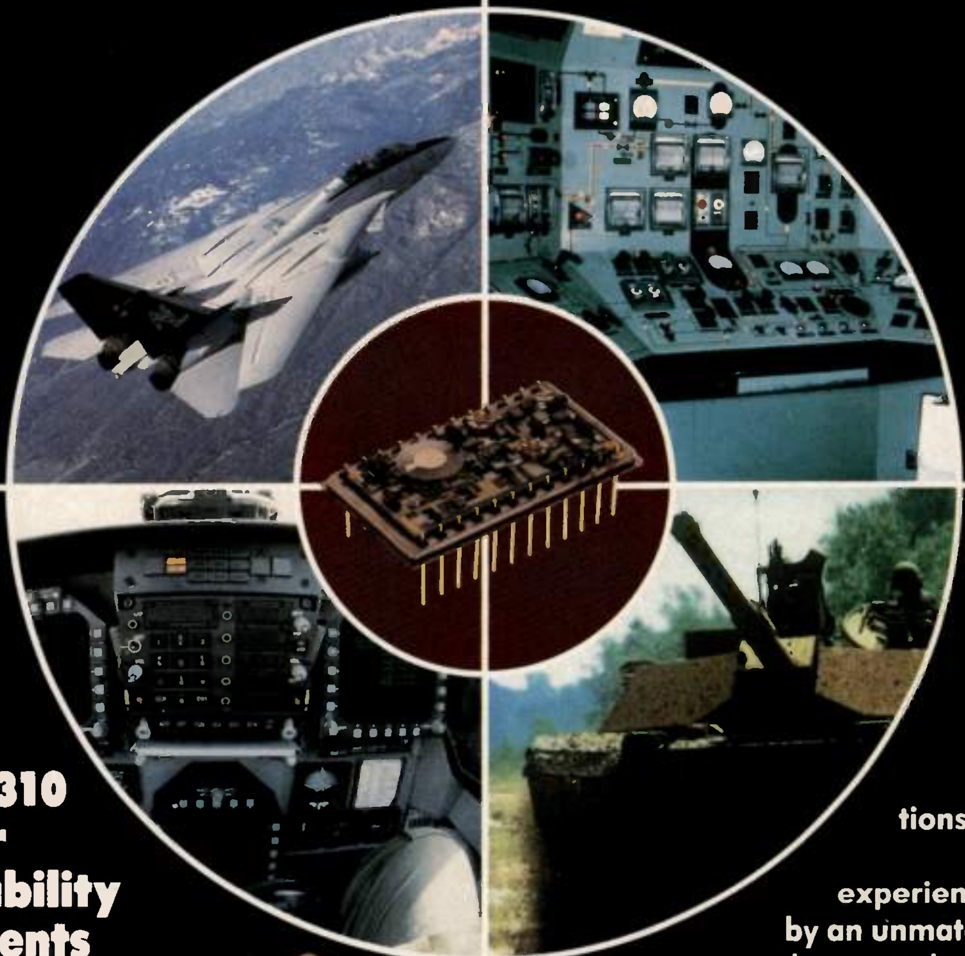
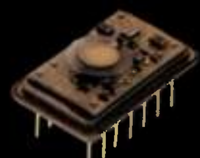
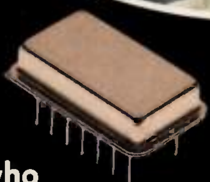




Reeves-Hoffman fills your MIL-O-55310 and other high reliability requirements



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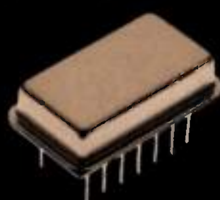

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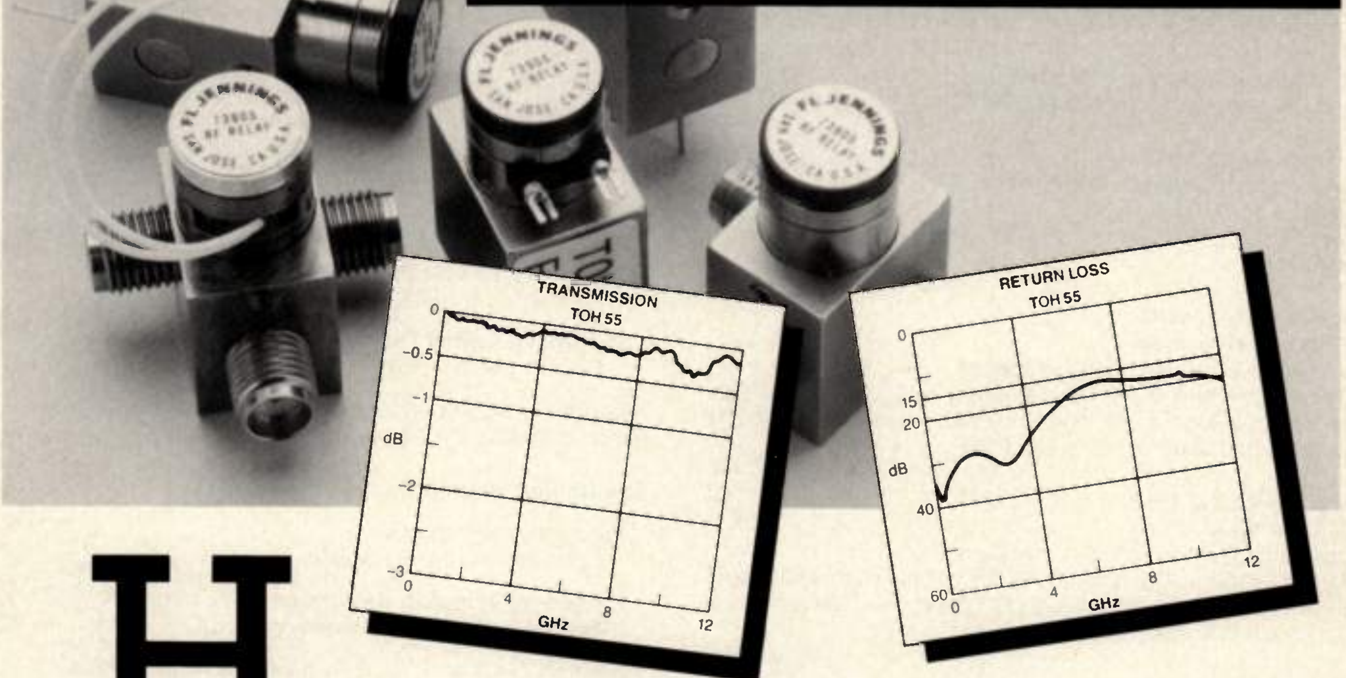

Here is a welcome addition to the microwave relay market from a company that has spent over 40 years developing high frequency relays. Our new TOH Series offers designers a microwave relay with small size and outstanding performance, that can be used for a variety of applications where stringent impedance matching and isolation are required. Typical applications include antenna switching, radar, communications, radio telephones, and cable TV systems.

Both PCB mount and SMA mount models are available in frequency ranges from DC to 2.5 GHz. Operating voltages of 6, 12, 24, and 28 VDC can be ordered with your choice of coil terminals, PCB terminals, flying leads, and solder lugs. Rugged construction assures long life (tested to over 2.5 million cycles), and materials used meet strict mil-spec requirements.

We felt the time was right to show you what 40 years of relay experience can provide to the microwave relay market. Now you can find out for yourself by asking for design assistance or a copy of our brochure. Call or write FL Jennings, 970 McLaughlin Ave., San Jose, CA 95122, (408) 292-4025.

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INFO/CARD 20

rf calendar

January 12-15, 1987
SMART III
Hyatt Regency, New Orleans, Louisiana
Information: Electronics Industries Association, 2001 Eye St. N.W., Washington, D.C. 20006; Tel: (317) 261-1306

January 20-23, 1987
Institute of Navigation's National Technical Meeting
Anaheim Marriott Hotel, Anaheim, California
Information: ION Headquarters, 815 15th St., N.W., Suite 832, Washington, D.C. 20005; Tel: (202) 783-4131 or Leonard Jacobson, General Chairman, Interstate Electronics Corp., 1001 E. Ball Road, Anaheim, CA; Tel: (714) 758-4036

January 29-30, 1987
Measurement Science Conference
Irvine Marriott Hotel, Irvine, California
Information: Dennis Pinnecker, Conference Registrar; Tel: (714) 762-4574.

February 11-13, 1987
RF Technology Expo 87
Disneyland Hotel, Anaheim, California
Information: Kathy Kriner, Convention Manager, Cardiff Publishing Co., 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111; Tel: (303) 220-0600 or (800) 525-9154

February 24-26, 1987
NEPCON West 87
Convention Center, Anaheim, California
Information: Show Manager, NEPCON West 87, Cahners Exposition Group, 1350 East Touhy Ave., P.O. 5060, Des Plaines, Illinois 60017-5060; Tel: (312) 299-9311

February 25-27, 1987
Industry-University Advanced Materials Conference
Colorado School of Mines, Golden, Colorado
Information: Dr. Jerome G. Morse, Advanced Materials Institute, Colorado School of Mines, Golden, CO 80401; Tel: (303) 273-3852

March 24-26, 1987
Southcon/87
Georgia World Center, Atlanta, Georgia
Information: (800) 421-6816 (outside California); (800) 262-4208 inside California; or (213) 772-2965

April 1-8, 1987
Electronics and Electrical Engineering '87
Hannover Fairgrounds, Hannover, West Germany
Information: Hannover Fairs USA, Inc., 103 Carnegie Center, P.O. Box 7066, Princeton, NJ 08540; Tel: (609) 987-1202

April 21-23, 1987
Electrical Overstress Exposition
San Jose Convention Center, San Jose, California
Information: Jim Russell, EOE, 2504 N. Tamiami Trail, Nokomis, FL 33555; Tel: (813) 966-9521

April 27-29, 1987
IEEE Instrumentation and Measurement Technology Conference
Sheraton-Boston Hotel, Boston, Massachusetts
Information: Robert Myers, Myers/Smith, Inc., 1700 Westwood Blvd., Los Angeles, CA 90024; Tel: (213) 475-4571.

rf courses

Georgia Institute of Technology

Principles of Pulse Doppler Radar: High, Medium, and Low PRF
February 10-12, 1987, Atlanta, Georgia

Microwave Devices: Present and Future
February 11-12, 1987, Atlanta, Georgia

Laser Technology and Systems Applications
February 23-24, 1987, Atlanta, Georgia

Infrared Technology and Systems Applications
February 25-27, 1987, Atlanta, Georgia

Information: Deidre Mercer, Department of Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332; Tel: (404) 894-2547.

Besser Associates, Inc.

Microwave Circuit Design — Linear Circuits
February 2-6, 1987, Los Angeles, California

Microwave Circuit Design — Non-linear Circuits
February 9-13, 1987, Los Angeles, California

Information: Besser Associates, Inc., 3975 East Bayshore Road, Palo Alto, CA 94303; Tel: (415) 969-3400

The George Washington University

Frequency Synthesis
February 9-11, 1987, Washington, DC

Frequency Hopping Signals and Systems
February 23-25, 1987, Washington, DC

SAW Devices and Their Processing Applications
February 23-26, 1987, Washington, DC

Defense Electronics Executive Overview
March 2-6, 1987, Washington, DC

Spread Spectrum Communication Systems
March 9-13, 1987, Washington, DC

Information: Merril Ann Ferber, Assistant Director, Continuing Education Engineering Program, The George Washington University, Washington, DC 20052; Tel: (800) 424-9773

Southeastern Center for Electrical Engineering Education

Antennas: Principles, Design, and Measurements
March 24-27, 1987, St. Cloud, Florida

Information: Ann Beekman, SCEEE, 1101, Massachusetts AVe., St. Cloud, FL 32769; Tel: (305) 892-6146

R&B Enterprises

TEMPEST — A Detailed Design Course
February 2-6, 1987, Philadelphia, Pennsylvania

TEMPEST — An Overview for Managers and TEMPEST Officers
February 9-10, 1987, Philadelphia, Pennsylvania

EMI/EMC in the Automotive System
February 9-11, 1987, Dearborn, Michigan

Information: Greg Gore, R&B Enterprises, 20 Clipper Road, West Conshohocken, PA 19428-2721; Tel: (215) 825-1960

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INFO/CARD 24

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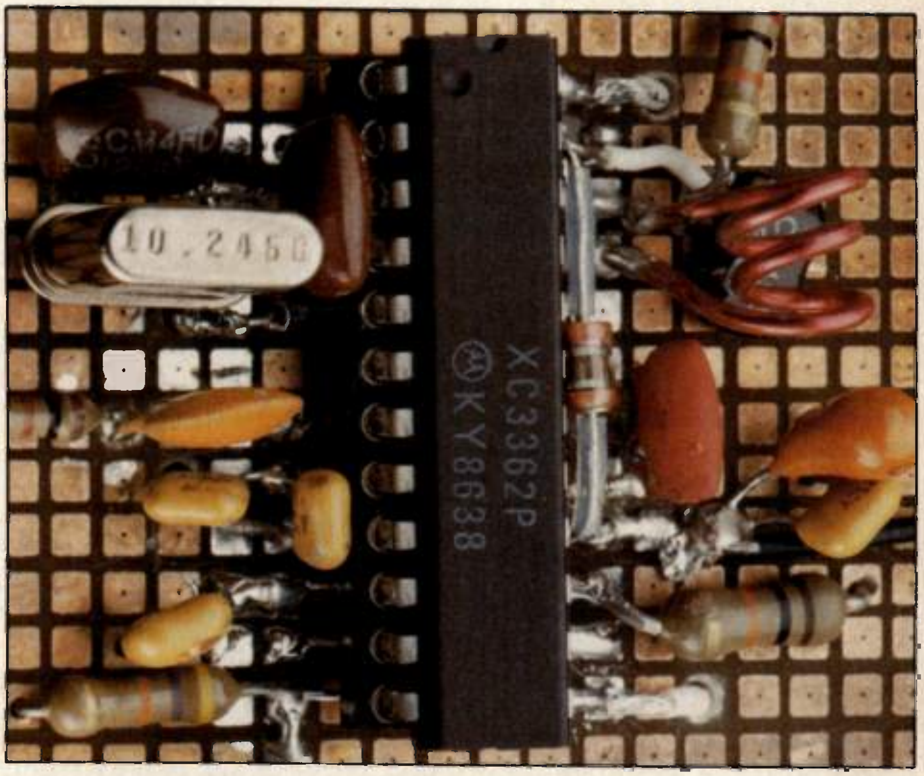
A One-Chip Dual-Conversion FM Receiver

By John Stilwell
Motorola Bipolar Analog IC Division

The MC3362 is a new bipolar analog IC from Motorola which gives the designer a single-chip FM receiver from antenna input to audio preamp output. Useful from 50-150 MHz, the low voltage FM dual conversion design yields low power drain, excellent sensitivity and good image rejection in narrowband voice and data link applications. Closely related to MC3362 is the MC3363 dual conversion FM receiver which contains all MC3362 features and functions, plus an NPN transistor for RF or LO amplification and a muting operational amplifier to allow a noise triggered muting/squelch function.



These new ICs are specified to run from V_{cc} = 2 to 7 and draw very little power (4-35 mW). MC3362/3 are manufactured in Motorola's MOSAIC 1.5® process technology. This process develops NPN transistors with f_T = 4+ GHz, much like those available in low cost RF discrete products.

In a typical application, the first mixer amplifies the incoming signal (conversion gain 18 dB typical) and converts the incoming frequency to 10.7 MHz. This 10.7 MHz high IF is filtered externally and fed into the second mixer. The second mixer has a conversion gain of 22 dB (typical) and converts the high IF to a 455 kHz low IF. Second mixer output frequencies above 500 kHz are rolled off internally. For both conversions, the mixer impedances and pin layout are designed to employ low cost, readily available ceramic filters.

The first local oscillator can be used as a free running LC tank, a VCO using PLL synthesis, or can be driven from an external oscillator. At higher V_{cc} values (6-8 V), it has been operated as high as 170 MHz. The second local oscillator is a common base Colpitts type which is typically run at 10.245 MHz under crystal control. The limiting IF has 10μV sensitivity, flat to 1 MHz. The connection to the quadrature detector, a quadrature capacitor and twice-IF filtering are provided internally.

MC3362 contains meter drive/carrier detect circuitry which detects the amount of IF limiting. This provides a radio signal strength indicator (RSSI) function with excellent linearity and wide dynamic range (>65 dB). Hysteresis is available. MC3363 also contains a muting op amp to allow design of a noise triggered squelch circuit.

A data shaping comparator is also included which detects zero crossings of FSK modulation, allowing construction of a low cost RF data link. Data rates of 2,000 to 35,000 BPS have been obtained using a narrowband configuration and a single audio to data coupling capacitor of 1,000 pF. Comparator hysteresis is available.

Single Chip Two Meter Receiver

MC3362 was featured at RF Expo East as a single chip receiver operating on the two meter band (144.585 MHz). The fixture used is in the accompanying photo. No matching or amplification was done at the input of MC3362. The sensitivity for 20 dB (S+N)/N was 4μV for a deviation of ±3 kHz. It is expected that matched RF amplified systems will attain sensitivities below 0.5μV.

The first local oscillator was free-running using L_p = 0.028 μH, C_p(ext) = 43 pF, and the internal C_p of a varactor diode. An external trimpot was used for frequency tuning. Excellent frequency stability was achieved with this configuration, which included a regulated supply voltage of 8.0 Vdc. MC3362/3 are specified for supply voltages of 2 to 7 V, but operate well from 1.8 to 8 V.

External elements used included Toko LFC455F and SKM1 ceramic filters (455 kHz filter not visible in photo), and Toko RMC2A6597 quadrature coil. The quadrature resistor used was 47Ω. Recovered audio was amplified using MC34119, a new low voltage audio amplifier.

Price of the MC3362P (24-pin DIP) and MC3362DW (24-pin SOIC) is $1.80 (100s). The MC3363P/DW will be available in the first quarter of 1987. **Motorola, Inc., Bipolar Analog IC Div., Tempe, Ariz. For more information, circle INFO/CARD #180.**

On the Leading Edge: RF's Role in Scientific Research

By Gary A. Breed
Editor

RF technology is at the heart of many scientific research efforts, from elementary particle physics to the behavior of whole galaxies. For many endeavors, RF plays a supporting role, providing communications, telemetry and navigational aid. For other areas of research, RF techniques are central to the work itself, with an active role in power or measurement. Some of these areas will be explored in this Special Report, as we see how RF has an integral role in some of the most "mind boggling" areas of science.

The frustration of a short report is that many important items must be omitted. We will cover a few areas where there is significant work being done right now, and take a look at some of their RF applications. We will also point out some other areas where RF is playing an important role, just to remind you that there is a nearly endless list of exciting RF applications in research.

Radio Astronomy

Because it is *all* RF, radio astronomy is a pursuit that pushes RF technology to the edge of performance capabilities. To receive signals from across the universe, the lowest noise amplifiers, the most sophisticated signal processing and the most advanced understanding of wave propagation must be used.

The most unique RF application in radio astronomy is in signal processing, particularly Very Long Baseline Interferometry (VLBI). The basic principle of VLBI is triangulation, where simultaneous observations from two distant points can achieve quite precise directional resolution. When the two observation points move in relation to the observed source (such as when the earth rotates on its axis, and moves in its orbit around the sun), the optical principles of interferometry further increase resolution. With observation from different continents, as has been done using the Very Large Array in New Mexico and West Germany's primary facility, the sky can be mapped with a fraction of an arc-second resolution, enough to transform previous "point" sources of radio emissions into well-defined regions emitting differing intensities and wavelengths.

The key to VLBI is "simultaneous" observation, corrected for the varying distance from the observed radio source as the earth moves. To accomplish this, the radio telescopes record the baseband received signal on videotape, with synchronization to atomic time standards. The tapes can then be sent to a common location for correlation and evaluation. Recently, a receiving location on a satellite was used for VLBI, demonstrating that baselines can be extended beyond terrestrial limits.

Other areas of RF development in radio astronomy are a bit more well known: cooled low-noise amplifiers, phased array antenna systems, precision-dimension parabolic reflectors and high-efficiency antenna feed systems, wave propagation behavior through interstellar space and earth's atmosphere, and signal processing techniques that precisely resolve amplitude and frequency components of the received signal.

One final note about radio astronomy: If the analysis techniques of today's are improved upon in the future, there is no need to repeat measurements! The data on videotape can be replayed any time for further analysis.

Weather Research

The hottest topic of conversation is always the weather — "Can't somebody do something about it?" Well, weather modification is one area of research, but RF is more closely involved with monitoring and prediction efforts. We are all familiar with weather radar and radiosonde (weather balloon) data collection, the closest thing to real-time monitoring except for looking out the window, but there is a new technique that promises to improve weather prediction: Atmospheric Profile Radar.

Profilers, as they are called, fall into two types. One measures wind, the other measures temperature and humidity. The thermodynamic type (temperature and moisture content) operates above 10 GHz, so we won't dwell on that type except to say it is based on the principle of water vapor absorption of microwave radiation, plus the temperature-dependent emission of microwave energy by atmospheric gases.

Wind profilers are much more interesting RF applications. A number of years ago, it was discovered that very sensitive radar could actually detect the Doppler variations caused by winds in the atmosphere. The process has been nearly perfected, incorporating advances in phased array antenna techniques, radar echo signal processing, and our improving understanding of the physics of clear air scattering and reflection.

The National Oceanic and Atmospheric Administration (NOAA) recently let a contract to Sperry Corporation to install a system of 31 profilers in the central U.S. The first prototype is expected to be operational in late 1987, with the entire system completed by the end of 1989. These radars operate on 404.37 MHz, and can monitor the winds above their location continuously, replacing the twice-a-day balloon launches that are now the primary winds-aloft data source.

Besides providing ongoing weather monitoring, profiler technology can be used to detect wind shear conditions near major airports, or they can be located around the world, providing unattended monitoring. In fact, two of the early research profilers have been dismantled and moved from their original Kansas test site to the South Pacific. These 50 MHz systems will be part of a research effort looking for ocean and atmospheric conditions preceding El Nino events, unusual warming of the ocean, a major influence on global weather patterns.

Elementary Particle Physics

If we consider a particle accelerator to be a giant RF vacuum tube, we are pretty close to the truth. The electron beams begin in klystrons, then enter the accelerator through a window, rather than being captured by a collector in a standard RF amplifier klystron. Whether the accelerator is linear or ring-shaped, the beam is accelerated by RF-excited cavities, riding the "crest of the wave" of RF energy.

The beam can be monitored by RF, too, since the motion generates a transverse magnetic field. At relativistic velocities, this field is essentially RF, and can be monitored by RF methods. Feedback from these monitors can be used to synchronize the beam and its accelerating potential.

Additional information on the application of RF in a linear accelerator is contained in the article "GaAs ICs Improve Efficiency of the Stanford Linear Accelerator," in *RF Design,* January 1987.

Nuclear Magnetic Resonance

Nuclear Magnetic Resonance (NMR) and its associated area, Magnetic Resonance Imaging (MRI) are growing areas of applied science. The RF aspects of NMR/MRI are becoming established, but the potential uses for the techniques are endless. The most publicized use is the MRI medical imaging systems, which can provide three-dimensional representations of the inside of the human body. This non-invasive testing is becoming an essential diagnostic tool.

The principle of NMR sounds simple, but has been quite difficult to develop. The nuclei of certain atoms contain both a magnetic moment and a spin angular momentum. When subjected to a strong magnetic field, the magnetic properties cause the nuclei to become aligned. When a transverse RF field is applied at the frequency of the spin (Larmor frequency), it pulls the nuclei out of alignment. When the RF turns off, the nuclei induces an RF signal through the motion of realignment with the magnetic field. This signal can be detected, with its location and intensity indicating the nature of the material. Different materials (hydrogen, phosphorous, etc.) have different Larmor frequencies, and can be differentiated by NMR equipment.

Operating over frequencies of about 10-90 MHz, NMR is a significant area of RF development, requiring kilowatt power levels, sophisticated gating techniques and sensitive detection circuitry for maximum effectiveness.

Photo courtesy National Center for Atmospheric Research.

Located in a remote region of New Mexico, the Very Large Array (VLA) is the world's premier radio astronomy observatory.

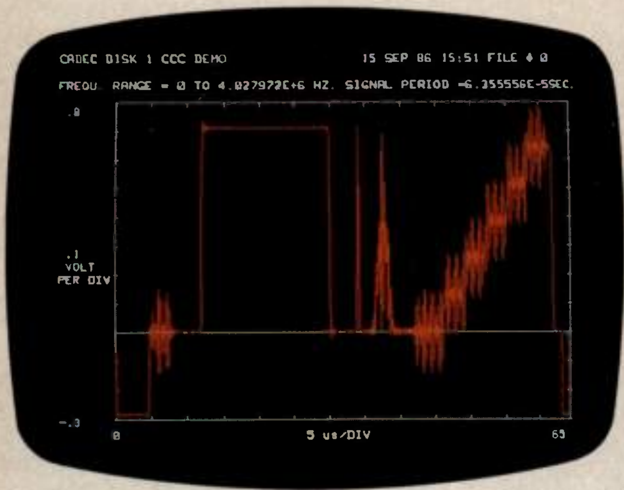
Other Scientific Efforts

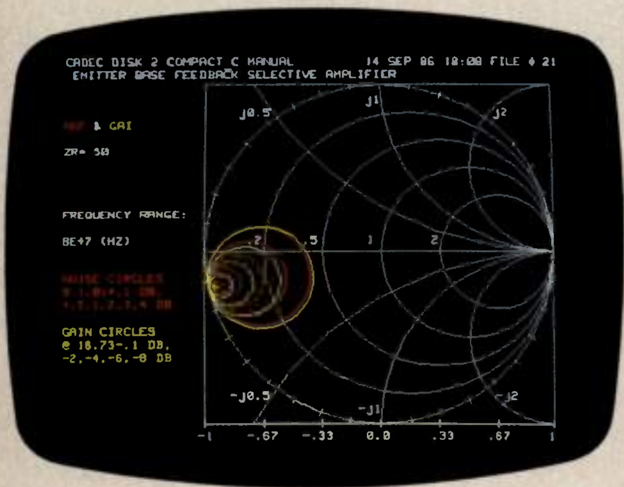
The Navstar/Global Positioning System (GPS) is in the process of deployment and when operational will provide precise location and tracking information for many applications. Ocean exploration, geophysical measurements, and other requirements for precise navigation and position measurement will have a valuable RF tool to work with. We will cover some of the GPS applications and circuit requirements in the June issue of *RF Design.*

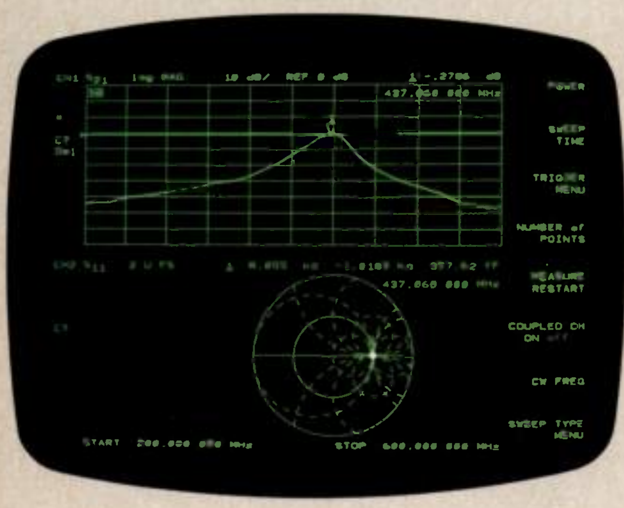
Other areas we would have liked to cover include RF drivers for high-power lasers, used in fusion research as well as SDI. Solid-state UHF pulse amplifiers with megawatt power output are being developed for laser applications, pressing RF capabilities to the state-of-the-art limits. Space exploration is another fascinating area, with the planned Venus radar mapping program, investigation of the earth's megnetosphere, and deep-space projects, such as the continuing Voyager flight and the Galileo probe to Jupiter.

RF is right in the middle of these research efforts. As science keeps developing and we gain more and more knowledge about our universe, the importance of electromagnetic energy from zero Hz to gamma rays is becoming increasingly evident. rf

MISSION IMPOSSIBLE?







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INFO/CARD 25

Low-Noise Preamplifier Design for NMR

By Otward Mueller and
William A. Edelstein
General Electric Corporate
Research and Development

An important component in any nuclear magnetic resonance (NMR) imaging or spectroscopy system is a low-noise preamplifier. The required minimization of its noise figure can be obtained only by careful design. It must go hand in hand with an optimization of the "noise figure" of the NMR receive coil. The latter requires that the coil quality factor Q is made as high as possible. Other receiver system components such as cables, protection circuits, matching networks, transmit/receive (T/R) switches, etc., should not be neglected in a low-noise design. They can easily add many tenths of a dB to the overall receiver noise figure.

The most critical item in a low-noise preamplifier is its input device. Bipolar transistors have the advantage of a relatively large bandwidth at higher frequencies (20-200 MHz). They must be selected for a high current gain, a large gain-bandwidth product F_T of several Gigahertz and especially a low base-region bulk resistance. The latter can be reduced by paralleling two or more transistors. With their high input impedance, juntion field-effect transistors are suitable for low-noise narrow-band preamplifiers. They should exhibit a high transconductance which increases with the electron mobility in the channel. Since the latter is much higher in gallium-arsenide than in silicon GaAs-MESFETs are also good candidates for low noise NMR preamplifier designs.

As far as circuit design is concerned, the following rule should be obeyed: eliminate all parasitic series or parallel impedances between base-emitter or gate-source terminals. This implies that, for example, by-passed emitter resistors must not be used and biasing resistors have values very high compared to the transistor input impedance.

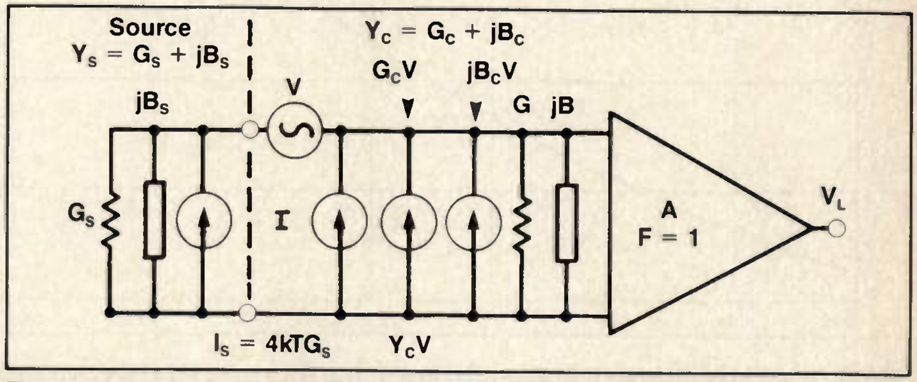

Figure 1. Equivalent amplifier noise circuit including correlation between voltage and current noise source.

Quantitative Design Criteria

The expanded noise equivalent circuit of a preamplifier or its input transistor is shown in Figure 1. $Y_s = G_s + jB_s$ is the source admittance producing the noise current I_s. Y = G + jB is the input admittance of the noiseless (F=1) ideal amplifier of voltage gain A. The amplifier noise is in good first-order approximation represented by the input related equivalent noise voltage and current generators V and I. At higher frequencies they may be partially correlated, an effect which can be represented by the additional current generators (YC) V = (GC+jBC)V where YC is the so-called correlation admittance. Table 1 summarizes the important noise formulas.

The noise figure F defined as the ratio of the total amplifier output noise due to the source resistor only is given by Equation 1. F is minimized by choosing an optimum source admittance $Y_s = G_s + jB_s$ as given by Equation 3. The minimum noise figure obtainable is expressed in Equation 4. The following relationship (Equation 5) shows that the noise has a parabolic dependence on the source susceptance B_s. The same is partially true for G_s. It is interesting to note that the formulas for F do not explicitly depend on the input admittance Y. Its effect is contained the noise generators V and I. In

$$F = 1 + \frac{V^2|Y_s + Y_o|^2 + I^2}{I_s^2} = \text{Minimum}$$

$$\partial F/\partial B_s = 0 \qquad \partial F/\partial G_s = 0$$

$$B_s(OPT) = -B_s \qquad G_s(OPT) = \frac{I^2 + G_C^2V^2}{V}$$

$$F_{MIN} = 1 + \frac{V^2}{2kT}(G_s(OPT) + G_c)$$

$$F = F_{MIN} + \frac{V^2}{4kTG_s}[(G_s(OPT) - G_s)^2 + (B_s(OPT) - B_s)^2]$$

$$Y_c = O: \qquad G_s(OPT) = |G + jB| \cdot \frac{V_L(G_s=0)}{V_L(G_s=00)}$$

Table 1. Noise formulas.

many cases, especially at lower frequencies, the correlation admittance Y_c is negligible. The optimum source conductance G_c(opt) is then given by the simple expression I/V.

The analysis suggests a simple algorithm for determining the optimum source admittance Y_s(opt) to minimize the noise figure F:

a. Determine the preamplifier input admittance Y = G+jB.
b. Measure the output RMS noise voltage VL(G_s = oo) for a shorted input and VL (G_s = 0) for open-circuited input.
c. Determine from Equation 6 a trial optimum source conductance G_s(opt).

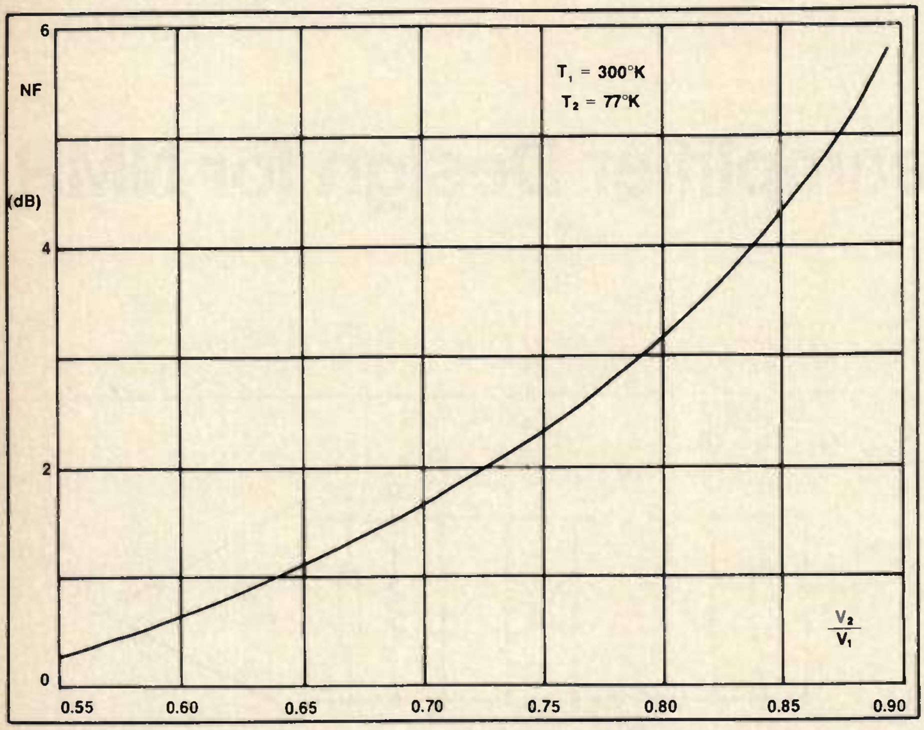

Figure 2. Liquid nitrogen method: Noise figure as a function of the noise voltage ratio V_2/V_1.

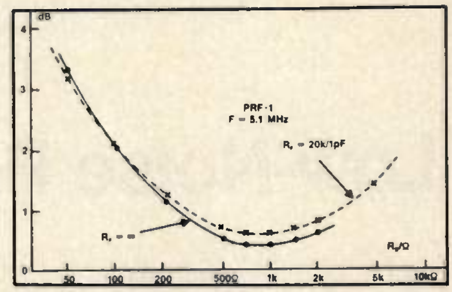

Figure 3. Noise figure vs. source resistor.

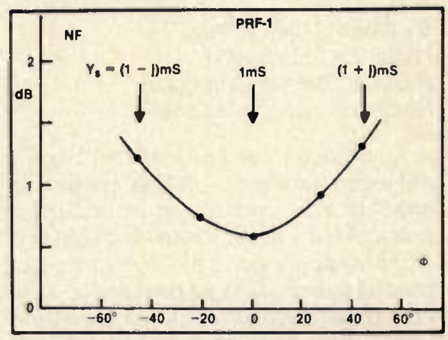

Figure 4. Noise figure as a function of the source admittance phase angle.

d. Measure the noise figure with this source resistor as a function of parallel source susceptance B_s. The value of B_s which minimizes the noise figure is $B_s(opt) = -B_c$.

e. Repeat step b with $B_s = B_c$ and obtain the final value of $G_s(opt)$ which will not be much different from the previously determined one.

It is interesting to note that $B_s(opt)$ is independent of G_s and that in the above procedure it was necessary to determine the correlation explicity. Note that if there is no correlation ($Y_c = 0$) then the optimum source impedance is real and simply given by $R_s = 1/G_s = V/I$.

In order to minimize the preamplifier and the NMR system noise figure it is now important that the receiver coil input impedance is matched by a transformation network to the optimum source admittance given by Equation 3 or 6 in Table 1. The question may arise: What should the input impedance Y of the preamplifier be? Since the formulas for the noise figure and the optimum source admittance $Y_s(opt)$ are independent of Y, the answer is: It does not matter as long as the source (in an NMR system the receiver coil) is matched to $Y_s(opt)$. Since the input impedance of NMR head or body receiver coils is dependent on the size of the patient to be imaged one can use a variable matching network in order to minimize the noise figure or one should use a preamplifier with a very low F.

Measurement Techniques

Since the NMR system operators have liquid nitrogen available in their facilities the so-called two-temperature method of noise figure measurement is very suitable. The preamplifier output noise voltage is measured with the source resistor $R_s = 1/G_s$ first at room temperature T1, (V1), and then dipped into liquid nitrogen (T2 = 77 degree Kelvin, V2). From the curve of Figure 2 (courtesy of Dr. Howard Hart, GE-CRD) and the output noise figure ratio V2/V1 the noise figure F is obtained. The advantage of this method is its low cost and its suitability for noise measurements in a complete NMR system. It also permits an easy determination of F as a function of source resistance without impedance transformation networks. Accurate measurements can be made with the HP-8970A noise figure meter (10-1500 MHz), but only in a 50 ohm system. A comparison between the two methods resulted in good agreement. For all NMR low-noise preamplifier measurements one should use only the HP346A and not the 346B noise source.

In Figure 3 the measured noise figure is shown as a function of source resistance. $R_s = 1/G_s$ for a preamplifier of a low-field NMR system (0.12 Tesla, 5.1 MHz). A cascade configuration of 2 junction field-effect transistors (U-310) is used in the input stage. The optimum source resistance is approximately 750 ohm. Feedback damping has been employed in order to increase the bandwidth of the receiver coil without degrading the noise performance too much. It is interesting to note that $R_s(opt)$ remains the same with and without feedback RF = 00) whereas the input impedance changes drastically from 1700 ohm, −82 degrees to 250 ohm, 22 degrees. This preamplifier was connected directly to an NMR receive coil tuned to Z_{in} = 750 ohm. For RF = 00 a noise figure of F = 0.5 dB and for RF = 20 kohm//1 pF, F = 0.7 dB was obtained. These measurements demonstrate also that the optimum source resistor for junction field-effect transistors relatively high.

Figure 4 shows F at 5.1 MHz as a function of the source admittance phase angle. For $\Phi = \pm 45$ degree a capacitor or inductor having a reactance of X = 1000 ohm was connected in parallel to a source conductance of 1mS. The minimum of the noise figure F occurs for $\Phi = 0$ indicating that the correlation admittance Y_c is zero. This means that the input related noise voltage and current generators V and I in the equivalent circuit of Figure 1 are un-

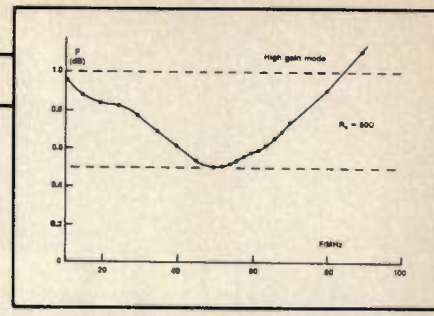

Figure 6. LNA-V-1: Noise figure F vs. frequency.

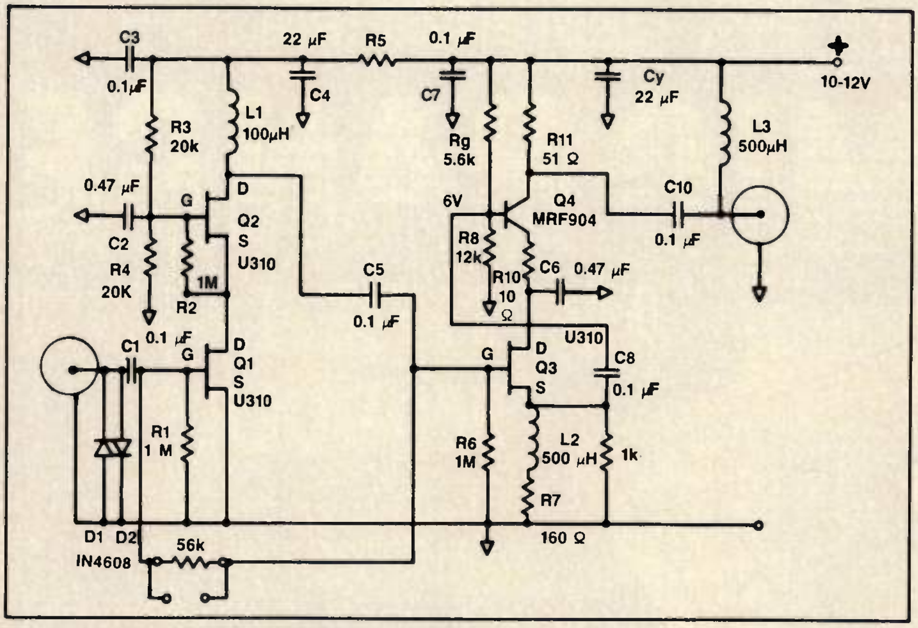

Figure 5. Low-noise preamplifier PRF-1.

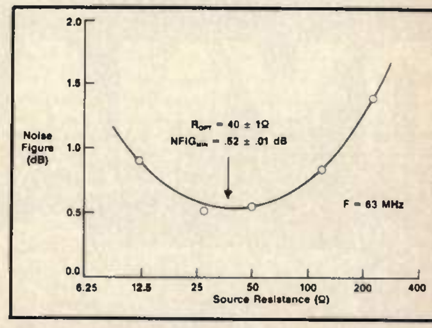

Figure 7a. Noise figure vs. source resistance.

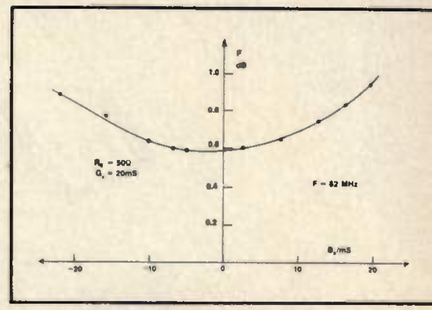

Figure 7b. LNA-V-1: Noise figure vs. source susceptance.

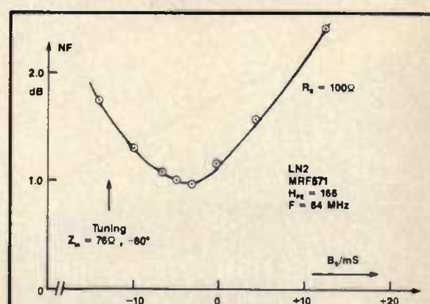

Figure 8. Noise figure vs. source susceptance.

correlated. The curve demonstrates that even relatively small deviations from the optimum source conductance by a capacitive or inductive component results in a noise figure degradation of several tenths of a dB. One concludes that for noise optimization it is necessary to control especially the phase angle of the source admittance Y_S. In practical terms this means that a few undesired picofarads in parallel with a preamplifier input can degrade F. On the other hand Figure 3 demonstrates that deviations from G_s(opt) are not that critical because that curve has a relative broad minimum. Figure 5 shows the circuit diagram of this J-FET preamplifier.

At higher frequencies bipolar transistors can be used, especially if a large bandwidth is desired, for example for a preamplifier covering the imaging and the spectroscopy frequencies. (64, 59, 26, 16 MHz). The optimum source resistor is much lower (R_s(opt) = 40 – 100). Figure 6 shows the frequency response of the noise figure for an amplifier using MA-42197 bipolar devices demonstrating that F-values of less than 1 dB can be achieved over a large frequency range. In Figure 7 the noise figure is plotted as a function of the source resistor and the source susceptance for 64 MHz.

Figure 8 demonstrates an example of a preamplifier for which the correlation admittance Y_c is not zero. The minimum noise figure occurs for a source susceptance of $B_s = -3$mS (Parallel inductance with a reactance of XL = 330 ohm). By not neglecting the correlation effect expressed by the correlation admittance $Y_c$one obtains in this case a noise figure improvement of about 0.2 dB. This amplifier used a by-passed emitter resistor in the first stage which probably caused the noise correlation.

Summary

In order to obtain good NMR image quality low-noise preamplifiers are required. With careful design and by providing the optimum source impedance noise figures of 0.5 dB can be achieved. At higher frequencies the correlation between V and I in the noise equivalent circuit should not be neglected if the noise figure is to be minimized. rf

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(2) W.A. Edelstein, P.A. Bottomley and L.M. Pfeiffer, "A Signal-to-noise calibration procedure for NMR imaging systems," *Med Phys.* 11, 180, (1984).

About the Authors

Otward Mueller and William Edelstein are researchers in the Medical diagnostics Systems Branch of the General Electric Corporate Research and Development Center, NMR Building, P.O. Box 8, Schenectady, N.Y. 12301. Dr. Mueller presented this paper at RF Expo East in Boston, November 11, 1986.

The Technical Program: RF Technology Expo 87

Wednesday, February 11
Morning Sessions

Session A-1 — RF Switching
Chairman: Gene Niemec, Merrimac Industries

9:00 — Lifetime Effect in PIN Diodes
P. Sahjani, SDI Microwave

Lifetime governs switching speed, on resistance, and low frequency distortion characteristics of a diode. The lifetime of a diode depends on I region length, forward bias current density, composition, and impurities and contamination introduced during processing. A mathematical model will be presented to compute on resistance R_s by estimating the diode's lifetime under certain conditions. Lifetime measurement techniques will also be discussed.

10:00 — (TBA)

11:00 — ATE Switching Systems — Predicting RF Performance
John Walsh, Racal-Dana Instruments

This paper discusses two methods to predict and analyze the RF performance of switching systems. The first of these addresses the limitations associated with undetermined stubs, e.g. as with classical matrix configurations. The second addresses the analysis of relay insertion loss effects as a function of frequency. The relative advantages and limitations of some typical switching networks are reviewed. Experimentally derived results using commercially available switching networks are compared to predictions.

Session B-1 — Amplifier Design I
Chairman: Sam Klein, Comstron Corp.

9:00 — CAA and CAD of Dispersive Microstrip Transistor Amplifier Circuits
R.F. Baeten, M.R. Wolski, A.S. Krauska and T.K. Ishii, Marquette University

This paper discusses a numerical method for analyzing a dispersive microstrip transistor amplifier circuit using a CAA approach. The computer program presented is also used to design the amplifier. Examples are given using 14 and 15 GHz dispersive microstrip GaAs FET amplifiers.

10:00 — A Monolithic DMOS Wideband Amplifier
D. Somppi, Linear Technology

A DMOS monolithic amplifier is described which exhibits 13 dB gain over a 650 MHz, 3 dB bandwidth. Input and output impedances are matched to 50 ohms. A 1 dB compression point of 18 dBm is achieved in conjunction with a 6.5 dB noise figure.

11:00 — Power Monolithic Silicon MMIC Amplifiers
J. Wholey and S. Taylor, Avantek

The capability of Si MMIC amplifiers based on resistive feedback and Darlington transistors has been expanded to include single chip circuits with increased output powers (up to approximately 2 GHz). This paper discusses the basic design considerations and performance of two power MMICs. Typical RF performance will be given with plots of gain vs. output power and frequency, wideband matching (VSWR), stability characteristics and third order intercept points.

Session C-1 — Modulation Techniques
Chairman: Clark Bell, Wavecom/Loral

9:00 — Generating an MSK Signal Using an 8PSK Modulator
S. Kuh, Motorola Inc.

Using small phase steps from an 8PSK modulator for generating minimum shift keying (MSK) signals eliminates the problem of multiplying the data shaping signals, allows wide variation in the design of the data filter, and results in an MSK-like signal with bit error rate (BER) degradation of less than 0.5 dB from that of ideal MSK signals.

10:00 — The Mixed Digital Method for Producing a Pilot-Tone Stereo Signal
Endre Hercz and Peter Sziebold, BHG Hiradastechnikai Vallalat

The mixed digital method is used to produce a stereo signal according to CCIR 450 recommendations for FM stereo broadcasting in Band 8. The result of this method is a pilot-tone stereo signal for radio broadcasting with performance enhanced by digital circuits.

11:00 — Topics in Broadband Modulator/Demodulator Design for Video Transmission
Mircho A. Davidov and Bob Hamell, Catel Telecommunications, Inc.

In standard broadband signal delivery system, performance degradations are caused by power and bandwidth limitations. To minimize these limitations the best type of modulation for the application at hand must be selected. One of the earliest techniques used by Catel was to transmit FM instead of VSB-AM over coaxial cable, microwave links, and, lately, fiber optic links, with excellent performance results. Some system considerations and experience gathered at Catel in designing VSB-AM or FM modulators and demodulators for video transmission over various transmission media and the applications in future systems will be addressed in this paper.

Session D-1 — Amplifier Design II
Chairman: Terry Simons, MMD

9:00 — Power Amplifiers Using Pulse Duration Modulation
S. Zhang, Wuhan University and D. Zhao, Huazhong University of Science and Technology
With the introduction of the basic PDM circuit and the PANTEL method common in tube circuits into transistor circuits, it is possible to use PDM in the transistor audio frequency modulator. The transistorized PDM modulator by the PANTEL method is shown to be superior to the basic PDM circuit.

10:00 — Practical RF Amplifier Design
G. Franklin, Hewlett-Packard
This paper covers the design and construction of lumped element RF amplifiers. The synthesis of input, interstage, and output matching networks of multistage amplifiers will be discussed. RF performance related to construction techniques will also be covered. A low noise, wideband UHF amplifier example will be presented.

11:00 — Parameter Extraction Techniques for RF Power Transistor Models
P. Sanders and Alan Wood, Motorola, Inc. Semiconductor Products Sector

Wednesday, February 11
Afternoon Sessions

Session E-2 — Amplifier Design III
Chairman: Robert Regan, GTE Laboratories

1:30 — The Degenerative Feedback Topology for RF Operational Amplifiers
E. Filseth, National Semiconductor Corp.
The op amp has not been widely successful as a general purpose RF amplifier, principally because of the difficulty of handling large amounts of negative feedback at high frequencies. A recent development, the Degenerative Feedback Topology (DFT), is making possible op amps with real bandwidths in the hundreds of megahertz. This paper will discuss the DFT mechanism and the design of a DC-150 MHz, unity gain, stable, FET-input op amp.

2:30 — Wideband Amplifiers With Lossless Feedback
J. Bares, Motorola Inc.
Feeback is a powerful circuit technique to stabilize component sensitivities and improve distortion and frequency response bandwidth. Resistive feedback introduces noise generators which degrade the signal-to-noise ratio of the two-port. Replacement of feedback resistors by wideband transformers leads to a new class of amplifier. This paper covers shunt and series feedback in single stage, combined shunt and series feedback, extension to multistage amplifiers, and stability criteria for multiple feedback networks.

3:30 — Active Laser Tuning of RF Power Amplifiers Modules
R. Bickham and P. Larson, Motorola Inc., Communications Sector
A system for the active tuning of copper plated, thick film RF power amplifier modules in the UHF frequency range is described. The system monitors amplifier performance and adjusts the module input and output impedance matching networks to optimize such performance parameters as gain, efficiency, or input return loss. Tuning is done with a laser and is irreversable, so inadvertant detuning in the end application is not possible.

Session F-2 — Filter Design and Analysis

1:30 — (TBA)

2:30 — Applying CAD Terminals to Amplifier and Filter Synthesis
P. Wilhelmsen, EEsof, Inc.
New computer-aided design methods for the RF and microwave engineer are changing the way engineering traditionally approached the problem of network synthesis. This paper explores the use of computer-aided synthesis in the design of an 11.7-12.2 Ghz, two-stage, low noise

amplifier and an N-section image reject filter.

3:30 — A Voltage Tuned Filter System for a 900 MHz Band Radiotelephone Receiver
R. Huusko, Nokia-Mobira Oy

This paper describes a new kind of voltage tuned filter system in a 900 MHz band receiver. It consists of fixed and voltage tuned bandpass filters and voltage tuned filters in microstrip form, making possible a single IF receiver at 900 MHz. Low power signals do not cause intermodulation distortion problems and insertion loss is small.

Session G-2 — Safety and Medical Aspects of RF Radiation
Chairman: Tawna Wilsey, Varian Associates

1:30 — RF: Friend or Foe?
R. Vreeland, University of California R & D Laboratory

The hazards, or imagined hazards, of RF exposure have received a great deal of publicity. The author has studied blood cholinesterase levels of newly arrived university students who lived under a TV and FM transmitting tower in a field of about one or two microwatts per square centimeter. No statistically significant effect was observed. On the other hand, the author studied the effects of TV signals on cardiac pacemakers and found that most would stop pacing in a field of less than three volts per meter.

2:30 — Microwave Equipment Requirements for Hyperthermia
T.R. Wilsey, A. McEuen and E. Tanabe, Varian Associates, and P. Fessenden, Stanford University

Microwave hyperthermia, used as a therapeutic modality for cancer therapy, is under intense clinical evaluation at hospitals, clinics, and universities. This paper presents a brief overview of the equipment required for microwave hyperthermia. Included is a discussion of problems unique to a clinical environment of interest to RF engineers, plus the desirable features of power generators, distribution and control networks, antenna applicators, and other components.

3:30 — (TBA)

Session H-2 — Transmitter Design
Chairman: Jaime Borras, Motorola Inc.

1:30 — (TBA)

2:30 — High Power Transmitters for Narrow Pulse, Wide Band Applications
M.D. Clark, System Planning Corp.

This paper discusses the design of VHF/UHF high power amplifiers with 50 dB gain operating in a narrow pulse mode. The emphasis is on design areas critical to achieving octave bandwidths, fast rise times, narrow pulses, and peak powers up to 200 watts.

3:30 — (TBA)

Thursday, February 12
Morning Sessions

Session I-3 — Detectors in RF Circuits
Chairman: Scott Craft

9:00 — A High Resolution Coherent Detector for Imaging Radars
M.J. Willis, Texas Instruments Inc.

One of the requirements of high resolution imaging radars is a coherent detector followed by a wideband video amplifier and "flash" analog-to-digital converter for digitization of the video signal. Such a system provides detailed range and doppler information for the digital signal processing circuits that usually follow the digitizer. This paper discusses the requirements imposed on a coherent detector recently developed by TI from a mathematical viewpoint, then describes the circuit development and design tradeoffs made during hardware development.

10:00 — A PLL Frequency Synthesizer With an Analog Phase Detector
E. Kosty, Motorola Inc.

The Motorola MC145159 is a series input phase locked loop frequency synthesizer with an analog phase detector. The phase detector on the MC 145159 minimizes filtering requirements, reduces VCO modulation sidebands and allows for wider loop bandwidths than are normally possible with three-state phase detector outputs. Divide by R, N and A counters are programmed via a serial data stream, input frequency capabilities are from DC to 15 MHz and on-chip control logic eases interfacing with dual modules prescalar.

11:00 — A Low Temperature MOSFET Regenerative Detector
S. Cho and N. Sullivan, University of Florida

The authors describe a relatively simple marginal oscillator operating at a frequency of 300 MHz. The Colpitts oscillator uses a single MOSFET with a simple resonance circuit, and is suitable for such applications as an ultra low noise CW NMR receiver or for monitoring a high-Q resonator. Its most distinctive feature is operation at cryogenic temperature.

Session J-3 — RF Circuit Analysis
Chairman: William Childs, EEsof, Inc.

9:00 — Phased Array Simulation for Engineering Analysis
D. Grove and H. Hirsch, Applications Research Corp.

This paper discusses a powerful and innovative technique for digital simulation of a phased-array radar antenna. Classic mathematical techniques involving aperture functions and power series are cumbersome in terms of processing time. The highly accurate model presented manages all aspects of a phased-array, including gain, phase shift, and lobe distortion introduced by electronic pointing. Derivation and applications of the model are presented, as well as graphic correlation to classically-developed functions.

10:00 — Derive S-Parameters From Ladder Network Analysis Programs
G. Goodman, Northern Microwave Systems

Ladder network analysis programs usually indicate that the circuit input impedance, Zin, equals R+jx. To a working engineer this useful but limited information does not provide a complete picture of the circuit being analyzed. S-parameters provide more information about the circuit. This paper shows the development of S-parameters from a ladder network analysis program.

11:00 — A Computer Aided Frequency Multiplier Design
J.S. Wong, Hughes Aircraft Co.

This paper describes how a MIC frequency multiplier was designed and optimized with Touchstone® Multipliers (X3 and X5) were designed, built, and tested with results that fulfilled pre-fabrication performance specifications. The ability to optimize the design at the software level eliminates expensive iterations at the hardware level, reducing development costs.

Session K-3 — Oscillator Design
Chairman: Tom O'Shea, Sawtek, Inc.

9:00 — Noise Prediction in Oscillators
U. Rohde, Communications Consulting Corp./Compact Software

This paper shows how to use a linear CAD tool with complete noise analysis capabilities to determine the phase noise contribution in a Class C oscillator. Linear formal expressions, correlated and non-correlated noise source are used.

10:00 — A General Procedure for Low Noise Feedback Oscillator Design
E.C. Westenhaver, Quintron Corp.

This paper develops a philosophy for the functions and requirements of each circuit element in a low noise feedback oscillator design. Cavity and delay type feedback circuits are compared. Mechanical and voltage tuning are discussed.

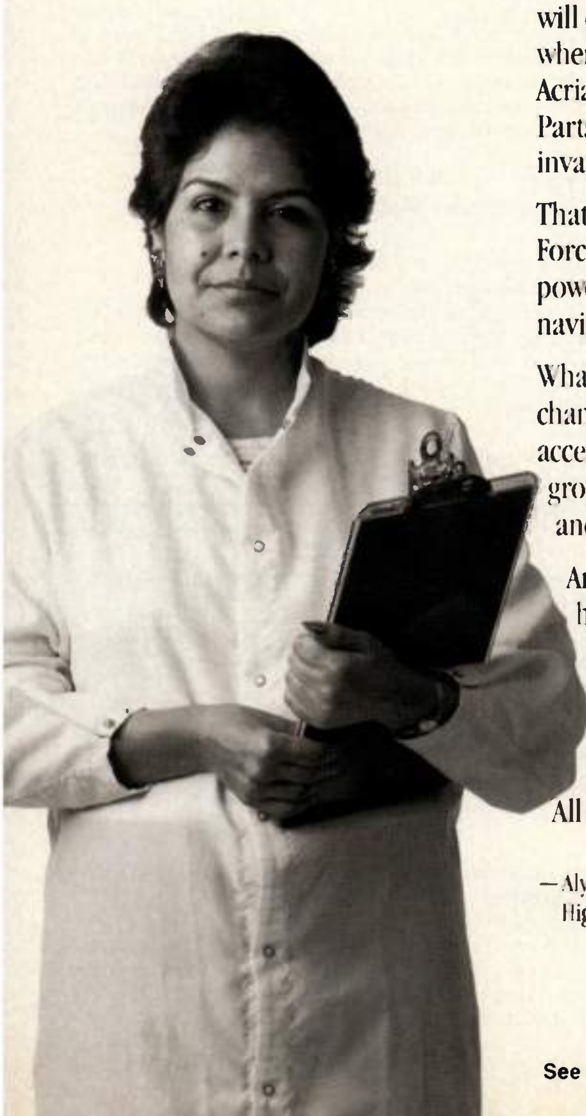
11:00 — (TBA)

Session L-3 — SAW Device Design
Chairman: Albert Comparini, Crystal Technology

9:00 — The Development of a 1030-1090 MHz Hybrid SAW VCO for IFF Applications
D. DePardo, Andersen Laboratories, Inc.

Due to recent developments in the area of military IFF, the need has

"Before it goes into the heavens, we put a little part of it through hell."



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LDR55LA	1200-1400 MHz	55 W	6.6 dB	36 Volts
23A008	2300 MHz	0.8 W	6.5 dB	20 Volts

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risen for oscillators in the 1030-1090 MHz range. This paper encompasses several major areas in the development of a suitable SAW oscillator, including design of the SAW device (theory and actual performance); design, placement and performance of active and fixed oscillator electronic elements; and development of the hybridized form.

10:00 — (TBA)

11:00 — (TBA)

Thursday, February 12 Afternoon Sessions

Session M-4 — Receiver Design Chairman: Malcolm Levy, Racal-Dana Instruments Division

1:30 — A Basic Tutorial on Noise Figure
J. Iseli, Texas Instruments Inc.
This paper describes noise figure concepts and applications in an easy-to-understand manner. The basic definition of noise figure is presented, along with explanations of noise figure calculation and measurement. The relationship of noise figure considerations to receiver system design is explained, and the link between noise figure, signal to noise ratio, and sensitivity is shown.

2:30 — GaAs Monolithic IC Receivers for the Global Positioning System
P. Ho, T. Holden, R. Benton and A. Podell, Pacific Monolithics, Inc.
With 24 satellites in orbit, the GPS receiver can determine the location and speed of any object on earth with unprecedented precision. This paper describes two GaAs MIC chips that will be used as a front end for the GPS receiver: an L-Band low noise amplifier and an L-band VHF/UHF frequency converter. The LNA provides better than 1.5 dB noise figure with 15 dB gain, and the converter demonstrates over 30 dB conversion gain.

3:30 — A 1 mW IC Receiver
P. Chadwick, Plessey Semiconductor

Session N-4 — Oscillator Design Chairman: Carl Erikson, Andersen Laboratories

1:30 — Direct Digital Synthesis and the Numerically Controlled Modulated Oscillator
E. McCune, Digital RF Solutions, Inc.
DDS techniques hold tremendous promise for economical, high performance solutions to many RF design problems. With the advent of the numerically controlled modulated oscillator (NCMO), another major stone is laid on the bridge between RF and digital technologies. This paper shows how many design problems can be solved simultaneously: low phase noise, microfine frequency resolution, rapid frequency agility, timebase frequency stability, and digital modulations of all three basic signal parameters — amplitude, phase, and frequency.

2:30 — Minimizing Harmonic Generation in Crystal Oscillators
J.F. Baran and E.P. Black, Certitech Laboratories
Small changes in circuit components or configurations have significant impact on the strength and number of harmonic signals produced by the oscillator. In digital circuits these harmonics, which are unrelated to actual digital signals, create propagation and radiation problems that can significantly impact the RF emissions profile of the system. This paper examines some of the most critical considerations and discusses methods of minimizing the harmonic overtone content.

3:30 — Digital Temperature Compensation Techniques for Crystal Oscillators
E.K. Miguel, CTS Knights Corp.
A means of compensating crystal oscillators for specific accuracies over specific temperature ranges is described which replaces the traditional resistor-thermistor analog network with digital components consisting of a microprocessor and a memory device. An overview of the more common digital compensation schemes will be presented, followed by some techniques and results pursued at CTS.

Session O-4 — Transistors Chairman: Howard S. Hench, Amperex Electronic Corp.

1:30 — A Simple Low Cost ALC Method for MOSFETs
K. Barkley and G. Lopes, M/A-Com PHI, Inc.
A simple method for controlling MOSFET's output power using only passive components is presented. The method can be adapted to provide VSWR shutdown for an amplifier. A 100-500 MHz, 40 W, push-pull MOSFET amplifier will be described.

2:30 — S-Band Bipolar Microwave Transistors — A New Approach
J. P. Manhout, La Radio Technique Compelec, and J. Salvey, Amperex Electronic Corp.
The application of micron level chip processing has led to the development of a new generation of high power pulse transistors for use in advanced solid state radars. This paper describes the method used to develop the high gain power transistor chip and the method applied to make the chip function.

3:30 — Power Static Induction Transistor Amplifiers
S. Butler, GTE Laboratories
SITs demonstrate very high output power for a single-ended device (>200 watts CW at 225 MHz), and high efficiency (>70%), as well as significantly higher breakdown voltages (>100 volts DC) and higher terminal impedances than conventional bipolar transistors and MOSFETs. This paper describes advances made over the past year in both narrow bandwidth and multi-octave bandwidth amplifier performance.

Session P-4 — RF Circuit Basics Chairman: Rich Potyka, Motorola, Inc.

1:30 — A SOT-23 Mixer
J.H. Lepoff, Hewlett-Packard Co.
The SOT-23 package has become popular for low cost surface mount digital circuits. Schottky diodes in this package are also useful as mixers. This paper describes a balanced mixer designed on Duroid® microstrip. The complete circuit, including a 2 GHz branchline coupler, fits on a 1.6 inch square substrate.

2:30 — A Crystal Controlled Frequency and Amplitude Calibrator
Dan Baker, Tektronix, Inc.
Winner of the First Annual RF Design Contest, this circuit provides frequency and amplitude reference signals at 100 kHz or 1 MHz intervals.

3:30 — The Phase Locked Loop That Works (Almost) — Part II
M. Black, Texas Instruments Inc.

Friday, February 13 Morning Sessions

Session Q-5 — Satellite Communication Systems Chairman: Jeff Schoenwald, Rockwell International Science Center

9:00 — The Potential for Direct Access FDMA Satellites Using Narrowband Techniques
J. Eagleson, Project OSCAR
Using 40 W with 10 dB antenna gain, the author has achieved reasonable performance with amplitude compandoring via amateur radio satellites, even on the rather noisy 146 MHz downlink and 435 MHz uplink band. This paper discusses STI and amateur equipment used and the

results achieved, with the spectrum efficiency implications for commercial satellite usage.

10:00 — An Automated Measurement and Evaluation System for the Vandenberg Space Shuttle Data Relay
J.D. Colson, Johns Hopkins University Applied Physics Laboratory
Two totally automated computer-controlled test and measurement systems have been developed for the Goddard Space Flight Center to evaluate the performance of the space shuttle RF data relay. The relay operates at S- and Ku-bands and consists of numerous antennas and amplifiers and long lengths of coaxial cable and waveguide. This paper describes the computer software developed to provide fully automated control of system equipment, all measurements, and calculations of link performance.

11:00 — (TBA)

Session R-5 — Phase Locked Loops
Chairman: Brian Rose, Q-Tech Corp.

9:00 — Phase Locked Loop Circuit Emulation
C. Fahrenkrug, Niagara Scientific
This paper is a duscussion of the software modeling of a phase locked loop in a computer-aided design and circuit emulation. The software computes hold range, capture range, pull-in range, pull-out range, pull-in time, and noise response for a user defined PLL setup. Setups allow five different loop filters, as well as a linear phase detector. Optimization of tracking and the stability of the system are also considered.

10:00 — A Practical Design Approach to PLL Frequency Synthesizers
J.K. Liukkonen and T. Poutanen, Nokia-Mobira Oy
The PLL frequency synthesizer has become an essential part of VHF and UHF radio telephones. There are several contradictory demands concerning settling time, bandwidth, and linearity in modulation. This paper presents practical design rules for the construction of loop filters and other parts of the synthesizer.

11:00 — A Parametric Tool for the Analysis of Phase Locked Loops
J. Nowicki and I.J. Dilworth, University of Texas
A computer-aided design investigation and simulation of modern phase locked loop design is presented, complete with software. The software allows observation of the influence of such variables as loop bandwidth and gain, and present certain computations in graphical form.

Session S-5 — RF Signal Transmission
Chairman: Bill Avery, Sandel-Avery Engineering

9:00 — Point-to-Point Microwave System Design
B. Ziemienski, City of Fresno, California
All lower frequency systems at one time or another must be tied together for audio or control signals. With costs of telephone circuits high and still rising, microwave service for system interconnect is a viable, cost-effective alternative. This paper shows how to design, apply for and coordinate these systems with the FCC and other users.

10:00 — Considerations in the Transmission of Analog Signals (FDM) on Fiber Optic Links
J. Koscinski, General Optronics, Inc.
An explanation of how to determine the signal degradations of noise and distortion when FDM signals (AM/FM) are transmitted over fiber optic links. The effects of source, fiber, and receiver are discussed.

11:00 — A 1.7 GHz, 5km, QPSK Fiber Optic Link
Larry Stark, Ortel, Inc.

Microstrip Filters for Lower Frequencies

By John Ness and Jim Dougall
University of Queensland

Microstrip bandpass filters are widely used at microwave frequencies since they offer reasonable performance at very low cost. They can be directly integrated into most planar circuits and typically require no tuning once the design has been finalized. However, in the range of a few hundred MHz up to about 1 GHz microstrip filters are less common. At these frequencies filters based on λ/2 (e.g., coupled line designs) or λ/4 (e.g., planar interdigital) line length elements require large layouts even when folded. The resonator Q of microstrip filters is low at these frequencies so the filter performance also deteriorates.

Recently, microwave filter prototypes using elements that are λ/4 long at a stopband frequency selected well above the filter passband frequency have been described in the literature (1). This design method can yield microstrip filters with good passband responses at frequencies down to a few hundred MHz, including wide stopband performances. The filters can be made quite compact and be realized very cheaply using standard epoxy board.

The method does require the computer capability to synthesize filter designs for the general case. It is also useful to have a computer analysis and optimization program available to check the design and allow for performance tradeoffs. The computer analysis is also useful in identifying how to tune the filter since tuning procedures for standard λ/2 or λ/4 resonator designs are not applicable. The filter synthesis and prototype design and selection are covered in reference (1) and will not be repeated here. Instead, the approach will be illustrated with a specific example, with filter requirements as follows:

Center frequency:	310 MHz
Bandwidth:	186 MHz
Rejection:	>50 dB at 170 MHz
	>40 dB at 470 MHz
Insertion Loss:	1 dB
Ripple:	±.1 dB

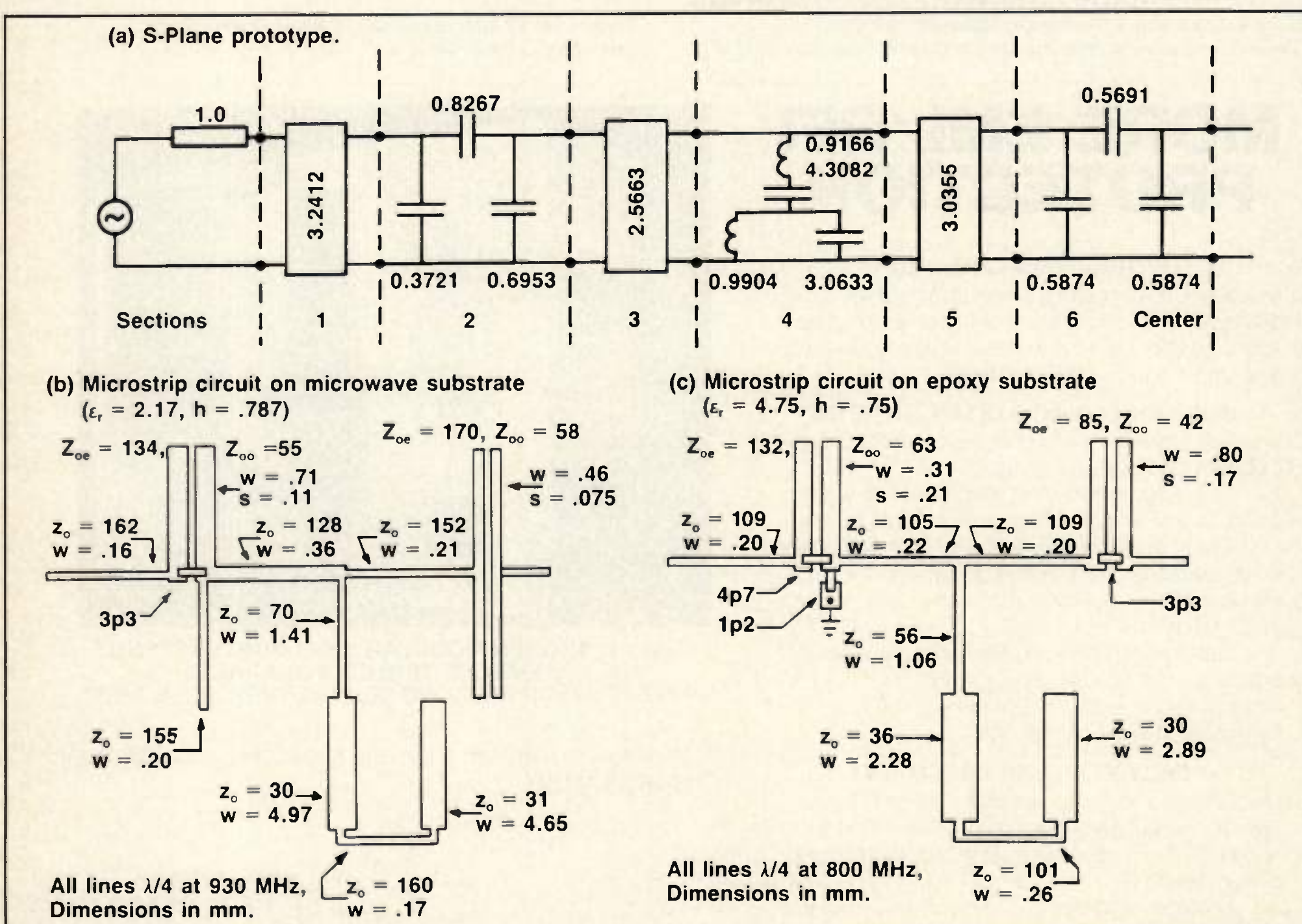


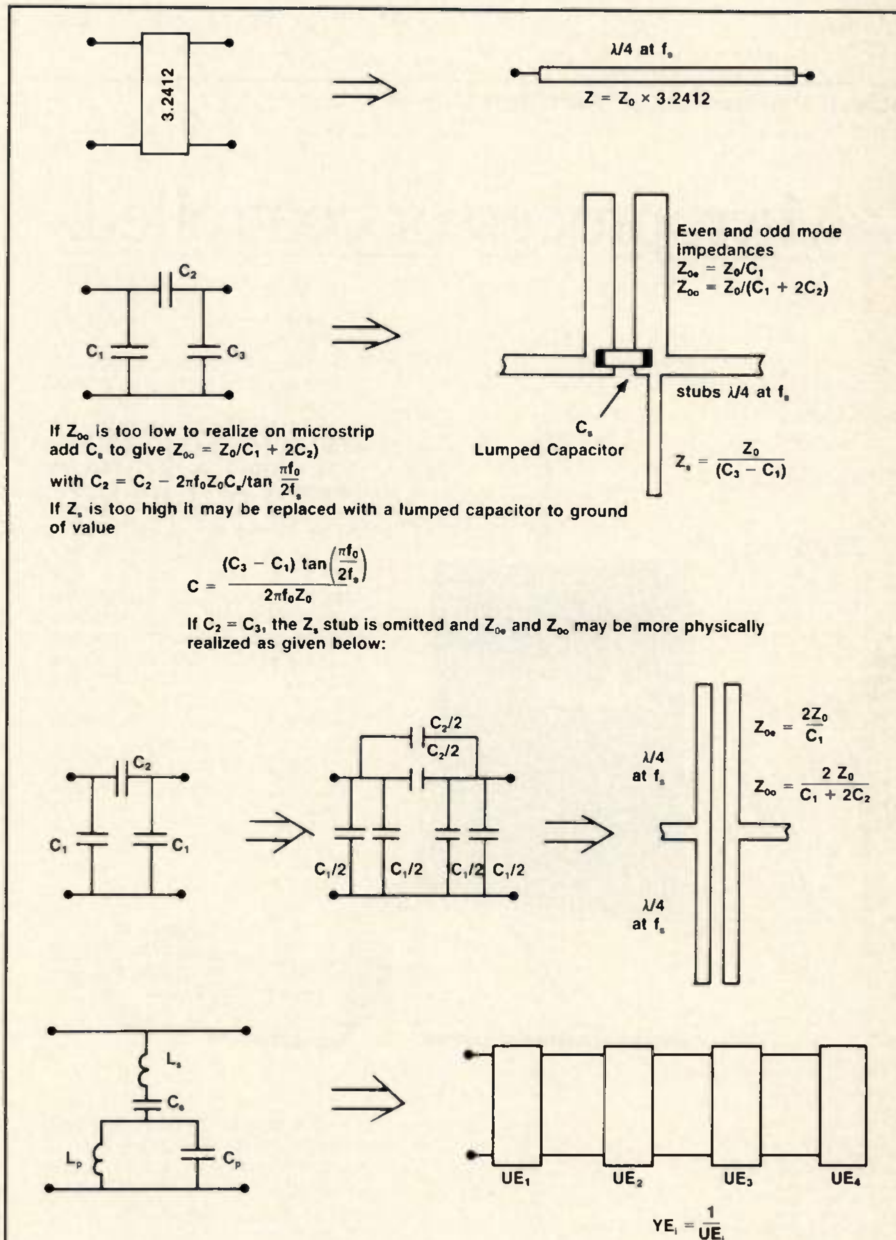
Figure 1. 200-400 MHz filters.

In addition, the filter was required to have a wide stopband response as far out as 1 GHz. Based on the theory of (1) a suitable filter prototype is shown in Figure 1(a). The microstrip filter versions realized on the low loss substrate and on standard epoxy board are shown in Figure 1(b) and (c), respectively. The line lengths, widths and gaps were calculated using the methods given in references (2), (3) and (4).

The stopband frequency f_s was selected at 930 MHz for the microwave substrate filter and at 800 MHz for the epoxy filter. The microstrip line lengths are then $\lambda/4$ at the frequency f_s. The unit elements in Figure 1(a) simply become $\lambda/4$ lines at f_s with the normalized impedance values as shown in Figure 2. The capacitive sections can be realized by coupled lines or if the capacitance values are too large they can be augmented by lumped element capacitors. Finally, the LC network can be converted to a series of unit elements as depicted in Figure 2. At these frequencies it is, of course, possible to use lumped elements to realize the LC network, but part of the reason for using this filter was to avoid the use of wound coil inductors.

A comparison of the impedance levels in Figure 1(b) and (c) shows that they are not the same. The impedances of Figure 1(b) resulted in line widths that were too thin for the epoxy substrate design. A computer optimization was done to maintain the filter response, but with an impedance level constraint of 110Ω. Because of the higher losses in the epoxy substrate filter and the greater varition in the dielectric constant compared to the microwave substrate the passband was increased. This effectively puts the rounding at the edges of the passband outside the specified bandwidth, keeping a relatively flat passband. Extra lumped capacitors including a shunt capacitance to ground were also necessary for the epoxy substrate design.

The filter shown in Figure 1(b) occupied an area of 45 × 65 mm on the microwave substrate. The epoxy substrate design was deliberately more compressed by reducing the spacings between the (ideally) non-coupled microstrip lines. The filter occupied an area of only 33 × 60 mm. A more compressed version was tested, but the unwanted cross coupling levels were too high leading to an unsatisfactory response. The artwork for the epoxy sub-



$$YE_1 = \frac{C_s\,(L_pC_p + 1)}{(L_pC_p + 1)\,(1 + C_sL_s) + C_sL_p}$$

$$YE_2 = \frac{YE^2{}_1\left[C_pL_s - \dfrac{1}{L_pC_s}\right] + \dfrac{YE_1}{L_p}}{YE_1\left[1 + \dfrac{L_s}{L_p} + \dfrac{C_p}{C_s} + \dfrac{2}{L_p + C_s}\right] - \dfrac{1}{L_p}}$$

$$YE_4 = \frac{C_s - YE_1 - YE_2}{\dfrac{YE_2}{L_sC_sL_pC_pYE_1} + 1}$$

$$YE_3 = C_s - YE_1 - YE_2 - YE_4$$

Figure 2. Filter design details.

IMPEDANCE	MATERIAL L	THICKNESS (mm)	Q 300 Mhz	Q 2 GHz	Q 10 GHz
50	EPOXY	.75	39	46	48
50	EPOXY	1.5	45	49	50
50	TFG	.75	133	240	355
110	EPOXY	.75	30	40	46
110	EPOXY	1.5	38	47	49
110	TFG	.75	85	165	255

Table 1: Comparison of Microstrip Line Q.

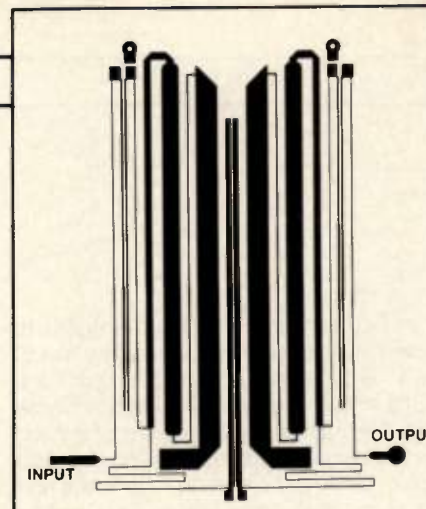


Figure 3. Artwork for the epoxy substrate filter.

strate filter is shown in Figure 3 and the degree of folding is evident.

Filter Performance

The ideal and measured responses of both filters are shown in Figure 4. In general the agreement is quite good with deterioration in the stopband for the epoxy filter being due to the increased loss, as well as the stronger cross coupling. The insertion loss of the high performance filter is comparable to or better than an equivalent LC filter. The 2.2 dB insertion loss of the epoxy substrate filter is higher than desired, but is considered acceptable in view of the size and cost advantages of this design.

The wideband response for the microwave substrate filter is shown in Figure 5. The first spurious response does not occur until about 1.2 GHz, which is four times higher than the filter center frequency. The filter also has its maximum stopband rejection level of nearly 70 dB around the design stopband frequency of 930 MHz. The thecretical results (which do not include cross coupling effects) are also shown. In general, apart from the response around 1.2-1.4 GHz, the theoretical results predict quite closely the spurious responses out to at least 2 GHz.

It is informative to consider the effects of the different substrates at different frequencies. Table 1 compares the Q for 50Ω and 110Ω line resonators of a typical microwave substrate (ε_r = 2.17, tan δ = .001) with that of the same impedance lines on two epoxy substrates (ε_r = 4.75, tan δ = .02) at 300 MHz, 2 GHz and 10 GHz. For simplicity, radiation losses and changes in dielectric properties with frequency are ignored and the copper conductivity and surface roughness are assumed to be equal in all cases.

(Continued on page 59.)

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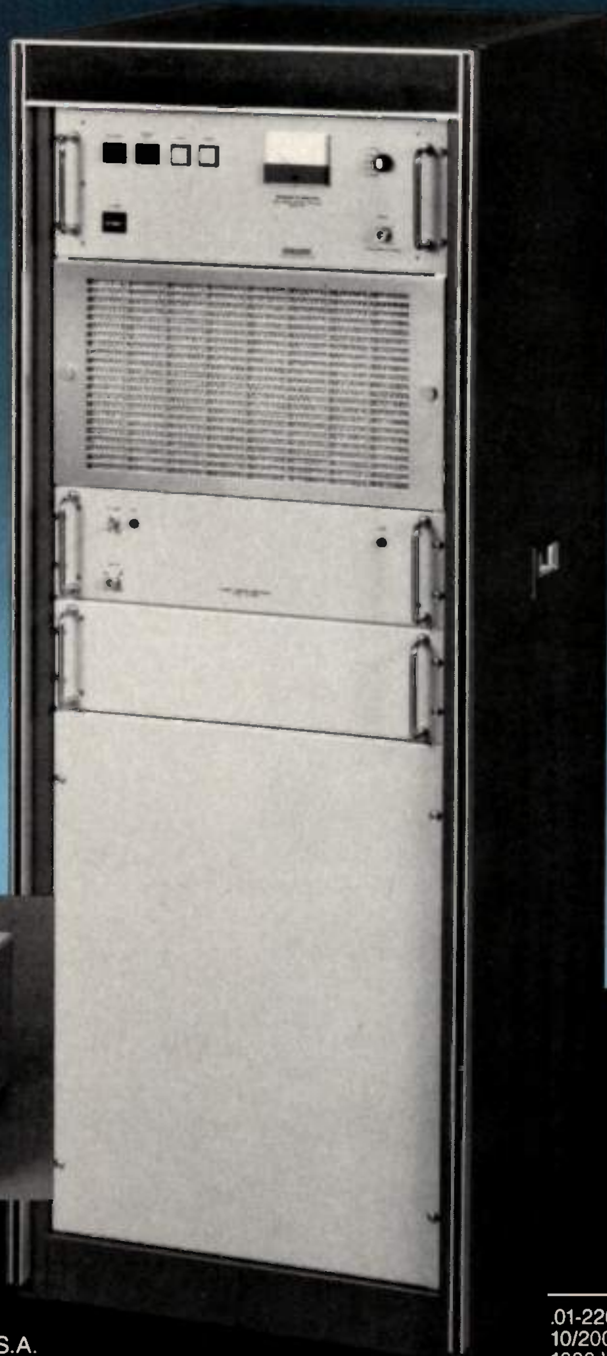

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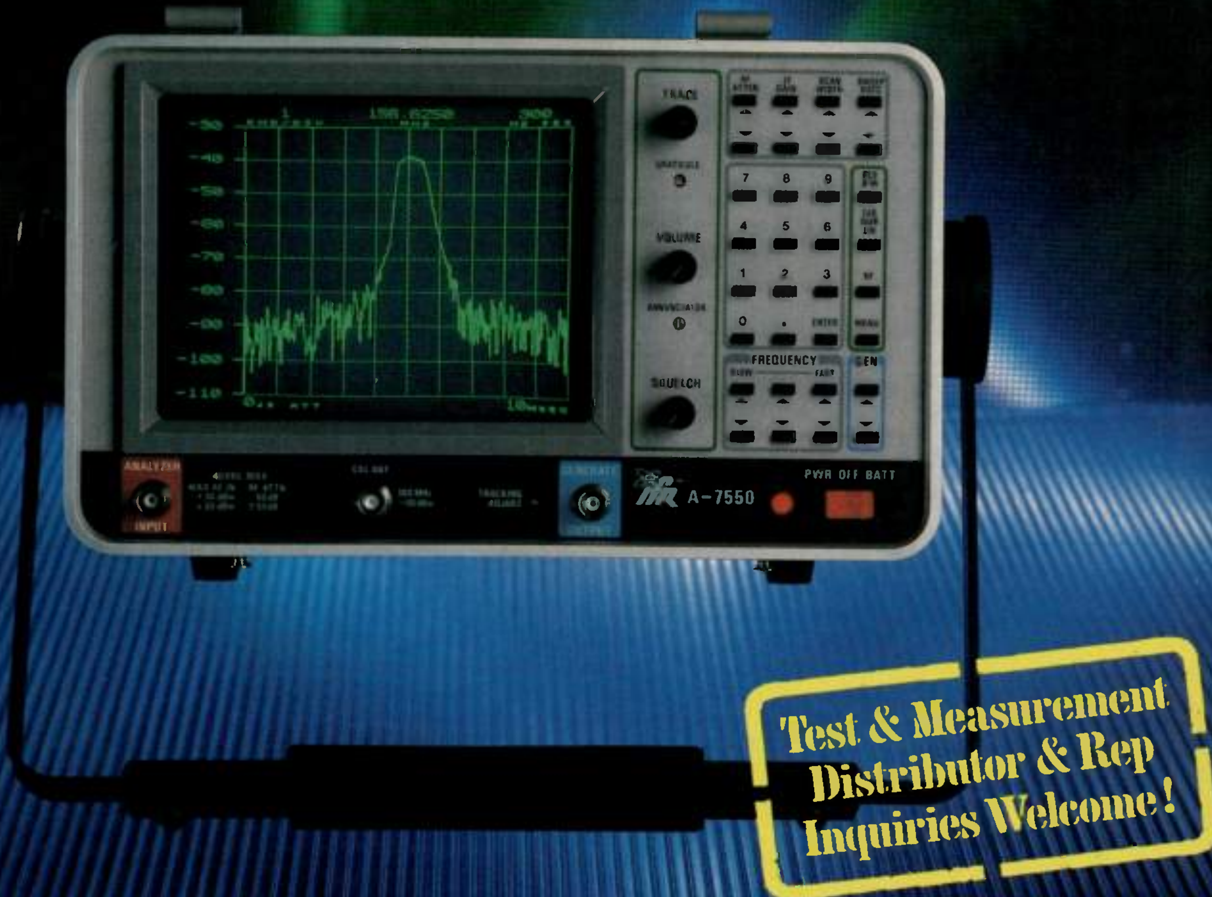

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At high impedance levels the relative improvement in the Q with the microwave substrate is not as great. This is due to the higher copper losses in the thin tracks compared to the dielectric loss. The marked improvement in the Q for the microwave substrate as the frequency increases shows that microstrip filters will have much improved performance at the higher frequencies at least until radiation losses begin to affect the Q. The much lower Q of the epoxy material at the higher frequencies also illustrates that such filters on this material will have very poor performance even at 2 GHz.

At 300 MHz, the insertion loss of a filter on the epoxy substrate with a mixture of high impedance (110Ω) and moderate impedance lines (50Ω) would be expected to be about 2.5-3 times higher than a comparable filter on the microwave substrate, based on the ratio of the Q values. After allowing for the wider bandwidth of the epoxy substrate filter and higher impedance lines of the microwave substrate filter the relative insertion loss increase of about 2.2 for the epoxy substrate filter is close to the expected result. At 10 MHz, the Q ratio for 50Ω lines on the .75 mm substrate is nearly 7.5 so an epoxy substrate filter is not practical. If this filter had been etched on a 1.5 mm thick epoxy board then the Q ratio of about 1.2 compared to the .75 mm epoxy board would have resulted in an insertion loss of about 1.8 dB, a small, but nevertheless real, improvement.

This discussion shows that, besides the larger board area necessary, the performance of conventional microstrip filters at the lower frequencies is considerably inferior to microwave filters. For example, a conventional 10 GHz filter etched on the microwave substrate using 50 Ω resonators if scaled to 300 MHz would have nearly three times the insertion loss. This design by contrast achieves the same performance at low frequencies as at the microwave frequencies. The 4-8 GHz filter described in reference (1) (on which this design was based) had a 1 dB insertion loss. This is about the same value as the 300 MHz filter etched on the microwave substrate.

As another example, for a Chebyshev filter to have a comparable roll off a 14 or 16 section design would be necessary. If realized on an epoxy substrate this filter would have a theoretical insertion loss of 4-5 dB.

(Continued on page 61.)

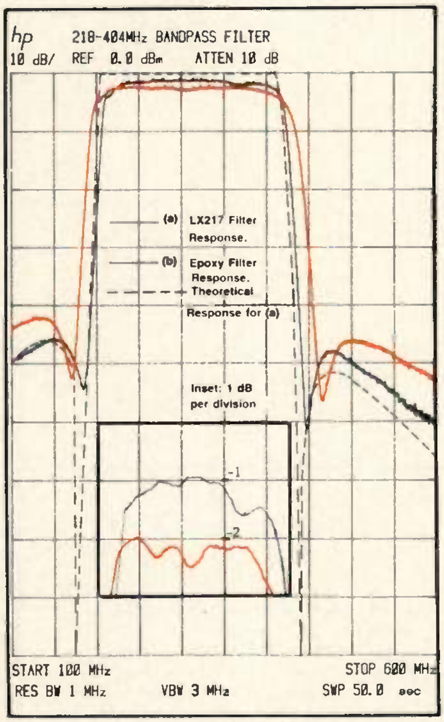

Figure 4. Narrowband response of filters.

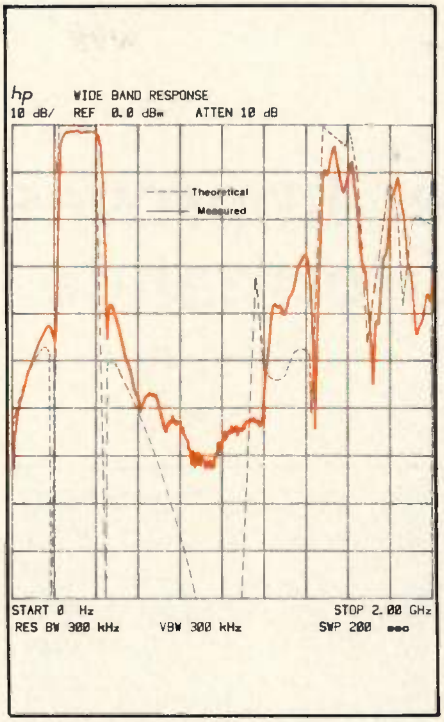

Figure 5. Wideband filter response.

Summary

A very compact planar filter suitable for wide band UHF applications has been described, which can be etched on standard epoxy material and still yield good performance. The filter does not appear to suffer the Q degradation of conventional microwave filters when etched in microstrip form at these lower frequencies. The area occupied by the filter is larger than a comparable LC filter, but it requires no coils and only a few capacitors. The filter does not require post etching tuning for filters etched from the same substrate. The performance is quite repeatable with wide predictable stopbands. The filter does require precision etching principally because of the fine gaps required, but this problem can be alleviated by computer aided design and the selective use of lumped element capacitors. rf

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About the Authors

John Ness is chief engineer of the Microwave Technology Development Centre (MITEC) at the University of Queensland. He holds a Ph.D. in electrical engineering from that university. In addition to his position supervising RF and microwave development projects, Mr. Ness has taught communication technology and worked on the Australian Microwave Landing System (MLS) project team.

Jim Dougall is a staff engineer at MITEC, working on microstrip filter design, converters, multipliers and dielectric resonator oscillators. Mr. Dougall holds an electrical engineering degree from the University of Queensland. Both authors can be reached at MITEC, University of Queensland, Electrical Engineering Department, Brisbane, Australia 4067.

Hybrid Splitter Improves Mixer IMD Performance

By Daniel Marz
Jerrold Subscriber Systems Div.,
General Instrument Corp.

Reducing intermodulation distortion (IMD) products in mixers is an ongoing challenge for design engineers. This article describes a method of IMD improvement in simple applications, where cost and complexity are important design factors.

It is well known to RF engineers that a mismatch at any of the ports of a balanced mixer increases the IMD products present at the output. In those cases where the use of a bandpass filter is required at the mixer output, frequencies outside the filter passband will see a mismatch and result in increased IMD product levels.

Figure 1 is an example of a mixer with a broadband termination, forcing a matched condition at all frequencies. The spectrum analyzer photo shows the actual IMD performance of a sample mixer. The use of a bandpass filter (Figure 2) increases the IMD products in this mixer by 10 dB or more.

If an additional loss of 3 dB can be tolerated, a two-way 0° hybrid power splitter can be connected between the mixer output and the filter. The function of resistor R1 in the splitter is to absorb the reflected energy from the filter, preventing re-entry into a mixer. The second splitter port should be terminated. Figure 3 shows about 8 dB improvement in IMD performance over the directly connected filter. rf

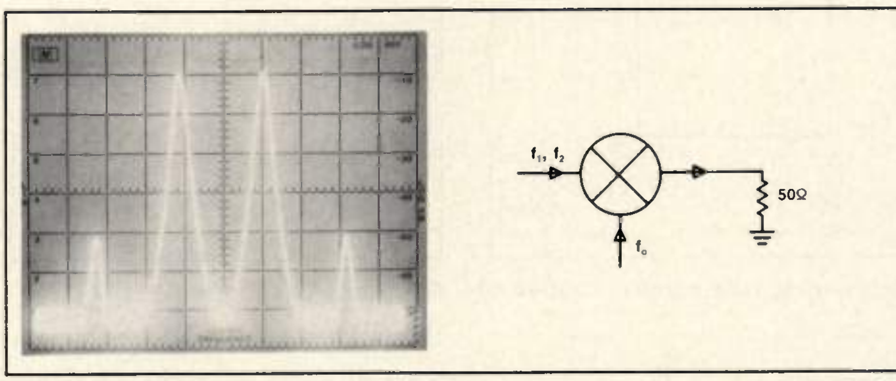

Figure 1. Mixer properly terminated.

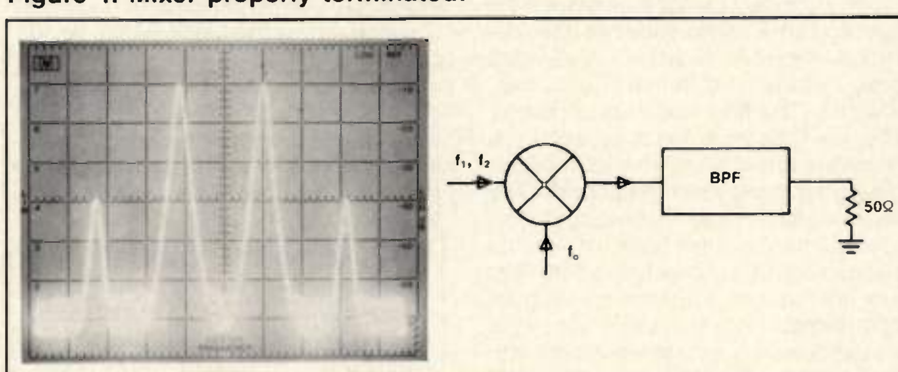

Figure 2. Bandpass filter at mixer output.

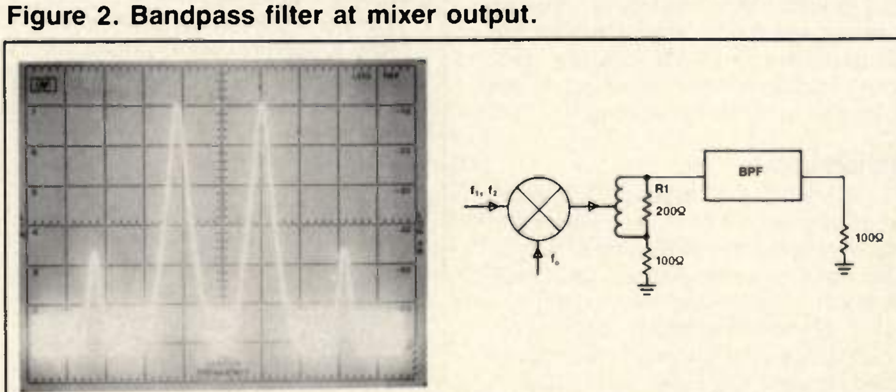

Figure 3. Hybrid splitter at output port.

About the Author
Daniel Marz is a Project Engineer with the Jerrold Subscriber Systems Division of General Instrument Corp., 2200 Byberry Road, Hatboro, PA 19040.

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SAS-200/540	20 - 300 MHz	Biconical
SAS-200/541	20 - 300 MHz	Biconi. Collapsible
SAS-200/542	20 - 300 MHz	Biconical, Folding
SAS-200/550	001 - 60 MHz	Active Monopole
SAS-200/560	per MIL-STD-461	Loop - Emission
SAS-200/561	per MIL-STD-461	Loop - Radiating
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Simple Computation of Spurious-Free Dynamic Range

Relationships Between Performance Parameters Identify Design Tradeoffs.

By Nubar Ayrandjian
Applied Communications

Electromagnetic compatibility (EMC) is an important aspect of receiver design, with the growing use of the radio spectrum. Prediction of performance in a strong multi-signal environment requires knowledge of a receiver's dynamic range. Conversely, the required dynamic range can be computed from the signal levels expected to be seen at the receiver "front end." Presented here is a review of the basic parameters of dynamic range, and the relationships between them.

Spurious-Free Dynamic Range (SFDR) is defined as the input level variation range over which spurious signals are not developed above the minimum discernible signal levels. Minimum discernible signal (MDS) is defined as the lowest signal a system can see or discern in the noise threshold. Noise threshold in 1 Hz bandwidth at room temperature in a 50 ohm system is given as KTB = −174 dBm. If the system is a 1 Hz bandwidth system, then noise threshold is at −174 dBm, but for any other practical bandwidth, such as 10 kHz, the noise threshold is: −174 + 10 log (10,000) = −134 dBm. This means that at room temperature the maximum noise will be at −174 + 40 = −134 dBm for a 10 kHz bandwidth, which is then defined as a 0 dB noise figure.

If the system is not an imaginary one, but one that has true working parameters, it will also have an input noise figure. If input noise figure is 10 dB then the system noise threshold in 10 kHz will be −134 +

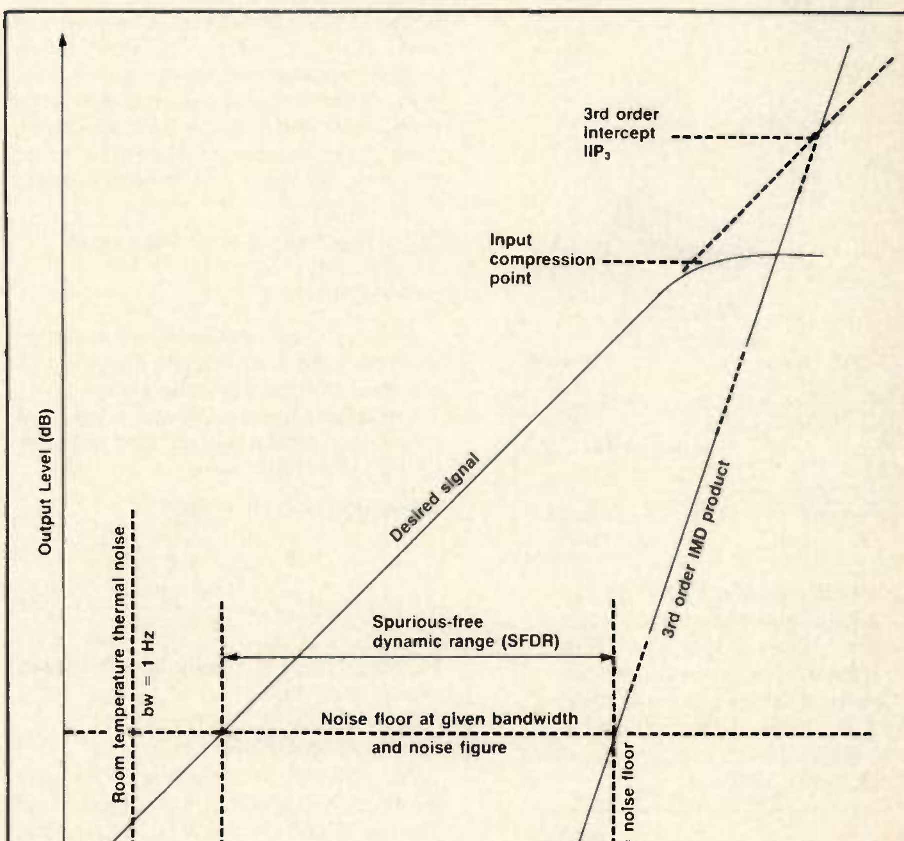

Figure 1. Graphical representation of dynamic range factors.

10 = −124 dB,. This simply means that, to discern a signal, the signal level must be −124 dBm or higher. Two −124 dBm levels will give a resultant −121 dBm level which is the 3 dB (S+N)/N definition of minimum discernable signal.

For spurious-free dynamic range, the starting input level (in the 10 kHz BW) will be −124 dBm, which is MDS. The level where input signals develop spurious signals of a level equivalent equal to MDS is the upper limit of the SFDR.

Since the third order input intercept point (IIP_3) of a system is a constant number and the noise floor (in the previous example the MDS level) is known, the SFDR can easily be computed from these two parameters. This approach assumes that when the third order intermodulation products are at the noise floor level, the MDS characteristics of the system are disrupted and the system is no longer considered linear.

In some cases, intermodulation specifications are given as two input tones with the product levels at a certain dB level below. If it is realized that input intercept point does not vary with input levels unless the system is driven into compression, all that is required to be known is the third order input intercept point which can readily be computed from input level used and how far down the Intermodulation Products are:

$$IIP_3 = \text{Input Level} + \text{IM Products}/2$$
$$IMP/2 = IIP_3 - IL$$
$$IMP = 2(IIP_3 - IL)$$

Since, for our approach, we assumed that the noise floor was the minimum input level starting point and maximum input level was the level at which the intermodulation products developed would be at the noise floor, then:

$$\begin{aligned}\text{Noise floor} &= IL - IMP \\ &= IL - 2(IIP_3 - IL) \\ &= 3(IL) - 2\,(IIP_3)\end{aligned}$$

$$IL = \frac{\text{Noise floor} + 2(IIP_3)}{3}$$

This represents the upper level for determining the SFDR.

Computing SFDR

We defined Spurious-Free Dynamic Range as the difference between the final input level and the noise floor, therefore:

$$\begin{aligned}SFDR &= IL - \text{Noise floor} \\ &= \frac{\text{Noise floor} + 2(IIP_3)}{3} - \text{Noise floor} \\ &= \frac{2}{3}\,(IIP_3 - \text{Noise floor})\end{aligned}$$

These are all values available to us, either from specifications or as results of design analysis. For example, if a receiver's design specifications are given as:

$$\begin{aligned}\text{Noise Figure} &= 15\text{ dB} \\ \text{IF Bandwidth} &= 10\text{ kHz} \\ IIP_3 &= 12\text{ dBm}\end{aligned}$$

Then Noise floor =

$$\begin{aligned}&-174 + 10\log BW + \text{Noise Figure} \\ &= -174 + 40 + 15 \\ &= -119\text{ dBm, and} \\ SFDR &= 2/3\,(12 - (-119)) \\ &= 87.33\text{ dB}\end{aligned}$$

This means that if two signals appeared within the passband at a level of 87.33 dB above the noise floor they will develop spurious at the noise floor level with the input level being −119 dBm + 87.33 dB = −31.67 dBm. The Spurious-Free Dynamic Range will begin at −119 dBm and stop at −31.67 dBm. Throughout this range any spurious developed shall be below or at minimum discernable signal level. Conversely, when the two input signals are above −31.67 dBm, unwanted spurious will occur above MDS and degrade performance.

Computing Receiver Requirements

All of the above relationships can be rearranged for other factors, if the "external" signal levels are known and receiver performance must be determined. For example, the SFDR equation can be rewritten as either:

$$IIP_3 = \frac{3}{2}(SFDR) + \text{Noise Floor, or}$$

$$\text{Noise Floor} = IIP_3 - \frac{3}{2}\,(SFDR)$$

By this type of analysis, the system design engineer can determine whether the specifications imposed meet the mission requirements, with the additional value of examining all of the relationships between receiver performance characteristics. rf

About the Author

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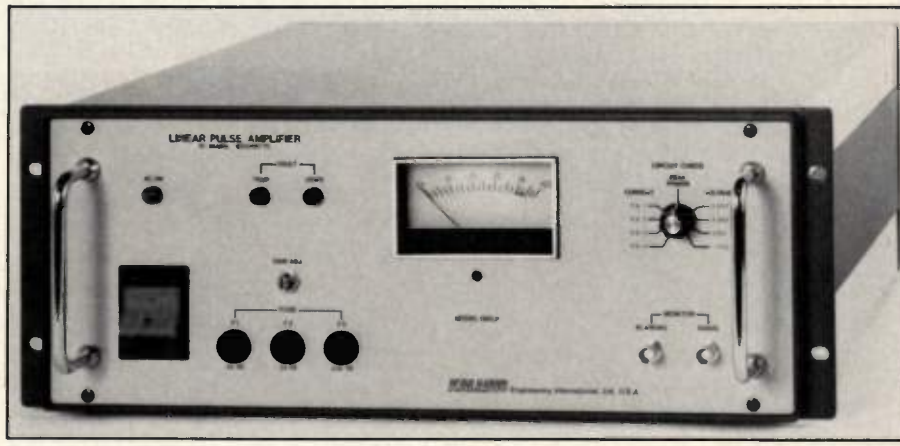
Kalmus Engineering Achieves 1 μs Blanking Speed for NMR/MRI

A 1000 watt amplifier for NMR/MRI applications has been introduced by Kalmus Engineering International, featuring one microsecond blanking speed for high resolution imaging. The 10-86 MHz version is the Model 166LP, with the Model 166HP covering 80-200 MHz.

The fast blanking speed is required to obtain sharp NMR images. The NMR process involves the excitation of the material (typically a human body) being studied and the immediate transition from transmit to receive mode for detection of the material's response. Slow blanking will cause a portion of the return pulse to be missed.



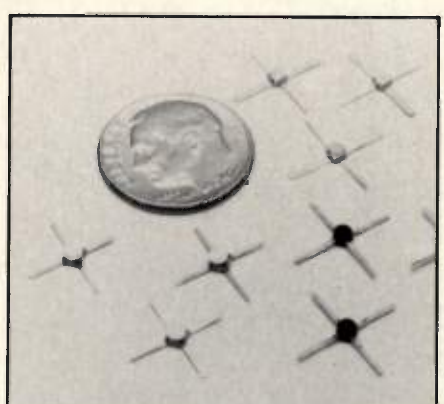
Another feature of the Model 166 amplifiers is an accurate peak-reading power meter, offering reliable measurement of power with pulse durations from 4 microseconds to 100 milliseconds. Other important specifications are: TTL-compatible blanking input, gated-OFF noise floor 15 dB (max.) above thermal noise and 60 dB gain with ±1 dB gain flatness.

THe units feature full protection circuitry, including VSWR and temperature. Power supply taps are provided for 190-240 VAC, single-phase 50-60 Hz. Linearity is specified in terms of third order intermodulation intercept point, which is typically +71 dBm. **Kalmus Engineering International, Ltd., Woodinville, Wash. INFO/CARD #202.**

Avantek Introduces MMIC Frequency Converters

Three new monolithic silicon frequency converters provide up or down frequency conversion with up to 20 dB of gain with RF inputs from 500 MHz to 8 GHz. These cilicon MMICs are optimized to simultaneously operate as a self-oscillating LO and two-port active mixer with conversion gain.

Typical electrical specifications (at +25°C with −20 dBm RF input at 4.2 GHz and 5.15 GHz LO) include conversion gain to 950 MHz of 9 dB, 1 dB compressed output power of 9 dBm, 3rd-order intercept point of +16 dBm, and IF band spurious signal level less than 70 dBc. Potential applications include CATV converters, satellite MATV and TVRO block converters, UHF/VHF communications systems, police radar detectors, cellular radio receivers, MDS television receivers, GPS and Inmarsat receivers and military manpack systems. The devices are suited for very low cost or size-constrained applications where simple external filters can be used to achieve adequate isolation. Package styles include a cost-effective, glass-sealed, microstrip ceramic micro-X package (MSF-8835), a high-reliability, 70-mil hermetic metal-ceramic package (MSF-8870) and a low-cost 85-mil plastic package (MSF-8885). All products are in stock at authorized Avantek distributors. In 1000 piece quantities, they are priced according to package options: $29.75 each (MSF-8870), $12.40 each (MSF-8835), and $5.20 each (MSF-8885). **Avantek, Inc., Santa Clara, Calif. INFO/CARD #201.**



Programmable Units Adds RF Switching

Three new plug-in switch modules now available from Hewlett Packard increase the switching flexibility of its low-cost, IEEE-488 programmable switch/control unit, the HP 3488A. Two of the modules are ideal for microwave switching applications up to 26.5 GHz. The third plug-in is a Form-C module with seven channels, each an SPDT switch, intended to drive remote mounted microwave switches or attenuators. The HP 44476A microwave switch module has three channels, each an SPDT 50-ohm coaxial switch with a frequency range of DC to 18 GHz with isolation of greater than 90 dB at 18 GHz and an internal 50-ohm termination of the ungated port. Price of the HP44476 switch module is $2200. The HP3488A Switch/Control unit is $1400. **Hewlett Packard, Loveland Instrument Division, Loveland, Colo. INFO/CARD #199.**

Test Set Monitors RF Radiation

The Model 8700 from Narda is an accurate, easy to use radiation monitoring system designed for RF hazard identification, safety and compliance monitoring. Consisting of Model 8716 Meter and your choice of ANSI shaped probe (Model 8722) or flat probe (Model 8721). Model

8700 offers 300 kHz to 40 GHz coverage, continuous automatic zero, ability to measure all modulation types (CW, AM, FM, Pulse) and built-in test field oscillators. **The Narda Microwave Corporation, Hauppauge, N.Y. Please circle INFO/CARD #200.**

2-6 GHz Amplifier Chip is Reliable, Efficient

A 2-6 GHz monolithic amplifier chip with 10 dB small signal gain is announced by Pacific Monolithics. The amplifier chip, model PM-AM0607, is ideal for thin-film hybrid assemblies where minimal tuning time and high reliability are important. It may be easily used as a stand-alone gain stage, or it may be directly cascaded (side by side) to produce higher gain. The chip measures .036 in. × .036 in., operates from a single supply voltage of 8 volts, and requires an external DC bypass capacitor. The amplifier has a gain flatness of ±0.75 dB over the 2-6 GHz. band. At the 1 dB gain compression point, power output is +5 dBm and harmonics are −20 dBc. Noise figure is 7 dB with reverse isolation of 30 dB. The amplifier consumes only 20 mA current at 8 volts. Price for the amplifier chip is $135 each in quantities of 100. **Pacific Monolithics, Inc., Sunnyvale, Calif. INFO/CARD #197.**

Power Meter Handles Automatic Measurements

The new Rohde & Schwarz-Polarad Meter NRV is a sensitive and versatile instrument specifically designed for automatic measurements. The standard IEEE 488 interface can control all front panel settings. Depending on the power sensor used, the NRV can meaure powers from 400 pW to 500 mW over a frequency range of 1 MHz to 18 GHz. With two channel capability, the NRV can be used with two sensors to measure two individual values, a ratio of one against the other, or against an arbitrary reference. Measurements may be in watts, dBm, dBv or volts. A peak function is included to measure the peak envelope power (PEP) of a modulated signal. **Rohde & Schwarz-**

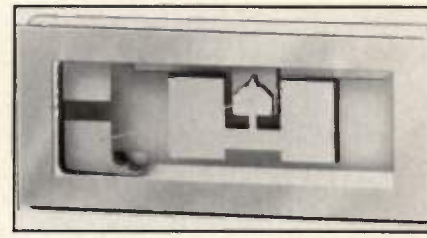
Polarad, Inc., Lake Success, N.Y. Please circle INFO/CARD #196.

5-1000 MHz Amplifier has 2.7 dB Noise Figure

Vector's Model MHT-1011 thick film high gain LNA is a cascadable wideband amplifier in a TO-8, 4 pin package. It has 15.5 dB (typical), 14 dB (min) gain over the 5 to 1000 MHz range. Noise figure is 2.7 dB (typical), 3.3 dB (max.) Power output at 1 dB gain compression point is zero dBm (typical), −2 dBm (min.) The MHT-1011 operates from a +15 Vdc source at 10 mA. **Aydin Vector Division, Newton, Pa. INFO/CARD #195.**

ZT-Cut Crystals Offer Stability

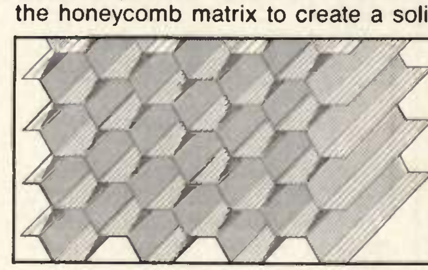
CX-ZT is a chemically milled quartz resonator with excellent temperature/frequency characteristics. Its high performance is achieved through concurrent width and length vibration of a unique double rotated quartz. A miniature ceramic package is available for standard mounting and for surface mounting. CX-



ZT quartz crystals cover the frequency range from 2.1 to 4.2 MHz and are intended for highly stable oscillators (overall stability better than 10 ppm without compensation in a temperature range of 100 deg. C). **ETA Industries, Micro Quartz Div., New York, N.Y. INFO/CARD #198.**

Waveguide Air Vents for Shielded Enclosures

Lindgren RF Enclosures has developed a new honeycomb waveguide air vent with more EMI/RFI protection and minimized resistance to air flow. A new solder fusion assembly process developed by Lindgren completely fuses all contact surfaces in the honeycomb matrix to create a solid



electrical and mechanical bond that eliminates tiny cracks and cavities along the fused surfaces. If present, these imperfections can cause RF leakage in the microwave frequencies. The new honeycomb construction technique provides attenuation of over 120 dB for frequencies up to 10 GHz. **Lindgren RF Enclosures, Inc., Addison, Ill. INFO/CARD #194.**

Coax Termination Dissipates up to 500 Watts

A new ceramic materials which can dissipate microwave energy levels as high as 500 watts in a 7/8" coaxial termination has been developed by Core-Tronics. This new material, Cortron 900, can be supplied in a full range of geometric shapes based on isostatic pressing, to meet the performance and mechanical requirements of microwave terminations. Attenuators fabricated of Cortron 900 exhibit minimum reflection with low, essentially constant dB loss over their full frequency range. They are capable of dissipating from 200 watts in a 3/8" coax termination to as much as 500 watts in a 7/8" termination without deteriorization. **Core-Tronics, Orange, N.J. INFO/CARD #193.**

Soft Ferrite Material Has Permeability of 5000

Ceramag® 24F, a new high permeability, low loss soft ferrite material has been developed for RFI/EMI filter applications. With an initial permeability value of 5000, anda maximum permeability of 8000, the ferrite material has a maximum loss factor at 100 kHz of 20×10^{-6}. Principal applications for the material include filters, wideband transformers, pulse transformers, antenna cores and other electronic applications. Coated and uncoated toroids are available, as are E cores, pot cores, and other configurations. **The Stackpole Corporation, St. Mary's, Pa. Please circle INFO/CARD #188.**

High-Speed Buffer Amplifier

The HOS-200 hybrid buffer amplifier from Analog Devices provides up to ±100 mA of continuous current drive (±250 mA peak) at frequencies to 200 MHz. This high-speed buffer amplifier features 1500V/μs slew rate, capability to drive 50Ω and 75Ω cables, and operation with ±5V power supplies. Additional key AC specifications include phase linearity of 2° (at a bandwidth from 1-20 MHz) and distortion of less than 0.1 percent, important parameters for faster graphics and video-speed applications. Propagation delay and rise time are both typically 1.5 ns. Pricing in 100s starts at $12.60 for the HOS-200AH (−25° to +85°C) and $17.00 for the HOS-200SH (−55° to +125°C). **Analog Devices, Inc., Greensboro, N.C. INFO/CARD #187.**

Miniature Microwave Relays

A new line of miniature microwave relays has been introduced by FL Jennings. Initially, the line offers two series — the TOH 54 Series with connectors for

PC boards, and the TOH 55 Series with SMA connectors. The TOH 55 series is rated at DC to 2.5 GHz, and offers a VSWR of 1.20:1, with isolation near 40 dB, and insertion loss of 0.15 dB. Operating voltages of 6, 12, 24, and 28 VDC are available, with coil connections of PCB terminals, flying leads, and solder lugs. **FL Jennings, San Jose, Calif. Please circle INFO/CARD #184.**

Interchangeable N and SMA Connectors

Various new N connectors are now available which can be directly mounted

in place of SMA connectors without the need of modifying the component or instrument to be equipped. This gives a high degree of freedom to the designers of OEM components like circulators, isolators, filters or any kind of stripline devices. The N and SMA connectors have identical flanges and rear ends and provide operation with low VSWR up to 12.5 GHz. **Huber & Suhner AG, Herisau, Switzerland, INFO/CARD #192.**

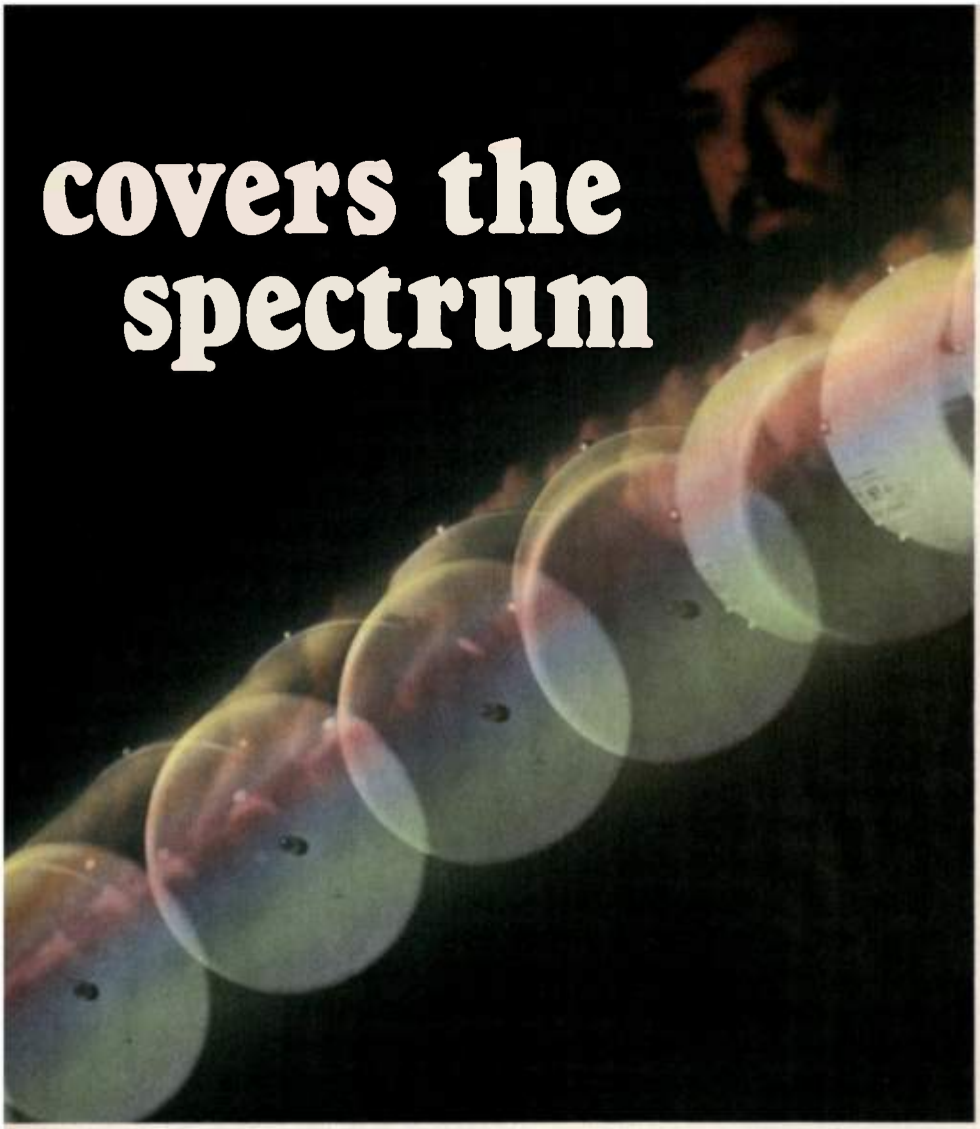
Transfer Switch Operates to 24 GHz

An intelligent coaxial transfer switch useful to 24 GHz has been announced by the Wavecom Division of the Loral Corporation. The model 130 2P2T switch, equipped with SMA connectors, offers a DC to 18 GHz frequency range as stan-

dard, with the 18 to 24 GHz band optionally available. The switch offers either failsafe or latching actuation. The user may specify any type of high- or low-level logic. RF performance features are: VSWR from 1.2:1 (3 GHz) to 1.6:1 (24 GHz), insertion loss from 0.2 to 0.6 dB (24 GHz), and isolation from 80 dB (3 GHz) to 50 dB (24 GHz). **Wavecom Division of Loral Corporation, Northridge, Calif. INFO/CARD #191.**

Double Balanced Phase Detectors

A new series of double balanced microwave phase detectors has been introduced by RHG Electronics Laboratory. The PDM series of phase detectors provides a DC output voltagte proportional to the phase and amplitude differences of the RF inputs. The DC offset voltage is the lowest available in this type of



Radiation Monitors

Narda has developed radiation monitoring systems consisting of a variety of field sensitive probes and metering instruments. These probes are interchangeable to provide electric and magnetic field measurements. The metering instruments are also usable for applications from 0.3 MHz to 26 GHz.

Broadband Isotropic Probes

Electric Field

FREQ.	0.3 to 300 MHz	10 to 3000 MHz	300 MHz to 26 GHz
PROBE	**8662**	**8644**	**8621, 8623**

Magnetic Field

FREQ.	0.3 to 10 MHz	10 MHz to 300 MHz
PROBE	**8652**	**8631, 8633, 8635**

Safety personnel with no specialized RF expertise can, for the first time, perform fast, easy, accurate measurements over the frequency spectrum from 300 KHz to 1500 MHz (exposure levels of RFPG contained in ANSI C95.1-1982). The Narda Model 8682 ANSI Standard Radiation Monitor conformal probe can be used with either 8611 and 8616 metering instruments. Both direct reading meters permit measurement with excellent resolution over the 30 dB dynamic range. This monitoring system features: direct readings in percent of ANSI exposure limit; operation even in multiple signal environments; true RMS indications regardless of modulation; isotropic response; and compatibility with existing meters.

Narda has pioneered, for over 20 years, the field with state-of-the-art system in radiation monitoring technology.

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Three meter styles are available. Each performs specific requirements. Model 8616 is our full-featured instrument and is calibrated in average equivalent power density. While the 8619 is identical in size, it is calibrated in mean squared electric and magnetic field strengths. Both accommodate all probes. Model 8611 is a compact unit with the same readout as 8616 and accommodates all probes.

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Come see us at the RF Technology Expo, Booth #526. INFO/CARD 50 device. Both RF ports utilize matching elements to ensure low VSWR, minimizing errors from impedance mismatches. Frequency range is 4-8 GHz, with a conversion loss of 8 dB, nominal. Output voltage with two 0 dBm signals is ±60 mV. The PDM4-8 is priced at $850. **RHG Electronics Laboratory, Inc., Deer Park, N.Y. INFO/CARD #190.**

Tubular Attenuators are Color-Coded

RF Industries is announcing a 1 Watt, BNC in-line tubular, fully shielded and color-coded attenuator line. These 1 dB through 40 dB models are fully shielded and have a nickel plated body. EIA color code bands indicate the value of each attenuator. These attenuators are for operation to 1 GHz and have an accuracy of ±.2 to .6 dB (depending on value). The attenuators are offered at an introductory price of $12.95 each. **RF Industries, Hialeah, Fla. INFO/CARD #189.**

Broadband Noise Sources

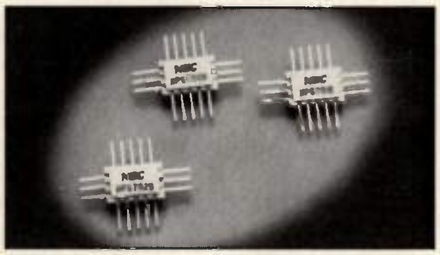
International Microwave's broadband coaxial solid state Noise Source provides high ENR from 1 to 18 GHz and eliminates the need for a separate noise source for each band. The noise source has a wide range of measurement applications including amplifier gain and noise figure tests, and on-line monitoring. Noise output flatness is ±0.5 dB over a temperature range from −55°C to +85°C. A built-in current regulator assures excellent output stability with voltage and temperature variations. **International Microwave Corp., Stamford, Conn. INFO/CARD #183.**

RF Relays Switch DC-1 Ghz

Single pole double throw, DPDT, SP3T and SP4T relay assemblies for remote control transfer of RF signals in the DC-1 GHz range are being offered by Alaun Engineering. The units are electro-mechanical with low insertion loss and high isolation for audio, video & RF. Power consumption is 200 mW at 5-24 VDC with polarity sensitive floating coils. Accessories available as options include remote power supply, control switch with cable and various connectors. Most models are available from stock with prices ranging from $26.00 and up. **Alaun Engineering, Montrose, Calif., Please circle INFO/CARD #182.**

GaAs Ultra High Speed Digital ICs

NEC has just introduced the first of the new UPG700 Series, three GaAs digital ICs designed for high speed digital signal processing. The UPG700B is a master-slave D-type flip-flop with set/reset func-



tions, while the UPG701B is a master-slave T-type flip flop with set/reset functions. The UPG702B is a 3 input OR/NOR gate. All three chips can operate beyond 2.4 Gb/s. The prices are $197 each for quantities of 100. **California Eastern Laboratories, Santa Clara, Calif. INFO/CARD #181.**

rf software

Filter and Data Conversion System Combines Hardware/Software

A menu-driven, board-level FIR (Finite Impulse Response) filter design system lets engineers design digital filters with no prior digital design experience. The EVK-128 by Intersil, Inc. is a moderate speed data acquisition, conversion and digital filtering system occupying a single slot on an IBM PC or compatible. The EVK-128 digitally filters data with a filter length of zero (unfiltered) to 128 taps using two Intersil chips: the proprietary IM29C128 Finite Impulse Response Filter Controller (FFC) and the industry-standard 29C510 16-bit multiplier/accumulator (MAC). Throughput is a function of required filter length, with an 80 nS per tap processing rate. Price of the EVK-128 is $799. **Intersil, Inc., Cupertino, Calif. Please circle INFO/CARD #220.**

Microwave Artwork Program is Updated

EEsof, Inc. announces the release of MiCAD™ 1.05, the newest version of its microwave layout and drawing program for the preparation of camera-ready artwork, drawings, and documentation associated with MIC, microstrip and stripline circuits. New features include all new Touchstone 1.4 microstrip and stripline elements, a geometric text editor, and full Disk Operating System (DOS) pathname support. Also, the graphics processing speed runs four times faster. MiCAD 1.05 runs on the IBM PC and compatibles with hard disk drive and the HP Vectra PC. The program retails for $8,400 (volume discounts available). **EEsof, Inc., Westlake Village, Calif. INFO/CARD #219.**

Software for RF/Microwave Directional Couplers

Microwave Software Applications announces the release of computer-aided engineering (CAE) software for the synthesis and analysis of directional couplers, including the following four products:

- LANGE: Microstrip interdigitated couplers.
- MSCUP: Microstrip directional couplers.
- SLCUP: Stripline directional couplers.
- WGTCUP: W/G multihole topwall couplers.

The software offers synthesis of coupler dimensions from coupling level impedances (Z_{oe} & Z_{oo}), or synthesis of coupler impedances from dimensions used in the device; sensitivity analysis of coupler impedances to changes in dimensions; four-port frequency analysis; and insertion loss. **Microwave Software Applications, Inc., Norcross, Ga. Please circle INFO/CARD #217.**

Automated Amplifier Testing Software

Software for automated measurements of amplifier gain, gain compression, SWR (return loss) and isolation using a scalar network analyzer has been introduced by Hewlett-Packard Company. The software, HP Part 86399-10001, is for HP 9000 Series 300 computers, and operates with the HP 8756A and 8757A scalar network analyzers, HP 8350B/83500 series sweepers, or HP 8340/8341 synthesized sweepers. A feature of the program is a routine that rapidly characterizes the 1 dB gain compression output power level of amplifiers as a function of frequency, normally a rather tedious measurement. Price of the amplifier test software is $250. **Hewlett-Packard Co., Palo Alto, Calif. Please circle INFO/CARD #216.**

Software Enhancements are Announced

Webb Laboratories announces TRANSCAD Version 1.1, with four new structures added to the 38 lines and waveguides included in the original package release. Coupled offset stripline, coupled inverted microstrip, asymmetric coupled stripline and asymetric coupled microstrip have been added. TRANSCAD Version 1.1 is available for $895.00 and may be operated via hard disk without the master floppy. In addition, the SYSCAD Microwave and RF System Design Package is now available for use with the 8087/80187 math co-procesor. Either version of the package is available for $895.00. TRANSCAD and SYSCAD operate on IBM PC or compatible computers. **Webb Laboratories, North Lake, Wisc. INFO/CARD #215.**

Program Adds Analog Standard Cells

Datalinear and Analog Design Tools, Inc., have signed a joint marketing agreement to integrate the Datalinear semicustom analog standard cell library into Analog Design Tools' Analog Workbench computer-aided engineering system. The Datalinear library offers dielectrically isolated semicustom analog arrays, a process that allows the positioning of high-bandwidth NPN and PNP transistors on the same chip. Applications include high-speed amplifier, comparator, filter, driver and receiver circuits. **Analog Design Tools, Menlo Park, Calif. Please circle INFO/CARD #218.**

rf literature

New RF Data Book

Motorola's RF Products announces an all new RF Data Book (DL110, Rev. 2). Over 100 new parts have been added along with 4 additional application notes. For the first time, small signal plastic parts containing RF die are included. These parts use the prefixes MPS, MMBR and MXR which identify TO-92, SOT-23 and SOT-89 packages, respectively. The manual has been extensively reorganized for ease in locating a particular device, including a revised selector guide and cross-reference. **Motorola Semiconductor Products, Inc., Phoenix, Ariz. Please circle INFO/CARD #214.**

Coaxial/Waveguide Measurement Accessories Catalog

The latest edition of HP's Coaxial and Waveguide Measurement Accessories Catalog is now available with product and applications information for more than 400 products operating from DC to 110 GHz. Seventeen product sections include attenuators, detectors, couplers, filters, power sensors, scalar analyzer accessories, noise figure equipment and even 75-ohm accessories. Twenty-seven pages are devoted to measurement techniques and reference data. **Hewlett-Packard Company, Palo Alto, Calif. INFO/CARD #213.**

Signal Filtering Handbook

Wavetek announces a design handbook on signal filtering, *The Application of Filters to Analog and Digital Signal Processing.* Although signal filtering is simple in concept and is easily understood quantitatively, its application to signal processing systems requires a sophisticated appreciation of such difficult disciplines as Fourier spectrum analysis, information theory and the time-domain characteristics of complex networks. This handbook begins with fundamental ideas and introduces more advanced concepts gradually. Topics include analog signals and spectra, noise, signal filtering at the input and at the output, sampling signals, types and characteristics of filters, programmable filters and ATE system applications. **Wavetek San Diego, San Diego, Calif. INFO/CARD #212.**

Short-Form Catalog Describes Microwave Semiconductors

A 28-page short-form catalog is now available from Siemens Components, Inc., providing major functional specifications on the Siemens' line of microwave semiconductors. These include Schottky diodes, varactors, PIN diodes, silicon bipolar transistors, GaAs FETs, and GaAs MMICs. Specifications present enough electrical and mechanical data to enable a designer to select a device for a specific job. To simplify device selection, an applications guide plots device families versus frequency. This gives the designer a way to determine the device class that suits his specific requirements. **Siemens Components, Inc., Iselin, N.J. INFO/CARD #211.**

RF Power Amplifier Catalog

ENI, Inc. has recently updated their RF Power Amplifier Catalog. The result is an attractive catalog containing complete descriptive information and specifications on the ENI line of standard off-the-shelf products. With power outputs ranging from milliwatts to kilowatts, the units cover the frequency range of 9 kHz to 1000 MHz. **ENI, Inc., Rochester, N.Y. INFO/CARD #210.**

Catalog Features Signal Sources

A 16-page catalog from Communications Techniques provides information on signal sources. Included are microwave phased-locked signal sources operating in bands from 0.1 to 21 GHz; microwave frequency synthesizers operating in bands from 30 MHz to 21 GHz; microwave mechanical and voltage-tuned oscillators operating in bands from 0.5 to 21 GHz; HF-VHF voltage tuned oscillators; microwave frequency multipliers operating in bands from 1 to 21 GHz; single and multiple crystal oscillators lockable to 5 or 10 MHz and 70/140 MHz FM modulators and demodulators. **Communications Techniques Inc., Whippany, N.J. INFO/CARD #209.**

Ferrite Products Catalog

Fair-Rite Products announces their 10th edition catalog, listing some of the many ferrite parts they manufacture and detailing the electrical parameters of their materials. The catalog includes three new configurations for power applications: EP cores, PQ cores and ETD cores, as well as an expanded line of cores and new shapes for EMI/RFI suppression. **Fair-Rite Products Corp., Wallkill, N.Y. INFO/CARD #208.**

Publication Describes Piezoelectric Ceramics

An illustrated six-page brochure is available from Vernitron, presenting the designer and production engineer an overview of the latest developments in piezoelectric ceramic materials. Subjects covered include: standard and customs configurations available in piezoid ceramics, Unimorph® and Bimorph® construction, material properties, performance characteristics and standard dimensional tolerances. **Vernitron Piezoelectric Division, Bedford, Ohio. INFO/CARD #207.**

Technical Bulletin Discusses PTFE Substrates

Taking Advantage of Pure PTFE's Qualities in Microwave Substrates has been prepared by Polyflon Company. the technical bulletin discusses PTFE's use as a dielectric material in microwave substrates, and covers PTFE's unique electrical, physical and mechanical properties, highlighting Polyflon's CuFlon® pure PTFE substrates. While CuFlon has been available for about eight years, it has generated a lot of new interest from engineers who are designing circuits/components that operate in the higher frequency ranges. **Polyflon Company, New Rochelle, N.Y. INFO/CARD #206.**

Catalog of Electronic Materials

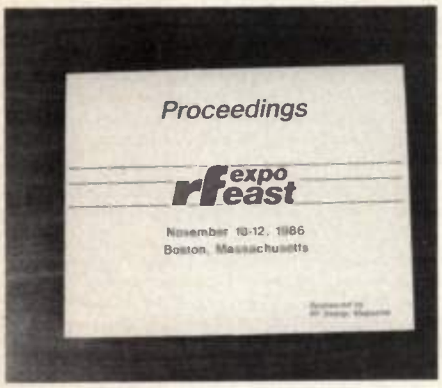
Electro-Science Laboratories' 1987 catalog is now available. The 16-page catalog describes ESL's complete line of electronic materials systems including applications in surface mount technology, thick film, multilayer and flexible circuits, packages, hybrids, photovoltaic cells, optoelectrics, sensors, discrete components, circuit boards and high frequency circuits. The catalog contains a variety of solder pastes for surface mounting, and polymer thick film materials for PC board and flexible substrates. **Electro-Science Laboratories Inc., King of Prussia, Pa. Please circle INFO/CARD #205.**

Radar Cross Section Measurement Brochure

Scientific-Atlanta has published a brochure which describes the Series 2090 Pulsed Radar Cross Section Measurement System. The brochure contains descriptions, applications information and specifications. The Series 2090 system provides fast, accurate RCS measurement on both indoor and outdoor ranges. System components are standard products with complete documentation. High sensitivity, real-time data collection and proprietary dual level detection ensure amplitude and phase accuracy over an 80 dB dynamic range. **Scientific-Atlanta, Inc., Atlanta, Ga. INFO/CARD #204.**

Advertiser's Index

THE PROCEEDINGS OF RF EXPO EAST BRINGS YOU TOGETHER WITH THE SUPERSTARS OF RF AND THEIR PRACTICAL SOLUTIONS TO RF DESIGN PROBLEMS.



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rf design

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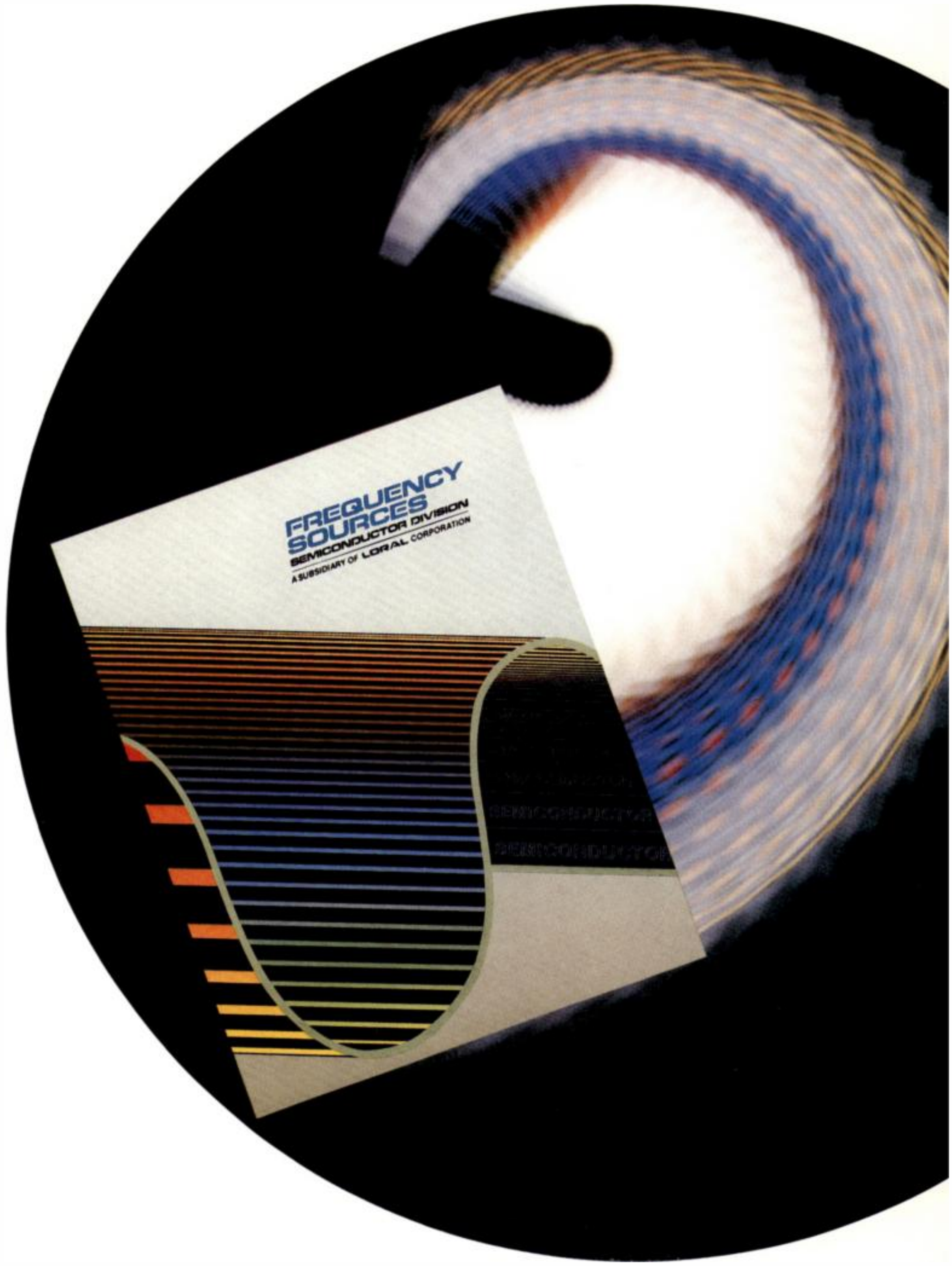

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INFO/CARD 62

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SAW Questions and Andersens.

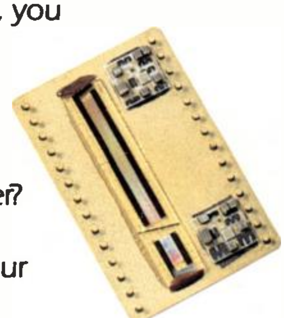
Bandpass filters:

QUESTION: I have an application that requires filters. Why should I consider SAW devices?

ANDERSEN: Want to eliminate tuning? Need very sharp passband skirts (i.e. low shape factor) with high close-in rejection? Low ripple? Phase that can be linear or non-linear, as you choose? Small size? Highly repeatable characteristics? These are the areas where SAW filters excel. If any of these factors are important, you should be looking at SAW's.

QUESTION: What about hybridizing?

ANDERSEN: This may be a very smart move. With our in-house hybrid facility, we can deliver maximum performance in a minimum space. Buying a zero-loss SAW filter module or an entire hybridized Andersen IF section may improve your system performance, reduce size, increase reliability and fully exploit the advantages of SAW technology.



QUESTION: How expensive and how long will it take to get my filter?

ANDERSEN: That depends on your specs. But we have hundreds of stock designs to choose from (we're the oldest SAW manufacturer), so it's very possible we already have one that meets your specs. If not, with our recent major staff increase we offer one of the largest groups of SAW designers of any U. S. company to meet your needs fast and at aggressive new pricing.

QUESTION: How do I get started?

ANDERSEN: Just give us a call. We'll do everything we can to meet your needs.

Or, if you simply want more information, send for Volume I of our comprehensive handbook on Acoustic Signal Processing. In it, you'll find the right Andersen to most of your SAW questions—and specs on the latest models.

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Or phone (203) 242-0761/
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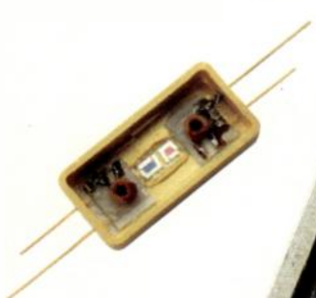
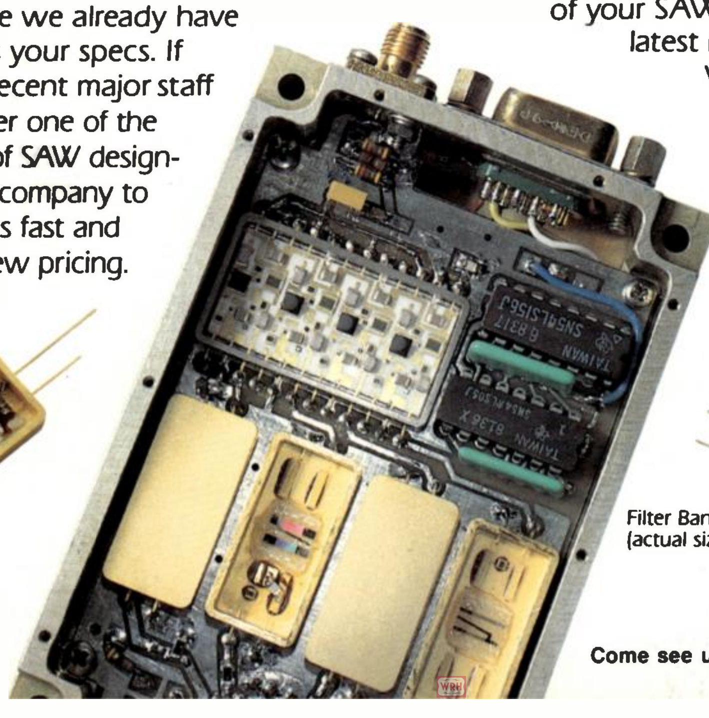
INFO/CARD 63





Filter Bank
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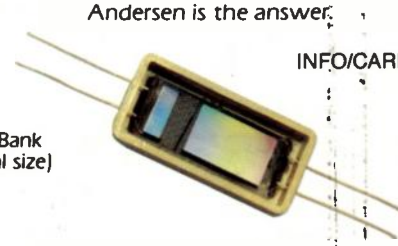

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