

SEPTEMBER 1989 / \$2.95

NEW HAM RADIO

Handy
Handy Pro CX



ICOM

IC-901 FM Mobile

SPEAKER

May be mounted on sun visor.

REMOTE CONTROL HEAD

May be mounted on dash and can be taken when you leave your car. Large LCD readout displays main and sub band frequencies, S/R/F units, volume and squelch settings.

Fiber Optic Modular

OPTION 1

BAND UNITS

Can be installed in your trunk. Optional Band Units include:
 • 10 W/10 meters • 25 W/220MHz
 • 10 W/6 meters • 10 W/1.2GHz
 • 2 meter/SSB/CW • 440MHz/SSB/CW • Broadband Receiver
 Select band units according to your interests. Even work OSCAR satellite mobiles!

INTERFACE UNIT A

Installs under seat.

THE WORLD'S MOST VERSATILE MOBILE

ICOM'S NEW IC-901 OFFERS THREE EASY-TO-OPERATE TRANSCEIVER CONFIGURATIONS

The IC-901 can be (1) field-combined as a fully separated and fiber optic-linked system with multiple trunk-located band units, (2) a single-cabinet transceiver for dashmounting or (3) a remote-controlled unit for underseat installation.

Compact Transceiver

OPTION 2

Control head is installed directly to the interface unit, making one compact unit.



Entire unit may be mounted in dash.

Under the Seat

OPTION 3

Dual band and interface unit can be installed under seat.



Remote Control on visor.

The IC-901 is supplied with 50 watts 2-meter and 35 watts 440MHz FM band units covering 138-174MHz Rx and 140-150MHz Tx plus 440-450MHz Rx/Tx. Adding more band units is a snap. They install easily out-of-sight in your trunk for security!

Outstanding Features Include: Full duplex operation, simultaneous dual band reception, ten memories per band, program-

mable band and memory scanning with skip function, any Tx offset, and much more.

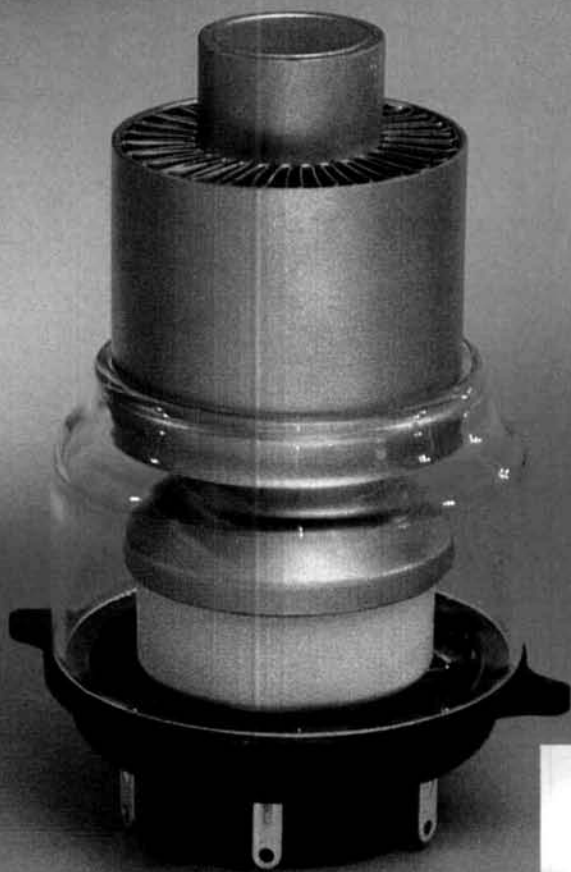
The IC-901 also features a clever new **DTMF Calling System** which silently monitors a busy frequency or repeater for stations calling you. Squelch automatically opens when a signal with the same DTMF code you present is received.

Optional Pager Function. When activated, your IC-901 transmits a six-digit DTMF code to call others. Its last three digits identify you as the calling station.

ICOM America, Inc., 2380-116th Ave. N.E., Bellevue, WA 98004
Customer Service Hotline (206) 454-7619
 3150 Premier Drive, Suite 126, Irving, TX 75063
 1777 Phoenix Parkway, Suite 201, Atlanta, GA 30349
 ICOM CANADA, A Division of ICOM America, Inc.
 3071 - #5 Road, Unit 9, Richmond, B.C. V6X 2T4 Canada

All stated specifications are subject to change without notice or obligation. All ICOM radios significantly exceed FCC regulations limiting spurious emissions. 901689

ICOM
First in Communications



The 3CX1200A7 continues the EIMAC tradition of serving AMATEUR RADIO.

EIMAC was right there to meet Ham requirements of 1500 watts PEP with its 3CX1200A7 tube. Leading manufacturers count on its proven performance and reliability.

Low-cost power for small spaces

The rugged 3CX1200A7 takes size into consideration and, by design, is recommended as a single, low-cost alternative for a pair of EIMAC 3-500 Z tubes for new amplifier designs.

General Specifications

The EIMAC 3CX1200A7 is a high-mu, compact, forced air cooled triode for zero-bias class AB2 amplifiers.

- 2.9" dia. x 6.0" long
- Plate dissipation: 1200 watts
- Glass chimney SK-436 available
- Standard EIMAC SK-410 socket available

More information is available on the new EIMAC 3CX1200A7 tube from Varian EIMAC, or any Elec-

tron Device Group worldwide sales organization.

Varian EIMAC
1678 S. Pioneer Road
Salt Lake City, Utah 84104
Telephone: 801 • 972-5000

varian 
eimac salt lake division

KENWOOD

...pacesetter in Amateur Radio

DX-cellence!

#1 Rated HF!



TS-940S Competition class HF transceiver

TS-940S—the standard of performance by which all other transceivers are judged. Pushing the state-of-the-art in HF transceiver design and construction, no one has been able to match the TS-940S in performance, value and reliability. The product reviews glow with superlatives, and the field-proven performance shows that the TS-940S is "The Number One Rated HF Transceiver!"

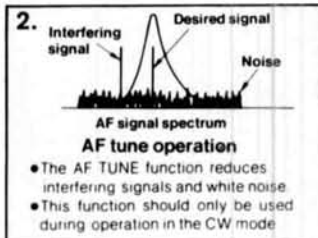
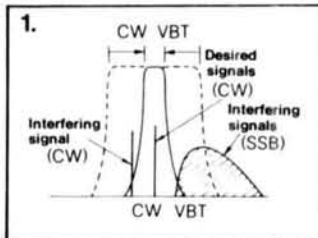
- 100% duty cycle transmitter. Kenwood specifies transmit duty cycle **time**. The TS-940S is guaranteed to operate at full power output for periods **exceeding one hour**. (14.250 MHz, CW, 110 watts.) Perfect for RTTY, SSTV, and other long-duration modes.
- First with a full one-year limited warranty.
- Extremely stable phase locked loop (PLL) VFO. Reference frequency accuracy is measured in **parts per million!**

Optional accessories:

- AT-940 full range (160-10m) automatic antenna tuner
- SP-940 external speaker with audio filtering
- YG-455C-1 (500 Hz), YG-455CN-1 (250 Hz), YK-88C-1 (500 Hz) CW filters
- YK-88A-1 (6 kHz) AM filter
- VS-1 voice synthesizer
- SO-1 temperature compensated

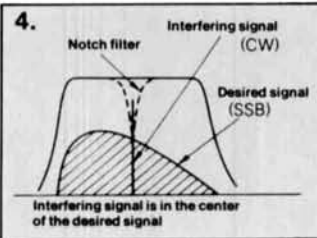
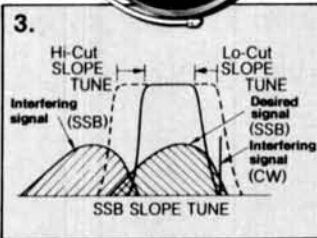
Complete service manuals are available for all Kenwood transceivers and most accessories. Specifications, features, and prices are subject to change without notice or obligation.

- crystal oscillator
- MC-43S UP/DOWN hand mic.
- MC-60A, MC-80, MC-85 deluxe base station mics.
- PC-1A phone patch
- TL-922A linear amplifier
- SM-220 station monitor
- BS-8 pan display
- IF-232C/IF-10B computer interface.



1) CW Variable Bandwidth Tuning. Vary the passband width continuously in the CW, FSK, and AM modes, without affecting the center frequency. This effectively minimizes QRM from nearby SSB and CW signals.

2) AF Tune. Enabled with the push of a button, this CW interference fighter inserts a tunable, three-pole active filter between the SSB/CW demodulator and the audio amplifier. During CW QSOs, this control can be used to reduce interfering signals and noise, and peaks audio frequency response for optimum CW performance.



3) SSB Slope Tuning. Operating in the LSB and USB modes, this front panel control allows independent, continuously variable adjustment of the high or low frequency slopes of the IF passband. The LCD sub display illustrates the filtering position.

4) IF Notch Filter. The tunable notch filter sharply attenuates interfering signals by as much as 40 dB. As shown here, the interfering signal is reduced, while the desired signal remains unaffected. The notch filter works in all modes except FM.

- Complete all band, all mode transceiver with general coverage receiver. Receiver covers 150 kHz-30 MHz. All modes built-in: AM, FM, CW, FSK, LSB, USB.
- Superb, human engineered front panel layout for the DX-minded or contesting ham. Large fluorescent tube main display with dimmer; direct keyboard input of frequency; flywheel type main tuning knob with optical encoder mechanism all combine to make the TS-940S a joy to operate.
- One-touch frequency check (T-F SET) during split operations.
- Unique LCD sub display indicates VFO, graphic indication of VBT and SSB Slope tuning, and time.
- Simple one step mode changing with CW announcement.
- Other vital operating functions. Selectable semi or full break-in CW (QSK), RTT/XIT, all mode squelch, RF attenuator, filter select switch, selectable AGC, CW variable pitch control, speech processor, and RF power output control, programmable band scan or 40 channel memory scan.

KENWOOD

KENWOOD U.S.A. CORPORATION
2201E. Dominguez St., Long Beach, CA 90810
P.O. Box 22745, Long Beach, CA 90801-5745

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Publisher & Editor-in-Chief:
T.H. TENNEY, JR., W1NLB

EDITORIAL STAFF

Managing Editor:

Terry Northup, KA1STC

Technical Editor:

Marty Durham, NB1H

Consulting Editor:

Robert D. Wilson, WA1TKH

Associate Editors:

Tom McMullen, W1SL

Joseph J. Schroeder, W9JUV

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Editorial Review Board:

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Forrest Gehrke, K2BT

Michael Gruchalla, P.E.

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Book Store: Maribeth Buchanan

Cover Illustration: Hans Evers, PA0CX

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Backscatter



More Cause for Thought

Last November I talked about the potential health hazards of electromagnetic radiation. While there is good reason to be concerned, too little is known at this time to determine if there is a direct link between electromagnetic radiation and cancer, or other diseases. Within the last few months, however, the story has received broad coverage in a number of different sources.

Paul Brodeur, author of *The Zapping of America* published in 1977, recently had a three-part series published in *The New Yorker* magazine on June 12th, 19th, and 26th that discusses the alleged hazards of electromagnetic (EM) radiation at length. Brodeur addresses a number of areas he feels are potential problems. They are: high voltage power lines, electrical wiring, radar, and video display terminals (VDTs).

High voltage power lines are a threat due to the high level electromagnetic field that surrounds them. Brodeur quotes research that claims these electromagnetic fields could alter the body's intricate, disease-fighting immune system and weaken its ability to destroy cancer cells.

Brodeur takes the Air Force to task for locating its PAVE PAWS radars near two major population areas — Cape Cod, Massachusetts and Sacramento, California — without having completed a study of the bioeffects of those radars. Finally, there is the ubiquitous computer VDT. Again, the threat is from various types of high level EM radiation.

Brodeur's series will be published this fall by Simon and Schuster as *Currents of Death: Power Lines, Computer Terminals and the Attempt to Cover Up Their Threat to Your Health*. Unfortunately, the sensational title does little to enhance the stature of Brodeur's piece.

Picking up on Brodeur's lead, both *TIME* and *NEWSWEEK* have run reports on EM radiation threats. The *NEWSWEEK* piece, published in its July 10th issue on page 77, was titled "An Electromagnetic Storm," with the subhead "Overblown charges about power lines and VDTs." Quoting from the article, "The reality is a bit more complicated. Scientists are only beginning to fathom the body's exquisite sensitivity to electromagnetic energy. The evidence linking exposure to disease is far less than Brodeur implies." Summing up, the article says: "Brodeur and many of those he criticizes seem to agree: we're not quite sure what we're up against, and we need urgently to find out." *TIME*'s piece ran in the July 17th issue and discusses many of the same points. The Department of Energy does not have enough information at this time to take any regulatory action regarding electromagnetic fields. If there is a link between certain illnesses, *TIME* asserts that appliances and electronic equipment will need to be redesigned, homes rewired, and the power distribution infrastructure completely rebuilt.

The New York Times ran a long article in its Tuesday, July 11th, "Science Times" section. While shedding little new light on the subject, the *Times* piece gives the reader a better explanation of the potential risks, and includes suggestions on how to limit exposure to electromagnetic fields. *The Times* also emphasizes that "prudence over panic" is the best course of action to follow.

I have also just received a press release from Congress's Office of Technology Assessment (OTA), dated Monday, June 19th, that discusses possible biologic effects of electromagnetic radiation. The report states that a number of different studies have demonstrated that "under specific circumstances even weak electric and magnetic fields can affect living cells and systems."

The OTA points out, however, that the health risk is much more complex and uncertain than that from other hazards like toxic chemicals and other known carcinogenic (cancer-causing) substances. Researchers do not know what parameters are the most important — "field strength, change in field strength over time, currents induced in the body, exposure, duration, or some other variation."

The OTA calls for careful work to establish, beyond a reasonable doubt, whether or not there is a relationship between certain illnesses and electromagnetic fields. The valuable 102-page OTA report is titled *Biological Effects of Power Frequency Electric and Magnetic Fields*. It is available from the U.S. Government Printing Office (GPO), Superintendent of Documents, Washington, DC 20402, stock #052-003-01152-2, for \$4.75. Another important document, *Health Effects of Transmission Lines*, covers many types of EM radiation. The 393-page report is available from the GPO for \$11. Ask for stock #052-070-06461-7, serial no. 100-22.

Finally, the ARRL Southwestern Division Convention, scheduled for August 25th-27th in Los Angeles, California, will be holding the first-ever Physician's Panel on Radiation Hazards. Wayne Overbeck, Ph.D., N6NB, will be the moderator. The panel consists of:

- W. Ross Adey, M.D., K6UI, internationally respected scientist in bioeffects research. Dr. Adey is the recipient of prestigious

(Continued on page 89.)

KENWOOD

...pacesetter in Amateur Radio

NEW!

Affordable DX-ing!

TS-140S

HF transceiver with general coverage receiver.

Compact, easy-to-use, full of operating enhancements, and feature packed. These words describe the new TS-140S HF transceiver. Setting the pace once again, Kenwood introduces new innovations in the world of "look-alike" transceivers!

- **Covers all HF Amateur bands with 100 W output.** General coverage receiver tunes from 50 kHz to 35 MHz. (Receiver specifications guaranteed from 500 kHz to 30 MHz.) Modifiable for HF MARS operation. (Permit required).
- **All modes built-in.** LSB, USB, CW, FM and AM.
- **Superior receiver dynamic range** Kenwood DynaMix™ high sensitivity direct mixing system ensures true 102 dB receiver dynamic range.



- **New Feature! Programmable band marker.** Useful for staying within the limits of your ham license. For contesters, program in the suggested frequencies to prevent QRM to non-participants.
- **Famous Kenwood interference reducing circuits.** IF shift, dual noise blankers, RIT, RF attenuator, selectable AGC, and FM squelch.

- **M. CH/VFO CH sub-dial.** 10 kHz step tuning for quick QSY at VFO mode, and UP/DOWN memory channel for easy operation.
- **Selectable full (QSK) or semi break-in CW.**
- **31 memory channels.** Store frequency, mode and CW wide/narrow selection. Split frequencies may be stored in 10 channels for repeater operation.
- **RF power output control.**
- **AMTOR/PACKET compatible!**
- **Built-in VOX circuit.**
- **MC-43S UP/DOWN mic. included.**

Optional Accessories:

- **AT-130** compact antenna tuner • **AT-250** automatic antenna tuner • **HS-5/HS-6/HS-7** headphones • **IF-232C/IF-10C** computer interface
- **MA-5/VP-1** HF mobile antenna (5 bands)
- **MB-430** mobile bracket • **MC-43S** extra UP/DOWN hand mic. • **MC-55** (8-pin) goose neck mobile mic. • **MC-60A/MC-80/MC-85** desk mics.
- **PG-2S** extra DC cable • **PS-430** power supply
- **SP-41/SP-50B** mobile speakers • **SP-430** external speaker • **TL-922A** 2 kW PEP linear amplifier (not for CW QSK) • **TU-8** CTCSS tone unit
- **YG-455C-1** 500 Hz deluxe CW filter, **YK-455C-1** New 500 Hz CW filter.



TS-680S

All-mode multi-bander

- 6m (50-54 MHz) 10 W output plus all HF Amateur bands (100 W output).
- Extended 6m receiver frequency range 45 MHz to 60 MHz. Specs. guaranteed from 50 to 54 MHz.
- Same functions of the TS-140S except optional VOX (VOX-4 required for VOX operation).
- Preamplifier for 6 and 10 meter band.



Complete service manuals are available for all Kenwood transceivers and most accessories. Specifications, features, and prices are subject to change without notice or obligation.

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KENWOOD U.S.A. CORPORATION
2201 E. Dominguez St., Long Beach, CA 90810
P.O. Box 22745, Long Beach, CA 90801-5745

Comments



Documenting extraordinary accomplishments

Dear HR

Your article on the "Bloody Beams" was great — not only from its technical perspective, but also knowing how one or two clear thinking individuals can win out over the "it's impossible/we can't do that" establishment.

Perhaps with your encouragement United States hams who played a key role in World War II electronics could document their experiences. One story that hasn't been written is how we achieved the extraordinary quality/functionality of our electronic equipment? This is something that we have now lost to the Japanese.

Dr. William H. Taubert
V.P., Beatrice/Hunt-Wesson, Inc.
Fullerton, California

The right formula

Just a note to let you know I think you have hit upon the right mix in articles. Referring to May 1989 issue of *HR*, I see everything from soup to nuts in way of construction articles — from the complicated to the simple, which is the way it should be. Carry on.

John L. McDonald, W6SDM,
Camarillo, California

Initiation rites

Dear HR

Is it possible that some of us do not have an aptitude for the code?

Psychologists tell us that the two hemispheres of the brain serve different functions. The left hemisphere is supposed to deal with analytical processes while the right side deals with speech, music, art, and the like. As one who can't dance, find the beat

in rock music, or copy code well, I believe that code, like music is a right-brain activity. The theory portion of the exam is a left-brain process. To be a "good" amateur, one must have talents that some of us were not born with.

I started to try to learn the code in 1948. By 1953, I got a Novice ticket. I built a working 8-tube superhet receiver and a 75-watt transmitter. Alas, I could not copy off-air code, and never made a Novice contact. In 1956, after getting my First-Class Radiotelephone ticket, I also passed my Technician exam. I worked 6-meter phone, but no CW. My Technician license expired in 1961 and I became inactive.

Over the years, I tried to increase my code speed, but gave up each time after weeks and weeks of practice. In 1987, I practiced daily for about 10 weeks. The theory wasn't a problem, so I passed my Advanced in July. Incentive licensing does work, so I studied code for an entire year and passed my Extra in 1988. I can copy the practice tapes, but I cannot copy CW off air. Most operators seem to send at about 30 to 35 WPM. I might as well try to copy RTTY by ear. I don't even own a key and have yet to make a CW contact. CW is too intimidating for this individual who must have a walnut for a right brain.

Does CW make someone a better operator? Just listen to the antics of the idiots in the pile-ups or the grouches of 75 meters and tell me that knowing CW made them into better Amateurs.

For me, the code requirement is analogous to a fraternity hazing. Forty years is a very long initiation.

Donald J. Sinex, K16YE,
Huntington Beach, California

A winner!

Dear HR

Many thanks for *The Radio Handbook* by Bill Orr, W6SAI. It was a real surprise to win in the April drawing.

Keep up the good work with the magazine. I have been a subscriber since the very first issue.

Kenneth L. Frank, WB5AKI,
Copperas Cove, Texas

The old man's disease

Dear HR

Its not trying to work 100 countries, or sending out QSLs, or getting QSLs from the bureau. Its not running off at the mouth on 2 meters, or getting on the soap box on 75, and hitting the green keys day and night. Oh, no. We did all of that years ago. But you hear the old-timers say, "Packet radio is not for me. I am too old for that stuff." I can remember that same kind of talk when SSB first came on line.

But, some old-timers are having a ball on packet radio now. They are chasing each other from one BBS to another. You must work DX to do this, and you don't spend your time talking because you have to find the BBS where your buddy left a message for you. Then you send your answer.

I was one of those guys who became "uptight" when I was in a packet connect. Seems there are more BBS mail boxes than mail. So now we can do something we have not done before.

You old has-beens should quit running down packet radio and get with what's here (and not what's coming down the pipe). You are not too old; you are too bullheaded. You don't have to upgrade, just degrade.

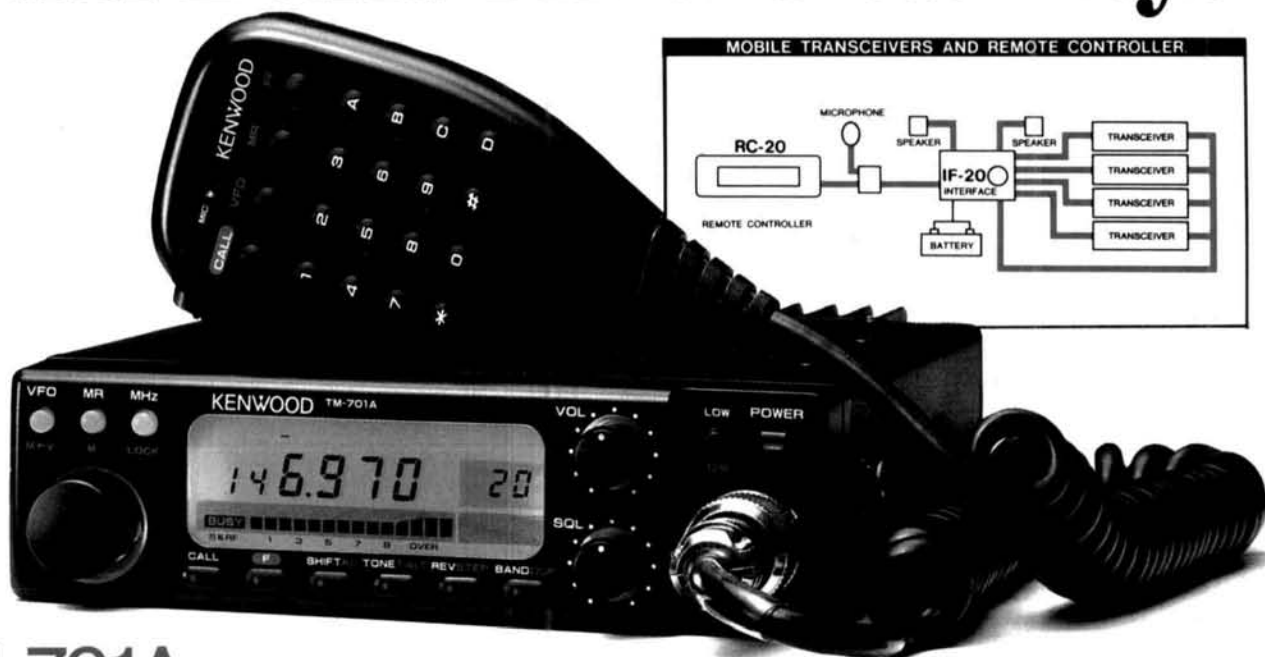
W. E. Huffman, K0CVT,
Moravia, Iowa

KENWOOD

...pacesetter in Amateur Radio

**Affordable
Breakthrough!**

Dual Band Afford-ability!



TM-701A

Dual Bander

The TM-701A combines two radios into one compact package. You get 25 watts on 2 meters and 70cm, 20 memory channels, tone encoder built-in, multiple scanning, auto repeater offset selection on 2 meters, and a host of additional features!

- **20 multi-function memory channels.** 20 memory channels allow storage of frequency, repeater offset, CTCSS frequency, frequency step, and Tone On/Off status, CTCSS and REV, providing quick and easy access during mobile operation.
- **25W on 2m and 70cm.**
- **Selectable full duplex-cross band (Telephone style) operation.**
- **Easy-to-operate front panel layout.**
- **Multi-function DTMF mic. supplied.** Controls are provided on the microphone for CALL (Call Channel), VFO, MR (Memory Call) or to change the memory channel) and a programmable function key. The programmable key can be used to control one of the following functions on the radio: MHz, T. ALT, TONE, REV, BAND, or LOW power.
- **Easy-to-operate illuminated keys.** A functionally designed control panel with individually backlit keys increases the convenience and ease of operation during night-time use.

• Optional full-function remote controller (RC-20).

A full-function remote controller using the Kenwood bus line may be easily connected to the TM-701A and mounted in any convenient location. The new controller is capable of operating all front panel functions.

• Built-in dual digital VFO's.

- a) Frequency step selection (5, 10, 15, 20, 12.5, 25kHz)
- b) Programmable VFO

The user friendly programmable VFOs allow the operator to select and program variable tuning ranges in 1 MHz band increments.

• Programmable call channel function.

The call channel key allows instant recall of your most commonly used frequency data.

• Programmable tone encoder built-in.

• Tone alert system—for true quiet monitoring.

When activated this function will cause a distinct beeper tone to be emitted from the transceiver for approximately 10 seconds to signal the presence of an incoming signal.

• Easy-to-operate multi-mode scanning.

- a) **VFO scan**
Band scan, Programmable band scan.
- b) **Memory scan plus programmable memory channel lock-out**
- c) **Dual scan**
Dual call channel scan
Dual memory scan
Dual VFO scan
- d) **Scan stop modes**
Time operated scan (TO)
Carrier operated scan (CO)

e) Scan direction

f) Alert

When the AL switch is depressed memory channel 1 is scanned for activity at approximately 5 second intervals.

- **MHz switch.**
- **Lock function.**
- **Repeater reverse switch.**

Optional Accessories

- **RC-20** Full-function remote controller
- **RC-10** Multi-function remote controller
- **IF-20** Interface unit handset • **MC-44** Multi-function hand mic. • **MC-44DM** Multi-function hand mic. with auto-patch • **MC-48B** 16-key DTMF hand mic. • **MC-55** 8-pin mobile mic.
- **MC-60A/80/85** Desk-top mics. • **MA-700** Dual band (2m/70cm) mobile antenna (mount not supplied) • **SP-41** Compact mobile speaker • **SP-50B** Mobile speaker • **PS-430** Power supply • **PS-50** Heavy-duty power supply • **MB-201** Mobile mount • **PG-2N** Power cable • **PG-3B** DC line noise filter • **PG-4H** Interface connecting cable • **PG-4J** Extension cable kit • **TSU-6** CTCSS unit

KENWOOD

KENWOOD U.S.A. CORPORATION
COMMUNICATIONS & TEST EQUIPMENT GROUP
P.O. BOX 22745, 2201 E. Dominguez Street
Long Beach, CA 90801-5745
KENWOOD ELECTRONICS CANADA INC.
P.O. BOX 1075, 959 Gana Court
Mississauga, Ontario, Canada L4T 4C2

BEST OF MFJ

MFJ, Bencher and Curtis team up to bring you America's most popular keyer in a compact package for smooth easy CW



MFJ-422B

\$129⁹⁵

The best of all CW worlds - a deluxe MFJ Keyer using a Curtis 8044ABM chip in a compact package that fits right on the Bencher iambic paddle!

This MFJ Keyer is small in size but big in features. You get iambic keying, adjustable weight and tone and front panel volume and speed controls (8-50 WPM), dot-dash memories, speaker, sidetone and push button selection of automatic or semi-automatic/tune modes. It's also totally RF proof and has ultra-reliable solid state outputs that key both tube and solid state rigs. Use 9 V battery or 110 VAC with MFJ-1305, \$9.95.

The keyer mounts on a Bencher paddle to form a small (4 1/8 x 2 5/8 x 5 1/2 inches) attractive combination that is a pleasure to look at and use.

America's favorite paddle, the Bench, has adjustable gold-plated silver contacts, lucite paddles, chrome plated brass, and a heavy steel base with non-skid feet.

You can buy just the keyer assembly, MFJ-422BX, for only \$79.95 to mount on your Bencher paddle.

Artificial RF Ground

MFJ-931
\$79⁹⁵

You can create an artificial RF ground and eliminate RF "bites", feedback, TVI and RFI when you let the MFJ-931 resonate a random length of wire and turn it into a tuned counterpoise. MFJ-931 also lets you electrically place a far away RF ground directly at your rig - no matter how far away it is - by tuning out the reactance of your ground connection wire. 7 1/2 x 3 1/2 x 7 in.

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Now you can quickly optimize your antenna for peak performance with this portable, totally self-contained antenna bridge.

No other equipment needed - take it to your antenna site. Determine if your antenna is too long or too short, measure its resonant frequency and antenna resistance to 500 ohms. It's the easiest, most convenient way to determine antenna performance. Built-in resistance bridge, null meter, tunable oscillator-driver (1.8-30 MHz). Use 9 V battery or 110 VAC with AC adapter, \$9.95.

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'World Radio TV Handbook' says MFJ-1024 is "a first rate easy-to-operate active antenna ... quiet ... excellent dynamic range ... good gain ... very low noise factor ... broad frequency coverage ... excellent choice."

Mount it outdoors away from electrical noise for maximum signal, minimum noise. MFJ-1024 covers 50 KHz to 30 MHz.

Receives strong, clear signals from all over the world. 20 dB attenuator, gain control. ON LED Switch two receivers and aux. or active antenna. 6x23x5 in. Remote unit has 54 inch whip, 50 ft. coax and connector. 3x2x4 in. 12 VDC or 110 VAC with

MFJ-1024 **\$129⁹⁵** MFJ-1312, \$9.95.

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\$34⁹⁵ MFJ-1701



\$21⁹⁵ MFJ-1702



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Select any of several antennas from your operating desk with these MFJ Coax Switches. They feature mounting holes and automatic grounding of unused terminals. They come with MFJ's one year **unconditional** guarantee. **MFJ-1701, \$34.95.** Six position antenna switch. SO-239 connectors. 50-75 ohm loads. 2 KW PEP, 1 KW CW. Black aluminum 10x3x1 1/2 inch cabinet. **MFJ-1702, \$21.95.** 2 positions. Cavity construction. 2.5 KW PEP, 1 KW CW. Insertion loss below .2 dB. 50 dB isolation at 450 MHz. 50 ohm. 3x2x2 in. **MFJ-1704, \$59.95.** 4 position Cavity Switch with Lightning/Surge protection device. Center Ground position. 2.5 KW PEP, 1 KW CW. Extremely low SWR. Isolation better than 50 dB 500 MHz. Negligible loss. 50 ohm. 6 1/4 x 4 1/4 x 1 1/4 in.

"Dry" Dummy Loads for HF/VHF/UHF



\$28⁹⁵ MFJ-260



\$69⁹⁵ MFJ-262



\$109⁹⁵ MFJ-264

MFJ has a full line of dummy loads to suit your needs. Use a dummy load for tuning to reduce needless (and illegal) QRM and save your finals. **MFJ-260, \$28.95.** Air cooled, non-inductive 50 ohm resistor. SO-239 connector. Handles 300 watts. Run full load for 30 seconds, derating curve to 5 minutes. SWR less than 1.3:1 to 30 MHz, 1.5:1 30-60 MHz. 2 1/2 x 2 1/2 x 7 in. **MFJ-262, \$69.95.** Handles 1 KW. SWR less than 1.5:1 to 30 MHz. 3x3x13 in. **MFJ-264, \$109.95.** Versatile UHF/VHF/HF 1.5 KW Dry Dummy Load. An MFJ first. Gives you low SWR to 650 MHz, usable to 750 MHz. You can run 100 watts for 10 minutes, 1500 watts for 10 seconds. SWR is 1.1:1 to 30 MHz, below 1.3:1 to 650 MHz. 3x3x7 inches. SO-239 connector.

MFJ-1286 Gray Line DX Advantage

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For Kenwood, Icom, Yaesu, Santic

MFJ-284 or MFJ-286
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MFJ-284 fits Icom, Yaesu, Santic. MFJ-286 fits Kenwood.

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HF MOBILE ANTENNAS

Methods to help you improve radiation efficiency

By Robert Sherwood, NC0B, Sherwood Engineering Inc., 1268 South Ogden Street, Denver, Colorado 80210

In these days of miniaturization, HF mobile operation is more practical than ever before. Rigs are smaller, and DC inverter power supplies are virtually nonexistent. Are popular, small, antenna resonators a good choice also, or is too much given up in this critical area?

Background

My early days of low-band HF mobile go back to the early sixties when tube equipment was standard, and there was a mystique surrounding the hardware required to get a station to function from one's car. A typical installation consisted of an AF-67 transmitter with 6146 final, a dynamotor (motor generator) to supply 250 and 650 volts, and a converter to receive 160 meters on a standard AM radio. I noticed that mobile antennas seemed to bring out regional biases — hams running mobile in Northern Ohio favored base-loaded whips as long as possible, while those in the greater Cincinnati area worked the top band with center-loaded whips and capacitive hats.

160-meter whip antenna

Several Cincinnati hams pooled their resources to create a community mobile of sorts; the equipment, car, and effort were supplied by K8CRJ, K8IBQ, K8RRH, and WA8ADB (now NC0B). Our antenna construction was based initially on a Master Mobile 75-meter 5-foot whip and its matching resonator, which was 6 inches long and 1-3/4 inches in diameter. We discarded this no. 18 wire coil and modified its phenolic insulator to hold a 5-inch diameter plastic tube wound with 100+ feet of no. 16 close-spaced wire to resonate on 160. We added a 6-inch diameter capacitive hat that let us make minor adjustments to the antenna system's resonant frequency. The frequency wasn't easily changed once we had tuned it by removing turns from the coil. No one knew how efficient the antenna actually was, but it performed satisfactorily with daytime groundwave ranges of 50 to 75 miles to a base station.

For the next 20 years, my homemade mobile antennas evolved around variations of this same design. Discussion of HF mobile operation in *The ARRL Antenna Handbook* referred to maintaining the Q of the coil high, so I eventually abandoned the close-wound coil on a solid form. Even though the effect of plastic tubing on Q wasn't known, it was obvious that weather degraded coil operation severely. If the antenna coil got a little wet, the AF67 pi network started tuning backwards. The rig wouldn't load at all in a real down-pour. If today's broadband fixed-tuned PAs had existed then, the transmitter would have barely functioned given the slightest bit of inclement weather.

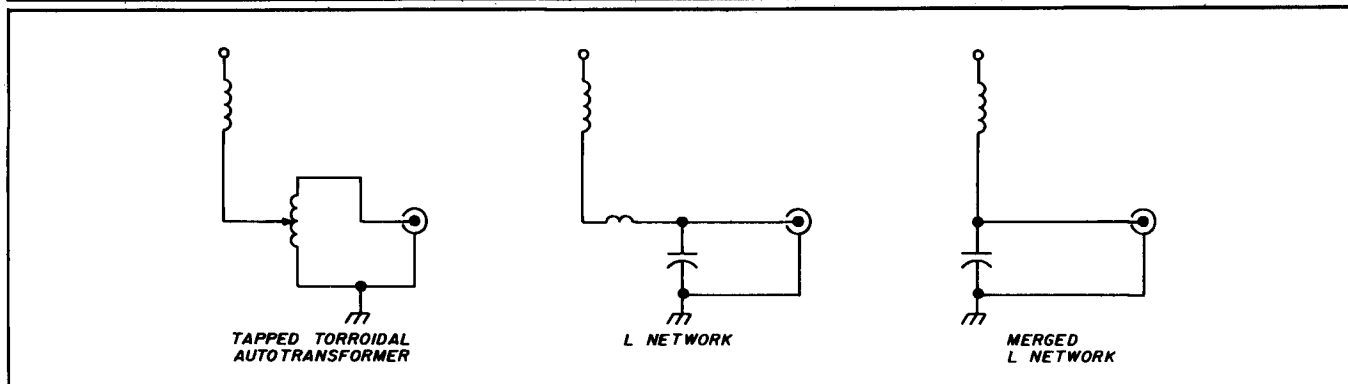
40-meter system

The original Master Mobile insulator was long enough to support half of a B&W 3033 10-inch coil made from six turns per inch of no. 12 wire. Because it was of ribbed construction rather than solid form design, this coil exhibited much less wind resistance than previous units. With a 3 to 6-foot base section and a 5-foot whip, the system resonated without additional top loading on 40 meters. It seemed desirable, however, to continue to use a capacitive hat, since what was advantageous on 160 would be an asset on 40 meters, too. Because my tendency was to assume that bigger was better, I built hats from 12 to 24 inches in diameter. The latter seemed to be the practical limit, especially since the consensus was that a hat should be kept out of the coil field, and that meant mounting it up the whip as much as 2 feet above the coil.

A side benefit of the open-air coil was a virtual lack of environmental effects. Rain didn't detune the coil, and it took a blinding snowstorm to pack it to the point where it wouldn't load.

A 5-foot whip let 5 inches of B&W coil resonate easily on 40 meters, even without a capacitive hat. This meant that I could make two resonators from one coil stock. Since resonance of a short, loaded antenna isn't a 50-ohm impedance, I chose an L network to provide a 50-ohm match. The added coil was simply an extra turn or two in the resonator, with an appropriate capacitor on the high impedance side of the network (across the coax feedpoint). That value was typically 470 pF on 7.2 MHz, 1200 pF on 3.8 MHz, and 2400 pF on 1.8 MHz, depending somewhat on the base

FIGURE 1



Matching options.

section length and mounting position (see Figure 1).

From a mechanical standpoint, this enhanced antenna with its large center loading coil and capacitive hat 2 feet up the whip put quite a physical stress on the bumper or deck mount, so I used a nylon guy line to keep things stable. However, I didn't use springs at the base because they allowed too much lateral sway.

Onward and upward

Once I had a well-developed 40-meter system using 5 inches of coil, I decided it was time to improve my design for 75 and 160 meters. Because 3-inch diameter no. 12 wire coils worked so well on 40, I chose 10 inches for 75 meters. Because it takes four times the inductance to tune a given whip when the frequency is halved, I knew that 10 inches of coil would require a longer whip or top loading. A 2-foot capacitive hat let me tune the antenna with less than 75 μ H, even on the low end of the CW band at 3500 kHz. As with the 40-meter resonator, moisture had very little effect on the operation of the coil with six turns per inch spacing.

In 1984, world class mobile DXer KD0U asked if I would make him reproducible 40 and 75-meter resonators. He had 87 countries confirmed and was trying for mobile DXCC. His antenna had to be able to handle a solid-state Metron linear, which produced 600 watts output. Once the project was under way, we were asked by the Dayton Hamvention™ Antenna Forum to present quantitative data on our findings on the 40-meter version in 1985, and the 75 and 160-meter designs in 1986.

Although subjective evaluations of these antenna systems had been acceptable for over 20 years, we needed hard data to truly evaluate what progress had been made toward the goal of transmitting the strongest possible signal on low-band HF mobile.

Comparative and absolute measurements

There are two basic ways to measure antenna performance, comparative and absolute. On 7 MHz, the only method available was the comparative one; I didn't have access to a field-strength meter that would tune that high in frequency. Seventy-five meters was a different case because I could use a broadcast station's field-strength meter to measure absolute signal intensity.

We performed initial 7-MHz measurements in Denver at a large city park with room to make comparisons, using

two mobile systems. One mobile was the transmit reference. The other, parked half a mile away, was the receive site. The reference system was a commercial 40-meter antenna with a bumper-mounted 5-foot base section. We tuned it to 7.2 MHz carefully, using a Bird wattmeter. Once it was adjusted for best possible match, we set the forward minus reflected power to 50 watts. We put a resonant antenna on the receiving end tuned for a perfect match at 7.2 MHz. We then inserted a laboratory-grade step attenuator into the receive coax line. Next, we set the received reference carrier from the commercial antenna for exactly S9, substituted a second commercial antenna for the first, and reset the receive S-meter to S9. Surprisingly, there was a difference of only 1/2 dB in favor of the second commercial antenna.

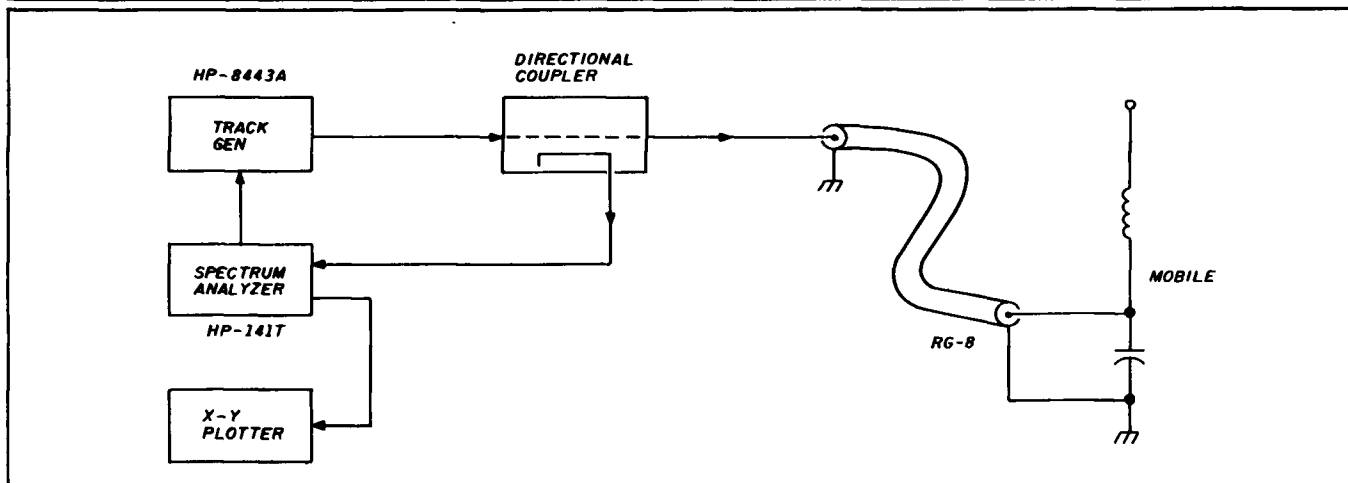
We continued by mounting a homemade antenna (now called the SE-40) in place of the commercial reference, and tuning it to 7.2 MHz. We measured its radiated signal both with and without a 24-inch capacitive hat. Without the hat, the signal registered 5 dB greater than the reference. With the capacitive hat attached and coil requirements reduced by about 40 percent, the signal was 6 dB stronger than the reference. With this much more signal radiated, it wasn't surprising that its coil ran very cool — barely above ambient. We also noted that a 40-percent reduction in coil size (and therefore coil loss) increased the signal only an additional 1 dB.

This implies that ground losses were now predominant in limiting radiation efficiency. We also found that the usable bandwidth of the antenna system with the hat was significantly greater than without; we investigated this later at the lab.

Tests on 3.8 MHz

We moved our testing to 3.8 MHz, again setting up a commercial antenna to radiate a signal with 50 watts of power. We adjusted the received carrier to S9 and recorded the attenuator setting. Then we removed the commercial antenna and substituted a homebrew antenna (SE-75) with 10 inches of open-air coil, a 5-foot whip, and 2-foot diameter capacitive hat mounted 2 feet above the coil. Its measured signal was 4 dB above reference. In this case the hat was necessary to resonate a 5-foot whip with the inductance available. To resonate without a hat required an 8-foot whip,

FIGURE 2



Instrumentation for measuring antenna bandwidth.

which measured 5 dB above reference, but was an impractical mechanical choice. As before, the B&W coil ran near ambient, while the commercial antenna got quite hot after a couple minutes of 50-watt carrier.

We made all tests using the same base section, appropriate coil, and accompanying whip. Additional measurements were later made with K7AYC and NØEYK to determine the effect of increasing base section length. Though it may not be completely obvious, you can change the length below the coil of the center-loaded antenna without changing its resonant frequency significantly. Feed impedance changes somewhat, necessitating a modest change in the shunt capacitor for a 1:1 match, but the length below the coil is rather removed from resonance effects. This is because the reactance of a short whip is very high, and the large inductance needed to cancel this reactance predominates.

We assembled a test setup identical to that used earlier, and repeated our measurements. We varied base section length in increments of 16 inches with both the commercial antenna and open-air coil SE-40 and SE-75. All antennas showed the same 1-dB improvement in radiated signal with a 16-inch increase in base length. Compare this to switching from a 5-foot whip and hat to an 8-foot whip to pick up 1 dB, and it becomes obvious where to add additional length. It was only practical to go to a second 16-inch extension; the system became unwieldy beyond that and would be practical only in a fixed mobile/portable environment. One thing became obvious: a 7-1/2 foot base section, 18-inch 75-meter coil/insulator assembly, and 5-foot whip with 24-inch capacitive hat looks impressive going down the highway! While I've never mobiled using more than a 6-foot base section and the aforementioned antenna assembly, a typical comment at gas stations is: "What you got there, satellite TV?"

Swept VSWR measurements

The next series of measurements we made on our antennas was swept VSWR. Because we're in the filter business, a tracking generator/spectrum analyzer is usual laboratory equipment. By adding a Mini Circuits directional coupler and a length of RG-8, we could run a cable to a parked mobile (see Figure 2) and take large amounts of

FIGURE 3

RETURN LOSS	VSWR
0 dB	∞
6 dB	3:1
10 dB	1.9:1
14 dB	1.5:1
20 dB	1.2:1
26 dB	1.1:1
32 dB	1.05:1
40 dB	1.02:1

Return loss as a function of VSWR.

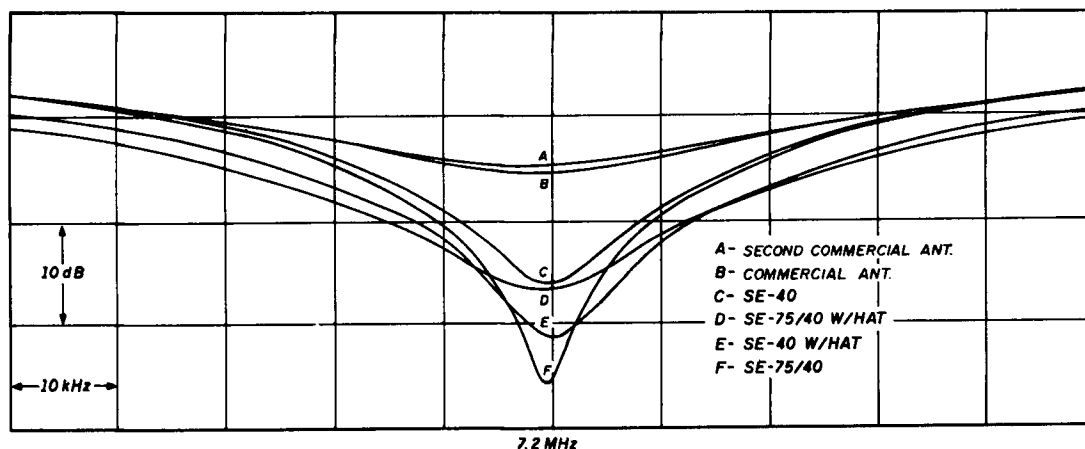
data on antenna bandwidth quickly. We plotted the output with an XY recorder for analysis.

With the test equipment set up to measure return loss, we attached a precision 50-ohm termination to the bridge output port, and measured a return loss of over 40 dB. An open circuit set the infinite VSWR reference line, and 25, 75, and 100-ohm terminations were attached to verify operation. All functioned as expected, so we connected the coax from the mobile. We also attached a 50-ohm termination on the car end, and measured over 35-dB return loss. We then attached the antennas, tuned them, and swept them for return loss.

Since the homemade antenna could be adjusted to nearly 1:1 by selecting the base shunt capacitor, it could always be adjusted for 25 to 30-dB return loss. We set the commercial antenna for the best match using its whip length tuning. On 40 meters it could be reduced to just a 15-dB return loss, or 1.4:1 VSWR. The 75-meter match was similar; it reached 14-dB return loss, or 1.5:1 VSWR. Of course you could add a capacitor across the coax with the commercial system, too. When we did this, the best match could be brought down to a 25-dB return loss and a VSWR better than 1.2:1, as shown in Figure 3.

After observing bandwidth plots, we noted that the best match at one particular frequency didn't necessarily give the widest bandwidth at a specified VSWR limit of, say, 1.7:1. If you do a lot of frequency changing, you might want to

FIGURE 4



Bandwidth measurements for six antenna configurations.

tune an antenna for the most power output over a measured bandwidth.

When tuned for lowest spot frequency VSWR, an SE-75 system showed a bandwidth of 10 kHz with a 1.7:1 VSWR limit. Retuning for a better average match increased this 1.7:1 bandwidth to 15 kHz, though the match at resonance was worse. The commercial antenna's 1.7:1 bandwidth (without added capacitor) was 7 kHz.

Adding a capacitive hat on an SE-40 also improved the usable bandwidth. There was a typical increase on 40 meters from 50 kHz to 75 kHz at 1.7:1. By comparison, the commercial unit showed about 35-kHz bandwidth. (See Figure 4.)

In 1985, a ham at the Dayton Hamvention™ bought one of these 40-meter antennas, and he and his friend rushed out to the parking lot to compare signals — one with a SE-40 and the other a commercial unit. They happened to have identical rigs, parked about 100 feet apart. About an hour later the gentleman returned to inform me that he and his friend had been on the air getting comparative reports, and the new antenna definitely was running about an S unit stronger.

Additional measurements

We took the next step in the measurement process in 1986 with a field-strength meter. K7AYC and I made measurements in a remote area of Arapahoe County near Denver using increments of 1/4 to 1 mile. With 100 watts of power as reference, we calibrated the field-strength meter and adjusted it for maximum readings at 1/4-mile points. We recorded test data on both 75 and 160 meters because this instrument tuned from 500 kHz to 5 MHz.

We used ground conductivity charts in the *ITT Reference Data for Radio Engineers* to calculate the theoretical groundwave signal for a 1000-watt broadcast station with a quarter-wave antenna and 120 quarter-wave radials. Then we compared this data with actual measurements made on 1600 kHz from a local broadcast station's construction permit proof of performance. Its measured signal strength in mV/meter at 1 mile correlated well with theoretical calculations for average terrain in Colorado. However, unlike the

TABLE 1

Signal strength as a function of frequency.

Frequency (kHz)	Signal strength (mV/M)
Theoretical	186, 1 mile, 1 kW
Typical reference—1600	165, good soil
KRXY—1600	160
NØSL—1800	110
160 mobile—1841	31
Typical reference 3800	112, good soil
75 mobile—3868	66

measurements of power and antenna current that a broadcast station makes, field-strength readings are much more variable and inaccurate. We weren't looking for 2-percent accuracy in field-strength values, but a general idea of what level of efficiency was obtainable with an optimized mobile antenna. Field-strength measurements vary with the weather, the season, and the water table. One local station had such difficulty maintaining its pattern that it was forced to move its antenna towers farther away from a grove of cottonwood trees that ran along a creek. The trees' sap content would change periodically and distort the licensed pattern out of FCC specifications. So much for antenna operation being an exactly predictable science!

The ITT book also gives data on groundwave field strengths for different vertical antennas. A quarter wave should give an E-field strength of 186 mV/M over perfectly conducting ground for 1 kW of RF. The correction factor for power is proportional to the square root of power in kW times the 186 mV/M figure. For our 100-watt test level, the correction factor is 3.16 times the measured values.

In the real world, with good soil, a value of 165 mV/M is reasonable on the high end of the broadcast band. We also obtained test data from the chief engineer of KRXY, which is licensed on 1600 kHz in Denver, as well as field-strength measurements made by NØSL on a top-loaded 50-foot vertical on 1.8 MHz. Measurements are summarized in Table 1.

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Advanced design and wide impedance matching range. Internal CPU stores previous settings on each band for rapid single-button operation. Automatically seeks for and memorizes new settings if SWR changes or antennas are swapped.

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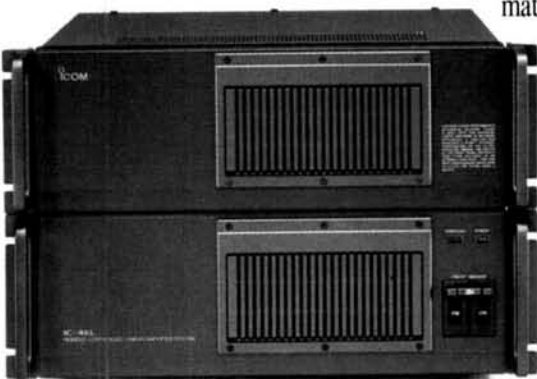
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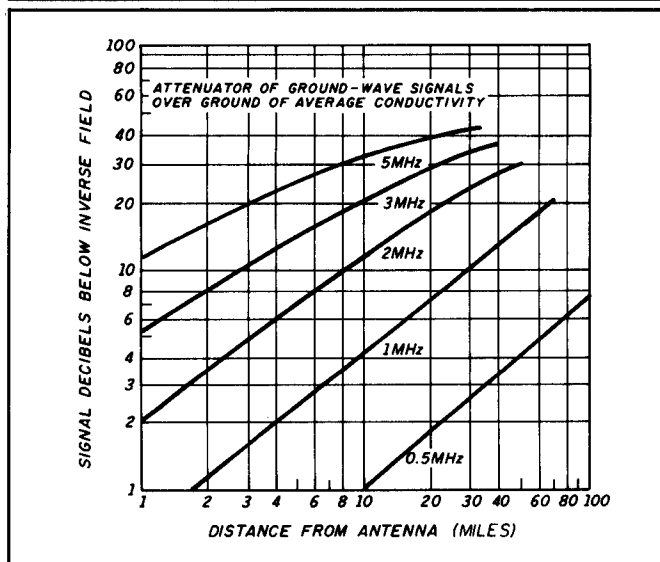
The IC-4KL comes complete with a remote control unit, RF/PS deck and nine feet of interconnecting cable for easy installation. The IC-4KL... Big Signal Performance backed by a one-year warranty at any one of ICOM's four North American Service Centers.

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FIGURE 5



Distance from antenna (meters). (Taken from *Radio Electronic Transmission Fundamentals*, B. Whitefield Griffith, McGraw Hill.)

When you compare E-field values of mobile antennas with reference values obtainable over good soil and a full quarter wave with 120 radials, the figures don't look too bad. Referenced to an antenna over a theoretically perfect conductor, groundwave losses at 2 MHz over good soil are about 2 dB, and approximately 8 dB on 4 MHz due to dielectric losses in the soil. When you compare the mobile signal levels to a fixed antenna over real ground, the 160-meter level is 15 dB down from a full-sized system and the 75-meter level is only 5 dB down (see Figure 5).

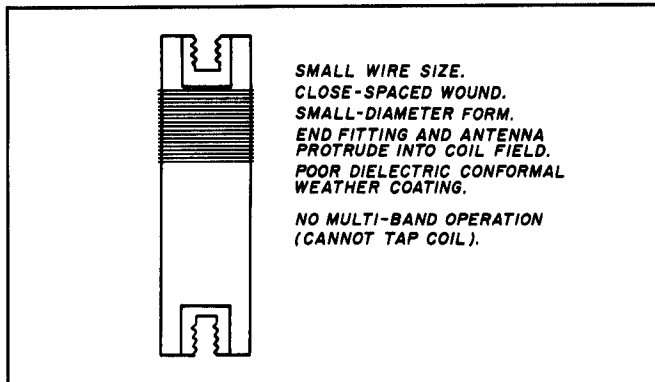
This means that groundwave range to a good base station is 100 to 125 miles for the prototype 160-meter coil used for these tests, and 200 watts of SSB. Compared with the 50 to 75-mile range of the 50-watt AM mobile mentioned earlier, this is a reasonable range increase. It may be interesting to note that it takes a rather elaborate 2-meter operation to better those ranges — unless your repeater is on a mountaintop.

Hardware hints

Here are a few reasons why these lower loss mobile antennas perform better than their smaller counterparts. Coils need to be air wound with only polystyrene ribs for support. Spacing of less than six turns per inch makes the coil susceptible to detuning and degradation from moisture (see Figures 6 and 7). Also, when we tried tighter spacing coils on 75 meters to allow a larger inductance and the option of no capacity hat, we noted spurious resonances that fell in the Amateur bands when the coil was tapped down for higher frequencies. While our initial coil support insulators were made from linen phenolic, its high cost and difficult machining problems necessitated a change to Lexan™.

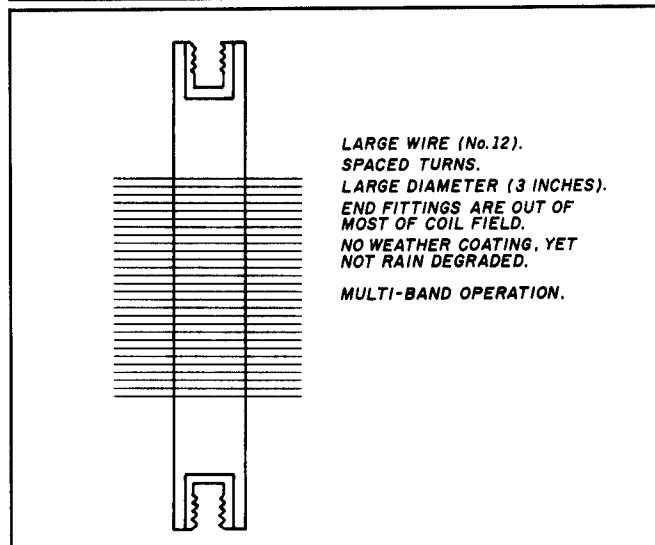
This polycarbonate plastic is stronger, cheaper, and easier to machine. I think it looks better, too. The insulator should be considerably longer than the coil itself to keep the threaded brass inserts out of the coil's immediate field. This

FIGURE 6




Characteristics of low-Q resonator.

FIGURE 7

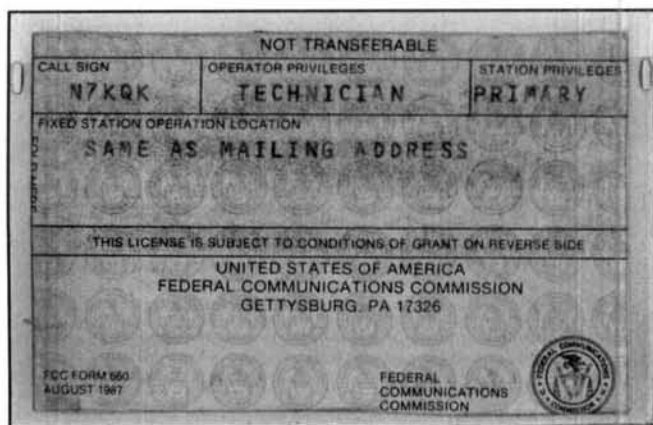


Antenna High = Q SE-40/SE75 antennas.

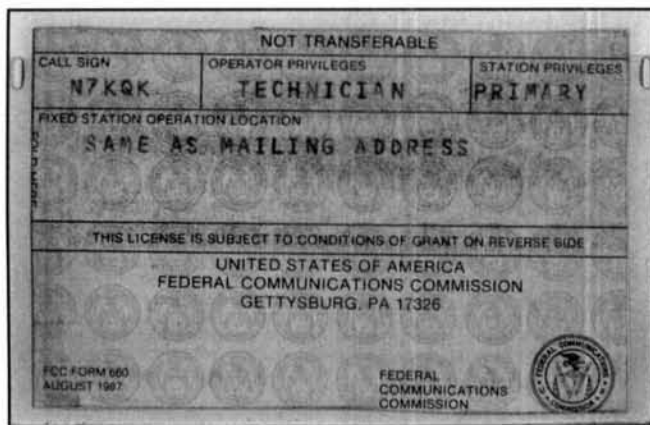
will also keep stainless steel antenna parts out of the field. Making frequency adjustment and band changes by shorting out turns with a clip lead may appear to be poor engineering, but so far any attempts at having multiple taps go to a switch have seriously detuned the coil.

You could argue that 6 dB isn't too much to give up to get the advantage of a small and aesthetically pleasing mobile antenna. Most will find that a signal that's an S-unit stronger often makes the difference between enjoyable mobiling and spending most of the time trying to find someone who can hear you. Add a good RF speech processor and a crisp microphone to this, and the difference is startling. Stations will start calling you! After you've done everything else, couple in a mobile kilowatt linear, and imagine that you're sitting in the passenger seat watching KD0U attack a pileup and come out with a contact and a new country against base station signals. The challenge is there waiting for you. 

This is an Amateur Radio License



This is an Amateur Television License



That's right, they are exactly the same. Your technician or higher class amateur radio license gives you the right to own and operate your own amateur television station.

It's Easy....

If you can operate a video camera, you can operate the new AEA Model FSTV-430. The FSTV-430 transceiver connects to the video output of your camera and transmits and receives live or taped video. You can even use two cameras for studio-like operation from your shack.

Fast Scan Television with the new FSTV-430 from AEA gives you live, color television that rivals broadcast quality. In fact, the AEA Vestigial Sideband (VSB) technique is similar to that used by broadcasters.

Inexpensive...

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KEEPING AN EYE ON YOUR SIDEBAND PEP

By John Fielden, GW4NAH, Penthouse 1,
Glyn Garth Court, Glyn Garth, Anglesey, LL59 5PB
U.K.

Single sideband is probably the most widely used mode on the Amateur bands today, yet few people can measure their peak output power. The quantity needs to be maximized for best reception at the other end, but at the same time limited to the "linear" capability of the RF power amplifier. Exceeding this may result in distortion, splatter, and license violation.

A modern SSB receiver's S-meter can "hold" signal peaks for comfortable observation, even if it is only of short duration. Unfortunately transmitters have no equivalent, and the only easy recourse for observing peak output on the RF-power/SWR meters that most of us have is to whistle. This is the only noise humans can produce which approaches the sine wave with which our meters are calibrated. This gives acceptable readings on constant power modes (FM, CW, FSK) but is useless and even misleading on SSB, because our whistle is just not that pure.

The error is down to the inability of a moving coil meter, and indeed our eyes, to follow the rapid transients of the voice. The transient voltages are, however, produced accurately by the SWR bridge, so the only modification required is to lengthen the response of the moving coil meter. The add-on module described here performs this function simply and accurately.

Circuit description

In Figure 1, the resistance of RV1+RV2 replaces the meter of an existing VSWR instrument; the voltage developed across these presets is fed via R1/C1 to the noninverting input of operational amplifier (op amp) A1. Its output, appearing at pin 1, charges C3 via CR2 and R6, with a rise time constant of 0.1 second, whereas C3 can discharge only through R7 with a decay time constant of 10 seconds. The voltage across C3 is buffered by voltage follower A2 to pin 7 and via CR3 to the moving coil meter of the existing VSWR instrument, and also via R5 as 100-percent feedback to the inverting input of A1. The total circuit has unity gain, causing the output voltage to rise quickly and exactly to the peak of an input voltage, but then holds the output for a few seconds after the input drops. C2 cre-

ates a slight phase advance in the feedback loop to prevent overshoot on rapid transients. The small voltage across CR1 of approximately 0 to 6 volts is used to balance out voltage and current offsets in the op amps via RV3, R3, and R4. The LM358 dual op amp was chosen because it can operate down to zero output on a single DC supply of 4 to 25 volts. CR4 protects against supply reversal and C4 provides a low supply impedance. CR5 and C5 protect the meter from overload and RF, respectively.

Construction

The module can be constructed from readily available components on a small pc board (the commercial version* measures 55 × 30 mm), which can be mounted inside an existing RF-power/VSWR instrument. It may be fixed there with BluTack™ or a bolt, spacer, and nut arrangement, but do so only after calibration. Placement is not critical, except where the SWR instrument is combined with an antenna tuner; in that case the module should be placed away from and shielded from the strong RF fields which exist around tuner coils, capacitors, and their leads.

Interconnections

Undo both leads from the moving coil meter (only from the forward power meter if there are two). Check that the negative lead is grounded; in most instruments it is, but you can find the odd one where the positive lead is grounded, and this has consequences when supplying power to the module. Now ascertain that the meter resistance falls within the range of RV1 + RV2, which is 0 to 2200 ohms. All commercial VSWR meters I have encountered so far do, but some homebrew models using meters with 100 μ A or less full scale deflection do not. In that case, make RV2 10 k.

Next, connect the former meter leads to the input terminals of the module and the module's output to the meter, carefully preserving polarities. A DPDT switch or PTT-

*The PEP module is available from Technical Software, Fron, Upper LLanwrog, Caernarfon, at 12 pounds, Incl. Vat, P & P. The pc board alone can be ordered from the HAM RADIO Bookstore for \$7.00 post paid.

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INSIDE VIEW — RS-12A

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MODEL RS-50M



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MODEL RM-35M

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MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H \times W \times D	Shipping Wt. (lbs.)
RM-12A	9	12	5 1/4 \times 19 \times 8 1/4	16
RM-35A	25	35	5 1/4 \times 19 \times 12 1/2	38
RM-50A	37	50	5 1/4 \times 19 \times 12 1/2	50

• Separate Volt and Amp Meters

RM-12M	9	12	5 1/4 \times 19 \times 8 1/4	16
RM-35M	25	35	5 1/4 \times 19 \times 12 1/2	38
RM-50M	37	50	5 1/4 \times 19 \times 12 1/2	50

RS-A SERIES



MODEL RS-7A

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H \times W \times D	Shipping Wt. (lbs.)
RS-3A	2.5	3	3 \times 4 1/4 \times 5 1/4	4
RS-4A	3	4	3 1/4 \times 6 1/2 \times 9	5
RS-5A	4	5	3 1/2 \times 6 1/8 \times 7 1/4	7
RS-7A	5	7	3 3/4 \times 6 1/2 \times 9	9
RS-7B	5	7	4 \times 7 1/2 \times 10 3/4	10
RS-10A	7.5	10	4 \times 7 1/2 \times 10 3/4	11
RS-12A	9	12	4 1/2 \times 8 \times 9	13
RS-12B	9	12	4 \times 7 1/2 \times 10 3/4	13
RS-20A	16	20	5 \times 9 \times 10 1/2	18
RS-35A	25	35	5 \times 11 \times 11	27
RS-50A	37	50	6 \times 13 3/4 \times 11	46

RS-M SERIES



MODEL RS-35M

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H \times W \times D	Shipping Wt. (lbs.)
• Switchable volt and Amp meter RS-12M	9	12	4 1/2 \times 8 \times 9	13
• Separate volt and Amp meters RS-20M	16	20	5 \times 9 \times 10 1/2	18
RS-35M	25	35	5 \times 11 \times 11	27
RS-50M	37	50	6 \times 13 3/4 \times 11	46

VS-M AND VRM-M SERIES



MODEL VS-35M

MODEL	Continuous Duty (Amps)			ICS* (Amps)	Size (IN) H \times W \times D	Shipping Wt. (lbs.)
	@13.8VDC	@10VDC	@5VDC	@13.8V		
VS-12M	9	5	2	12	4 1/2 \times 8 \times 9	13
VS-20M	16	9	4	20	5 \times 9 \times 10 1/2	20
VS-35M	25	15	7	35	5 \times 11 \times 11	29
VS-50M	37	22	10	50	6 \times 13 3/4 \times 11	46

• Separate Volt and Amp Meters • Output Voltage adjustable from 2-15 volts • Current limit adjustable from 1.5 amps to Full Load

• Variable rack mount power supplies VRM-35M	25	15	7	35	5 1/4 \times 19 \times 12 1/2	38
VRM-50M	37	22	10	50	5 1/4 \times 19 \times 12 1/2	50

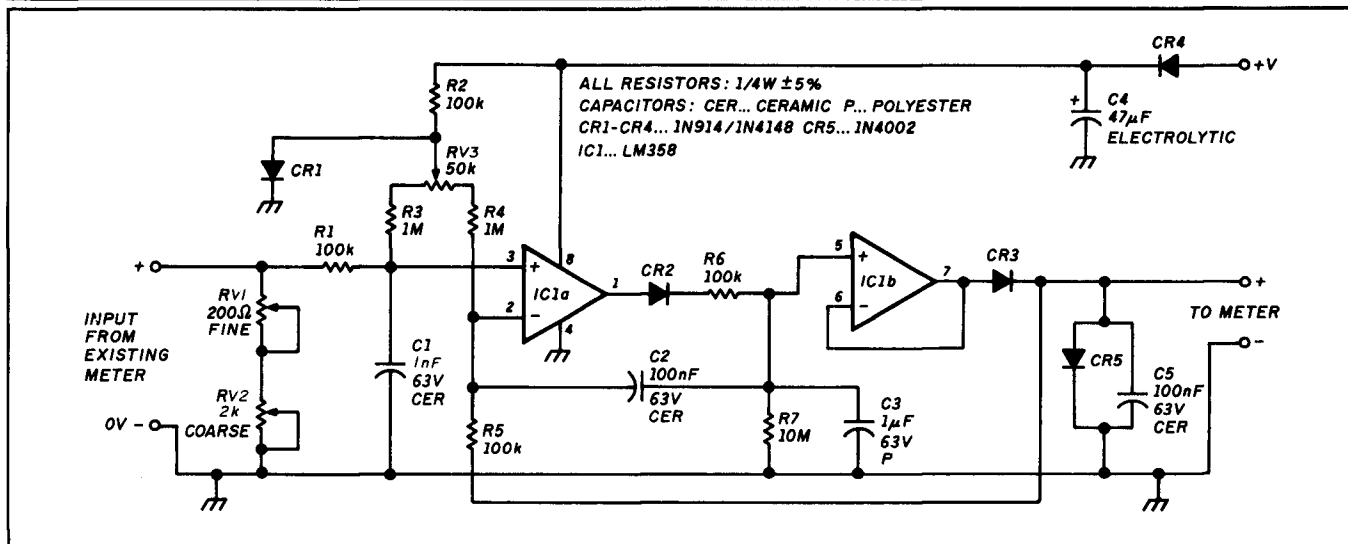
RS-S SERIES



MODEL RS-12S

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H \times W \times D	Shipping Wt. (lbs.)
• Built in speaker RS-7S	5	7	4 \times 7 1/2 \times 10 3/4	10
RS-10S	7.5	10	4 \times 7 1/2 \times 10 3/4	12
RS-12S	9	12	4 1/2 \times 8 \times 9	13
RS-20S	16	20	5 \times 9 \times 10 1/2	18

FIGURE 1



Schematic of the PEP measuring add-in circuit.

operated relay can be inserted to switch the PEP module in and out for SSB and other modes, respectively. Another method of reducing the peak holding feature of the module is to reduce R7, say by switching a 220-k resistor across it.

Power, anywhere from 4 to 25 volts DC at little more than 1 mA, must now be connected. If the negative meter lead was found to be grounded, a suitable voltage source, say 9 or 13.8 volts that is "on" when transmitting, can be found on the back of most transceivers. Use a single wire to connect that voltage, preferably through a 2700-ohm current-limiting resistor, to the positive terminal on the module. The coax shield will take care of the negative return.

In the rare case where the positive meter terminal is found to be grounded, a floating power supply must be used. In either case, three Duracell™ pen light cells would typically last nine months if left on continuously, or for years if switched on only when used. In all of the following adjustments, remember that the meter will travel upscale rapidly, but settle back slowly. Do wait for the meter to settle before reading.

First, the op amp offsets must be balanced out. For the commercial module this was done at the factory and RV3 was sealed. If you have built your own, or must replace the LM358 for any reason, a procedure is suggested below. A small positive meter reading with zero input is not an indication of an offset error and upscale readings will be correct.

Next, a calibration level must be established. With the PEP module out of the circuit, your transmitter in a constant carrier mode (CW, FM), and your SWR meter between the transmitter and a dummy load, pass some RF power through the meter. Increase the output to where a stable forward power reading (preferably over half scale) is obtained. Make careful note of the power reading and do not change the transmitter power setting until calibration is complete. Now reconnect the PEP module, set RV1 and RV2 to zero (fully CCW), apply DC power to it, and switch the transmitter back on at the power setting previously established as calibration level. Advance the "fine" preset

PARTS LIST

Capacitors

C1	1 nF, 63 volts ceramic
C2,C5	100 nF, 63 volts ceramic
C3	1μF, 63 volts polyester
C4	47μF, 16 volts DC electrolytic

Diodes

CR1-CR4	1N914/1N4148
CR5	1N4002
IC1	LM358


Resistors

R1,R2,R5,R6	100 k, 5 percent, 1/4 watt
R3,R4	1 meg, 5 percent, 1/4 watt
R7	10 meg, 5 percent, 1/4 watt
RV1	200 ohm Mouser Electronics Part no. 32RH202
RV2	2 k Mouser Electronics Part no. 32RH302
RV3	50 k Mouser Electronics Part no. 32RH405

RV1. If, with RV1, you can exceed the calibration reading previously noted, adjust to this reading. If the meter does not rise far enough upscale, set RV1 to about mid-travel and slowly advance the "course" preset to the calibration reading. RV1 will now allow more precise adjustment.

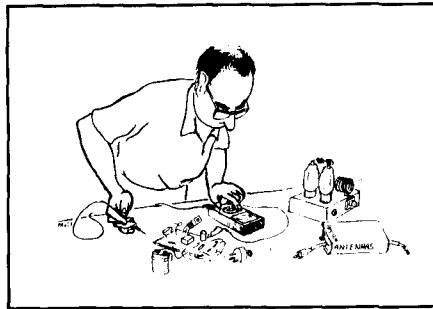
This calibration makes sure that RV1+RV2 presents the same load to the SWR instrument as the moving coil instrument previously did, so the input voltage to the module is unchanged. The module has exactly unity gain, so this voltage is repeated at the output, i.e., across the meter. Consequently the original meter calibration, nonlinearities and all, remains unchanged. On fast peaks, however, such as are encountered when speaking on SSB, the module will hold a peak long enough for the meter to rise to it and for you to check it.

Results

The results will probably surprise you. Without the module, normal speech will show peak meter readings of, say 30 percent of what an oscilloscope would indicate. With the module, it's 100 percent. A whistle, without the module, will show 80 or 90 percent, not 100 percent. Another interesting example is produced by tapping the mic with a pencil. The unmodified meter will show no reading, but with the module, full power will be indicated. 

Ham Radio Techniques

Bill Orr, W6SAI



THE LOG PERIODIC ANTENNA FAMILY

Bill Orr, W6SAI

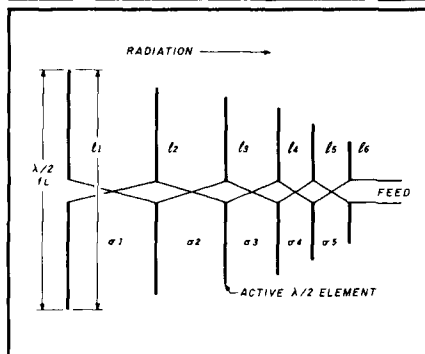
In 1957, D. E. Isbell and R. H. DuHamel published papers on the design of log periodic (LP) antennas.^{1,2} There was a flurry of interest among Radio Amateurs, who adapted some interesting VHF LP antennas from the original design. But it wasn't until 1973, when the log periodic dipole (LPD) array was published by P. D. Rhodes,³ that this class of antenna became practical for HF Amateur use.

Now that two new ham bands are available at 18 and 24 MHz, interest in the log periodic antenna is growing. How else can an active Amateur cover five bands? (How about a center-fed Zepp? — NX1G). The log periodic antenna's principal virtue is that it can cover a frequency span of 2:1, or more, while maintaining good power gain and front-to-back ratio over the whole range.

The log periodic dipole beam shown in Figure 1 is a popular configuration for VHF television antennas. It's also used on the VHF/UHF ham bands. The pattern is directed toward the apex. The bandwidth of operation can be roughly defined as the frequencies at which the outer dipole elements are about one-half wavelength long. The element lengths and the relative spacing δ are arranged in a geometric progression with a taper factor τ .

The dipoles are fed at their centers from a parallel wire transmission line transposed in such a way that successive dipoles are 180 degrees out of

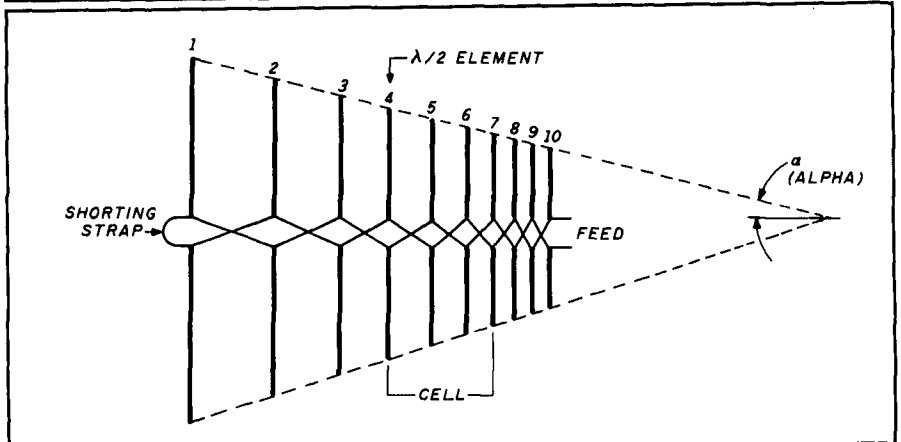
FIGURE 1



A six-element LPD beam. Element spacing (δ) and element length (λ) are determined by design factors, the longest element (λ) being about a half wavelength at the lowest operating frequency (f_l).

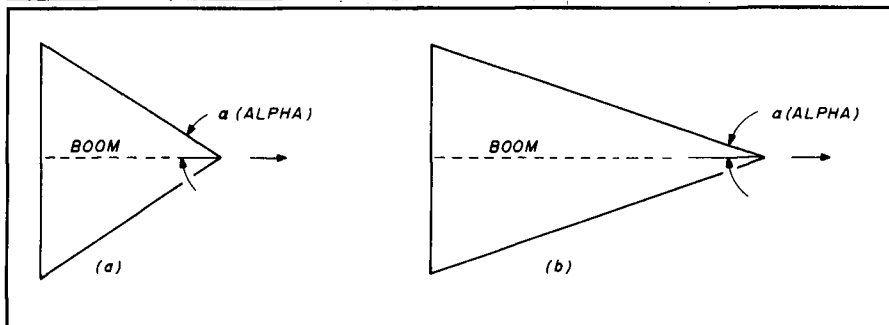
phase. A broadband structure is formed, with most of the radiation coming from those elements which are about a half wavelength long at the operating frequency. In a ten-element log periodic antenna that covers a 2:1 frequency span; perhaps only four of the ten elements are active at a given frequency within the operating range (see Figure 2). The shorter than resonance elements tend to act as directors and the longer than resonance elements as reflectors. The current distribution in the structure is such that only a "cell" (active region) of elements is active on a given frequency. The cell of active elements moves back and forth along the array as the operating frequency is changed. The gain and bandwidth thus bear a definite relationship to the length and included angle of the structure. The smaller the

FIGURE 2



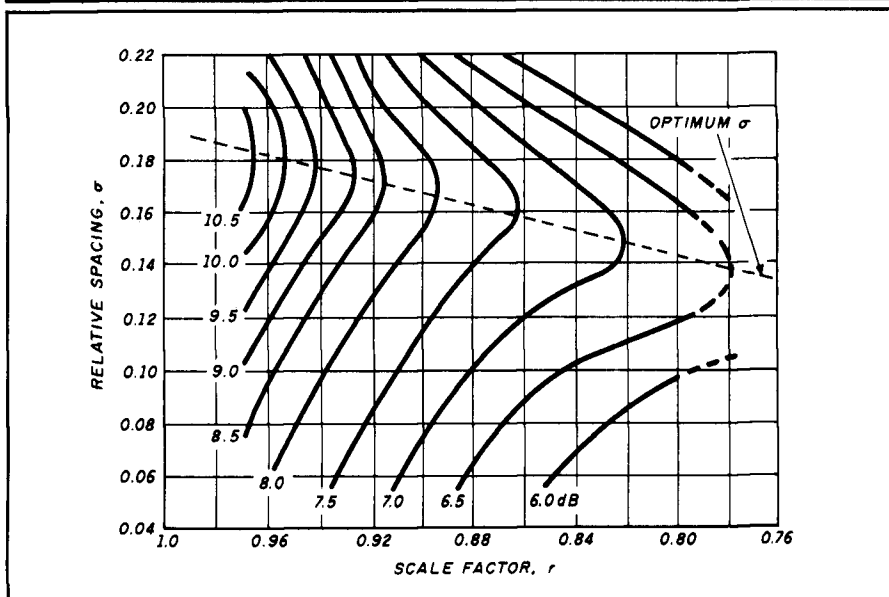
Log periodic active region (cell) encompasses elements a half wave long and a few shorter elements. Other elements have small induced currents and are not major contributors to the radiated energy. Shorting strap on longest element improves front-to-back ratio.

FIGURE 3



Increase in boom length and decrease in apex angle (α) mean more elements in a cell and increased gain. A greater frequency span also requires a longer boom (B). High gain on a short boom (A) restricts frequency span.

FIGURE 4



Reproduction of graph showing corrected gain figures for LPD array. Graph is in *Antenna Engineering Handbook*, Johnson and Jasik, First Edition, pages 14-28. (Illustration courtesy Gary Breed, K9AY, Editor, *RF Design* magazine.)

included angle the more elements in a cell, the longer the antenna, and the higher the power gain. (See Figure 3.)

The HF log periodic dipole antenna

Antenna boom length is of secondary importance in the VHF region, where a high gain, wide bandwidth log periodic array can be constructed on a boom about one or two wavelengths long. But because of the large size of the antenna, things begin to get out of hand quickly when you consider HF operation.

LPD array gain can be expressed in terms of the number of elements in the cell, the relative element spacing, and the scaling factor used. In general,

power gains from 5.5 to 10.5 dBi (3.36 to 8.36 dBd) are the minimum and maximum gain limits of practical HF log periodic designs. (The larger arrays produce the higher gain figures.)

A representation of LPD antenna gain is expressed in Figure 4, Chapter 10 of *The ARRL Antenna Book*.⁴ This chart was extracted from an early work of Carrel,⁵ which was later found to provide inaccurate directive gain computations.⁶ My Figure 4 shows a corrected graph.

High gain LPD arrays are defined in the relative spacing region of 0.12 to 0.22 and large values of scaling factor (0.98 to 0.92). Unfortunately, these figures produce large array sizes that are almost impossible to achieve in an

Amateur HF installation. One look at an HF LPD array at a military base quickly disproves the idea that a block-buster LPD rotary antenna can be placed in a typical backyard!

Practical HF LPD beams

However, all is not lost if those of us who use wideband LPD arrays are content to settle for a modest gain figure, while still retaining good front-to-back ratio and reasonable boom length. Ace Collins, K6VV, has described three LPD arrays (summarized in Table 1). These arrays can be built on boom lengths that approximate a single band Yagi beam.⁷

ATN Antennas of Birchip, Australia makes two commercial LPD beams that cover 13 to 30 MHz.* One design is on a 28-foot boom and has eight elements; another design covers the same range and has six elements on a 20-foot boom. The DJ2UT multiband antenna, built on a 20-foot boom, is a variation of the LPD design that covers 13 to 30 MHz.**

The ARRL Antenna Book (pages 10-5 and 10-6) describes a very small LPD design with a 10-foot boom that covers 18.06 to 29.7 MHz. It has just five elements and (according to the graph in Figure 4) provides only 3.2-dB gain over a dipole. It's doubtful that placing this amount of aluminum up in the air is worth the unspectacular power gain.

LPD power gain

You can compute the power gain of a LPD antenna from the design formulas and Figure 4. This figure can be expressed in terms of boom length for Amateur use in the HF region — much in the way it's done for conventional Yagi antennas. When compared on a band-by-band basis with a Yagi, the tradeoff of gain for bandwidth becomes apparent. For example, a three-element Yagi for 14 MHz provides about 6.5-dBd gain and is built on a 17-foot boom. At that boom length a typical 14 to 30-MHz LPD provides 3.5-dBd gain. The Yagi wins by 3 dB!

At 28 MHz, you can build an eight-element Yagi on a 45-foot boom which will provide nearly 10-dBd gain. An equivalent LPD on that boom provides only 7-dBd gain. The long Yagi wins by 3 dB.

* ATN Antennas, 56 Campbell Street, Birchip 3486, Australia.

** Sommer GMBH, Kandelstrasse 35, D-7809 Denzlingen, F.R.G. Sommer Antennas, W4/DJ2UT, PO Box 847, Cowpens, SC 29330.

TABLE 1

Three LPY designs by K6VV (QST, November 1988). Shorting strap on longest element is 8" long. Average feedpoint impedance is 64 ohms. Design constant (τ) = 0.9, spacing constant (δ) = 0.05, average gain (from Figure 4) = 4.61 dBd.

11-element array 13.5—30 MHz Boom = 25 feet			9-element array 17.5—30 MHz Boom = 16 feet		7-element array 20—30 MHz Boom = 12 feet	
Element number	Length feet	Spacing feet	Length feet	Spacing feet	Length feet	Spacing feet
1	36.44	3.64	28.94	2.78	24.53	2.45
2	32.80	3.28	26.05	2.50	22.08	2.21
3	29.52	2.95	23.44	2.25	19.87	1.99
4	26.57	2.66	21.10	2.03	17.89	1.79
5	23.91	2.39	19.00	1.82	16.10	1.61
6	21.52	2.15	17.09	1.64	14.49	1.45
7	19.37	1.94	15.38	1.48	13.04	-
8	17.43	1.74	13.84	1.33	-	-
9	15.69	1.57	12.46	-	-	-
10	14.12	1.41	-	-	-	-
11	12.71	-	-	-	-	-

The LPD array swaps bandwidth for power gain at any frequency, when compared with a Yagi of equivalent boom length. While the power gain figures of both types of antennas are approximate, the examples shown are indicative of the relative gain performance of these interesting antennas.

The LPD antenna has a couple of advantages. First, it allows a solid-state transmitter to operate efficiently over a wide frequency range without an antenna tuner. Second, it maintains its front-to-back characteristics over the complete operating range — something many Yagi designs can't do.

Is the tradeoff of power gain for bandwidth worth it? You'll have to answer that question yourself.

The log periodic Yagi (LPY) array

Peter Rhodes, K4EWG, and J. R. Painter, W4BBP, have described an interesting hybrid antenna.⁸ It's designed for single band use, and combines an LPD cell with parasitic elements. The designers claim this configuration achieves higher gain and greater directivity over a single Amateur band than either an LPD or a Yagi array alone (see Figure 5). Best of all, these attributes are achieved with a boom comparable in length to that of a small Yagi. They claim a gain figure of 11.5 dBd for a 14-MHz LPY with a boom length of 26.5 feet. A four-element Yagi on the same boom would provide about 7.3-dBd gain. This gives an apparent signal advantage of about 4 dB for the LPY array over the Yagi. It sounds almost too good to be true!

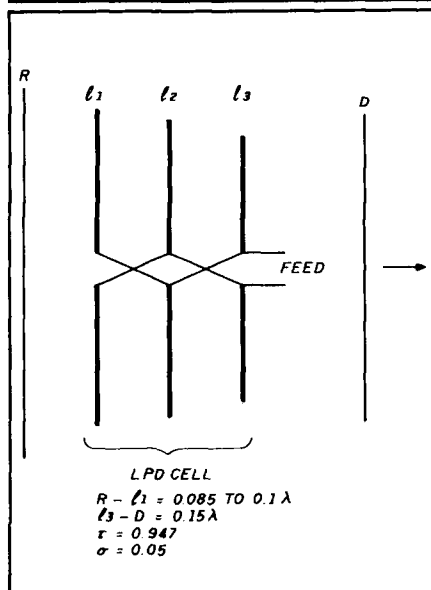
The log periodic cell in the K4EWG/W4BBP LPY is designed for a single Amateur band, rather than a wide range of frequencies. A three-element log periodic cell provides a power gain of about 3 to 4 dBd over the design range. According to Leo Johnson, W3EB, adding a single reflector and a director provides another 4.5 dB.⁹ If the gain figures are added, the resulting overall gain for the array is about 8.5 dBd. A second director boosts the gain an additional 1.5 dB, for a grand total of 10 dBd.

This agrees roughly with the gain fig-

ure proposed by K4EWB. Personally, I can't verify the gain of an LPY antenna. I know of no computer program that considers this antenna type and I'll reserve my judgment until somebody comes up with one. (I look forward to hearing from a programmer who can combine the virtues of the Yagi with the LP cell in one program and arrive at meaningful results.)

I must admit the LPY concept is tempting. I know that Burt, KV4AD, has a W3EB-type LPY beam on 12 meters, and I have heard his rock-crushing signal. Photo A shows a seven-element 10 to 30 MHz LP4 antenna. Perhaps I'll build one of these antennas and try it out on 10 meters. There's no substitute for experience!

FIGURE 5



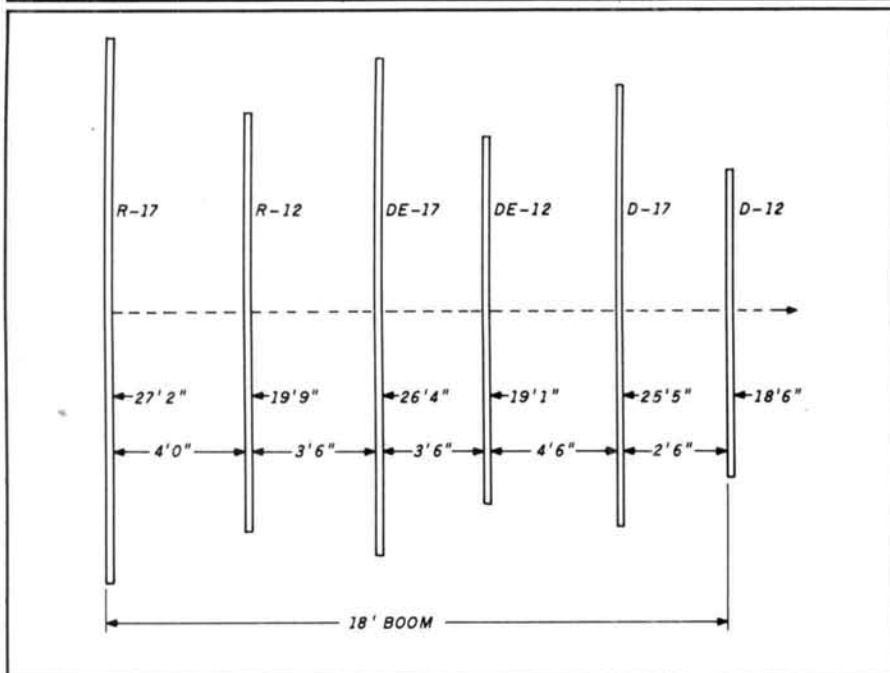
The log periodic Yagi design of K4EWG and W4BBP. Parasitic reflector and director(s) boost gain of LPY cell and improve front-to-back ratio.

A two band Yagi for 18/24 MHz

Brad Butcher, W9WPV, designed and built a two-band, interlaced, three-element array for 18 and 24 MHz. It's shown in Figure 6. The beams are built on an 18-foot boom and fed with separate gamma matches and coax lines. The SWR on each band is about 1.1:1; the front-to-back ratio on either band is better than 20 dB. You make your band selection at the operating position with a coax switch. This array, plus a conventional tribander, can provide coverage of the five popular HF bands with a minimum of fuss.

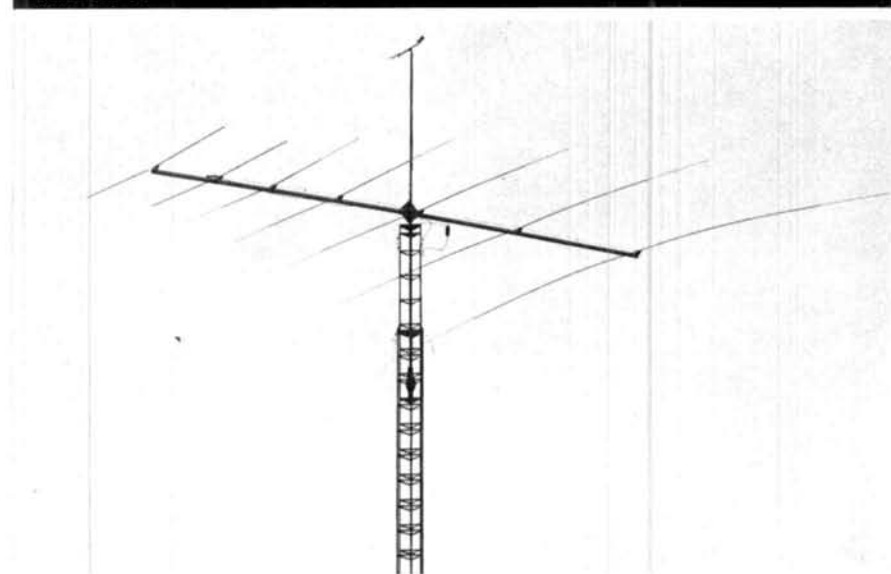
Did I hear someone ask about stacking this beam over a tribander on one tower? If I were to do this, I'd want at least 6 feet — and preferably 10 — between the antennas. Maybe some-

FIGURE 6



Dual Band (17/12 meter) beam of W9WPV. See August column for gamma match data. 17-meter gamma approximately 2'6" long. 12-meter gamma approximately 2'0" long.

PHOTO A



Seven-element LPY beam on 30-foot boom covers 10 to 30 MHz. Six-element cell plus director provides good gain and F/B ratio. Longest element is 42'9"; shortest element is 12'6". Director is 13'6-1/2". (Type KLM-10-30-7LP.)

one will try a stacking experiment to see how it works out!

The Dead Band Quiz


What with all the ionospheric fade-outs, solar storms, and summer lull in DX, there should have been plenty of time to solve the latest quizzes. Many thanks to those who have written to me.

I appreciate your comments and regret that I don't have the time to write and thank you all individually. I also appreciate your suggestions for future topics in this column!

The March quiz (the "black box") has several solutions. The simplest is a "star" of five 0.5-ohm resistors. Jack Cleary, N2JHS, and Curt Anderson,

K3GCM, found this solution. Ed Clegg, W3LOY, pointed out that a "pentagon" of 1.25-ohm resistors would also do the job.

The April quiz dealing with coax lines was quickly solved by W9BTI, WB4HXE, W5DS, KC2KB, N3GDE, W2RJW, W4EIN, K7FC, W7FSP, KJ6GR, VE4KZ, WB6BYU, and WX4D. They knew that the impedance between the shields was zero. Replies are still coming in. I'll try to list them in my next column.

Thanks to all and 73! 

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1. D.E. Isbell, "Log Periodic Dipole Arrays," *IRE Transactions on Antennas and Propagation*, Volume AP-8, No. 3, May 1960, page 0260.
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PROTECT YOUR AMATEUR STATION FROM LIGHTNING

By Richard Little, KY9L, Cellular Systems Group,
Motorola, Inc., 1501 West Shure Drive, Arlington
Heights, Illinois 60004

More lightning damage occurs to electronic equipment than is generally realized, because much of it is manifested in post-stress failures weeks or months after the damaging surge. Even if you have lightning insurance, these kinds of failures are rarely covered, nor is the lost time and aggravation. Surge damage is real, but it doesn't need to happen.

Most books and articles on the subject of lightning protection recommend extensive arbitrary cross bonding of grounds — often in ways that increase the flow of surge current through the equipment. I take exception to these practices. Thorough study of the problem as it relates to Amateur Radio shows that:

- Most Amateurs cannot afford the kind of installation that would permit them to operate safely with outside antennas during a thunderstorm.
- It is practical to ground an Amateur station in a way that can completely eliminate direct surging of the equipment while the shack is shut down.
- The techniques for eliminating surges during shutdown are consistent with providing at least modest protection if the operator is caught unaware of an impending storm.

I'd like to share some information on an improved method of lightning control that can eliminate damage while your station is shut down and provide some degree of protection if lightning strikes when you're operating.

Do you carry lightning insurance on your ham equipment? Does it cover the decrease in reliability that so often follows a lightning strike? It would be better if your equipment never receives this kind of exposure. But short of packing the equipment back in its shipping containers every time you leave the shack, what are your alternatives?

When the static charge at the base of a cloud builds up to around a hundred million volts, it can jump ("step" is a better word) 150 feet or so as a small arc toward a pocket of opposite charge in the surrounding atmosphere. Within about 50 μ s it may step again and again, extending the

small arc farther and farther along the previously ionized trail. If such an arc ultimately establishes itself to something on the ground, a massive surge of current will rush through the ionized path to neutralize the charge. The extremely high voltage forces the surge of current to rise to a peak value of 10 to 100 kA in 0.1 to 10 μ s. It then decays to half crest in 20 to 200 μ s. Most strokes consist of several of these surges, each neutralizing more and more of the cloud, but the first one is the largest and the one that usually damages electronic equipment. The fast leading edge (20 kA/ μ s typical, with 1 percent exceeding 100 kA/ μ s) can result in the top of a tower momentarily "jumping" a million volts with respect to its base. This is why lightning has no problem jumping across switch contacts and guy wire insulators, or even right through the wall of a house from an ungrounded exterior coax.

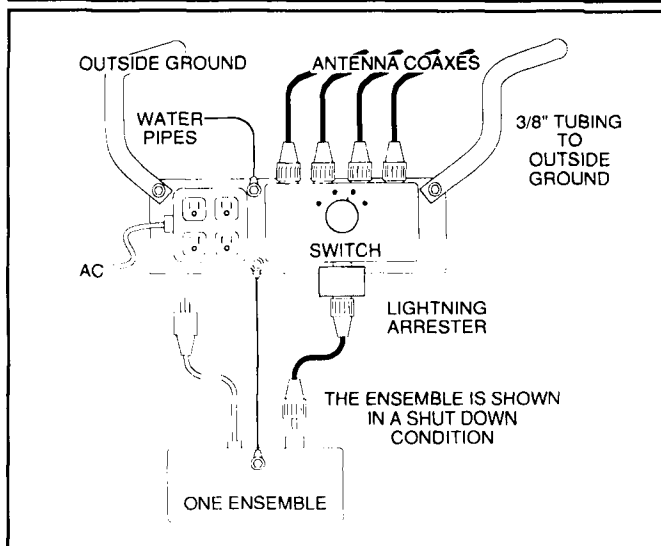
What kinds of protection?

Personal safety is your first concern. This means tying all grounded objects together to prevent side flashing between them, and perhaps augmenting the ground. Secondly, Amateur antennas expose our homes to more and larger surges so you may wish to add some protection to your more expensive non-Amateur equipment like stereos, TVs and VCRs, and home computers. You can provide excellent shutdown protection for your Amateur equipment and perhaps, depending on your pocketbook, some tolerance should you not shut down in time.

For safety of people!

I'm often asked if the antenna grounding should be kept separate from the house ground. Absolutely not! **I strongly encourage integrating everything into a common ground.** I don't think any lightning professional would disagree. The same reasoning is behind universal building codes which tie electrical ground, phone line protector ground, water pipes, and TV cable together. While bond-

FIGURE 1



Installation showing the station (ensemble) in a shutdown condition. All grounds are located at a small ground window.

ing them together may increase electrical surging in the house should the antenna get hit, it also makes the surge path more predictable. Everything moves (electrically) more or less together, proving safer for people as well as your equipment. This ground should include:

- Outside ground, made up of:
 1. Tower ground (including guy anchors)
 2. Radials
 3. Ground stakes (several recommended)
 4. Step voltage protection (if used)
 5. Chain link fence (if within 20 feet of other grounds)
 6. Rain gutters
 7. Well casing
 8. Connections to inside ground (at least two recommended)
- Inside ground, made up of:
 1. Water pipes, power ground, cable TV feed and phone line protector. (These should already be integrated, but if not, DO IT! Cross bond if in doubt!)
 2. Duct work
 3. Structural (like basement I beams)
 4. Shack ground, including:
 - a. connections to outside ground
 - b. coaxes where they enter the shack
 - c. open wire feedline shorting switch (if required)
 - d. grounds of each of the power outlets feeding the equipment
 - e. rotor control box (otherwise provide with a three-wire cord)
 - f. all equipment that is provided with ground lugs
 - g. equipment desk (if metal)

I'll discuss the shack ground in more detail later.

Protecting non-Amateur equipment

Use three-way surge-protected power strips for any expensive electronic equipment; those strips housed in metal cases are more convenient for making auxiliary ground connections. Plug the TV, VCR, and all video accessories into a common strip and ground the braid of the coax feed to that strip using a short bonding strap. For a home

computer, plug the computer and **all** of its peripherals into a common strip. If your system incorporates a phone line modem, acquire a secondary phone line protector and ground it directly to that strip with a short bonding strap.

Shutdown protection: surge isolation

For simple shutdown protection, pick a central point where it's convenient to bond all of the shack ground items listed — including all the antenna coax braids — and call that point "shack ground." If you arrange these connections into a neat, small, "ground window" (see **Figure 1**), you will also have a degree of surge attenuation. In any case, the antennas, rotor, and other equipment each bear separate consideration.

Equipment grounds

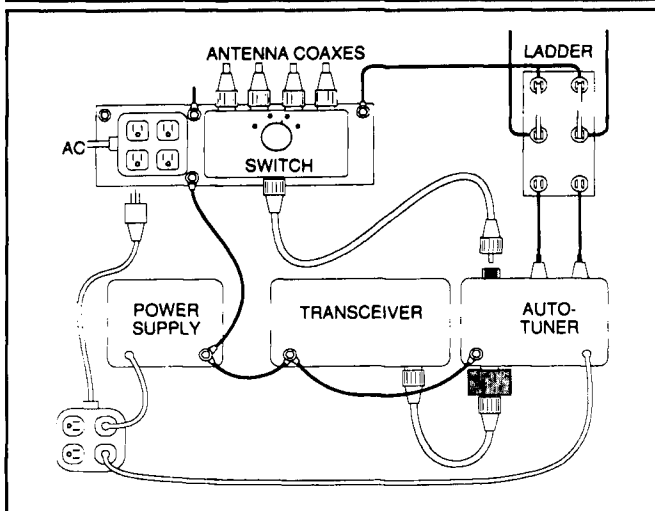
You can organize your shack into one or more equipment ensembles, each having just one connection to shack ground in addition to antenna(s) and power cord(s). **Figure 2** shows an example of a grouping with one connection to the shack ground. Most of you will prefer a single ensemble in which all of the equipment grounds are connected to a steel desk or a "bus bar," or otherwise cross bonded to one another and then grounded to shack ground via a *single wire*. Of course, a tuner that's being treated as "antenna," as depicted in **Figure 3**, must not be in conductive contact with any of the equipment of an ensemble (except via common shack ground when shut down, or coax when not shut down).

Connections between different ensembles are not permitted. If a power supply, a speaker, a microphone console, a keyer, or a computer interface connects to more than one transceiver, they must all be part of the same ensemble. One word of caution: A more elaborate ensemble tends to be less surge tolerant. Each ensemble may incorporate its own multiple outlet power strip, which simplifies shut down.

Antenna grounding and switching

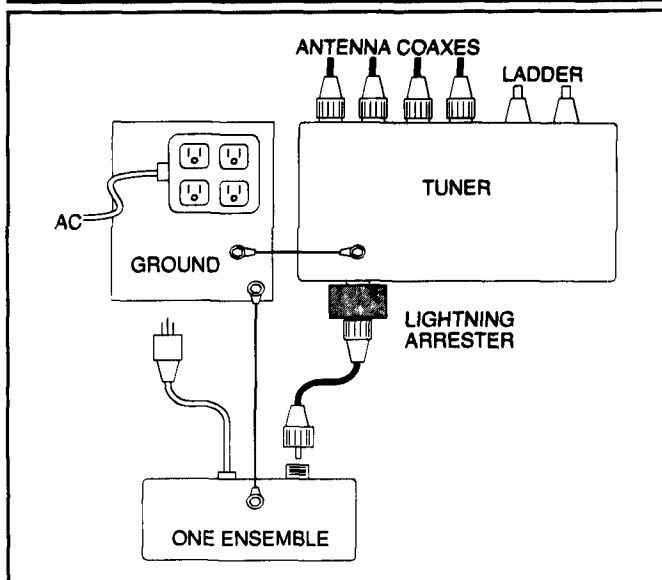
Bond the shields of all antenna coaxes to shack ground. A properly grounded coaxial switch will work. Including the antenna switches and/or the tuner as part of the antennas (as shown in **Figure 3**) minimizes the number of discon-

FIGURE 2



An ensemble using only one connection to the ground window.

FIGURE 3



Antenna tuner is treated like an antenna and must be isolated from the rest of the ensemble, except for the common ground.

nects required during shutdown. This also cuts down on HF "RF in the shack," particularly if the antenna isn't truly balanced or isolated by a feedline choke.

Tuners, built in transceivers, and autotuners are treated as part of an ensemble, as shown in **Figure 2**. In these cases, if any of your antennas are not well balanced or isolated, reduce RF in the shack by defining the shack ground as close as practical behind the ensemble to minimize the length of the single wire between the ensemble (preferably the tuner) and shack ground. Counterpoise wires must attach to shack ground, not directly to the ensemble.

Make sure antenna switches are the grounding type and able to ground all antennas at shutdown. Use a DPDT knife switch to disconnect *and* ground a ladder line if you use one. A remote coax switch that uses a separate control cable is best treated as a "rotor controller." Those switches using the coax for control and power are best treated as "equipment," thus the antenna coax will be disconnected and its center conductor grounded during shut down.

Rotor controller

The rotor can't avoid surging; neither can the controller, unless the rotor cable is disconnected and all its wires are grounded at shut down. Short of that, the rotor and its controller have an intrinsic degree of surge tolerance that the following procedure neither helps nor harms. You can modify them to improve this tolerance, but these modifications are beyond the scope of this article. However, to protect the rest of your equipment, and for your own safety:

- If it has a two-wire power cord, ground the controller to shack ground and pull the plug when you shut down.
- If it has a three-wire power cord, surge protect your grounded outlet box, and leave the rotor controller plugged in at all times.

Shutdown performance

This is a rudimentary ground scheme; it provides excellent surge isolation when shut down, but only modest surge attenuation otherwise. To shut down:

- Unscrew the antenna coaxes where they enter each equipment ensemble. Switches are unacceptable for this purpose.
- Pull the power plugs that feed each equipment ensemble from the shack-grounded outlet box. Again, switches are unacceptable.
- Ground the antennas, including all the center conductors.
- Disconnect the phone line from a phone patch or from a computer/modem that's part of an ensemble.

Check your work! There should now be but *one* ground path from each ensemble to shack ground.

Improving surge attenuation

Few of us can afford the full surge protection that would permit us to operate with impunity during any storm. Surge damage to equipment can occur in the following ways:

Coax differential voltage. The surge generates a difference in potential between the sheath and center conductor. This can damage a receiver, a transmitter, or just the coax.

Coax chassis surging. The sheath "whiplashes" the entire rig with respect to its other external connections like keyers, computer interfaces, phone patches, shared speakers, and microphone consoles, damaging the interfacing circuitry in either the rig or a peripheral, or both.

Coax chassis ground surging. The surge enters via the coax and leaves via either power or ground, causing destructive internal voltages in the equipment.

Power surging. A surge injected by an antenna stroke generates a large electric transient between AC hot, AC common, and/or the power panel ground. The three-way protector minimizes this.

Telephone line surging. A surge injected by an antenna stroke generates large voltage spikes on the equipment with respect to the telephone lines. A secondary phone line protector minimizes this.

The damage may be apparent immediately, or randomly after the fact. It could show up hours, days, or months later. Often a "zapped" rig exhibits poor reliability forever after.

For surge attenuation, the first prerequisite is three-way surge protection on the AC outlet boxes, secondary telephone line protectors grounded at those outlet boxes, and coax arresters between the antennas and the equipment ensembles. After that, the protection depends upon:

- The magnitude of the stroke.
- How well shack ground is developed into a small ground window — including the lengths of the coax sheath bonds and the AC outlet box bond. Short is important! Fat (wide) also helps. This is because lightning propagates like RF — on the surface of a conductor more than within the conductor, i.e., skin effect.
- The quality of the outside ground.
- How well the coax sheaths are grounded at the tower base, thus diverting sheath surge current into outside ground.
- The surge tolerance of the specific radio equipment.

The inside ground

Figure 1 shows how I have developed a *small* ground window at a point directly behind my operating desk. Commercial installations often provide a heavy copper plate for mounting the surge-protected power panel, the phone line protectors, and the coax terminators/arresters. A very low

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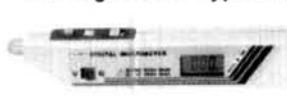


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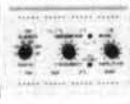
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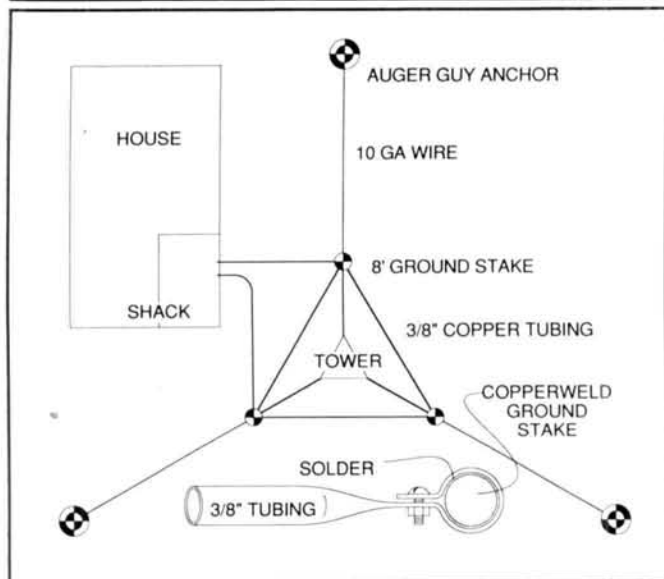
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FIGURE 4



Layout of a "good" outdoor grounding system.

inductance between these items and careful ensemble isolation (except at the window) are essential for good surge attenuation.

I've also cross bonded my water pipes, gas pipe, conduit, boiler, and water heater extensively, using heavy braid (sheath from scraps of RG-8/U) and stainless hose clamps, which may help reduce intermodulation TVI. The conduit that feeds the shack has braid jumpers across all of its joints and to the power panel.

Outside ground

In commercial work we use no. 2 gauge wire (no strands smaller than no. 17 gauge) for any conductor that must carry full strike current without vaporizing, and no. 6 gauge for miscellaneous grounds like rain gutters and chain link fence. At home I use 3/8" copper tubing between the tower legs and each of three ground stakes, between the stakes, and to inside ground (see Figure 4). I flatten the ends and either drill for bolts, or wrap around a stake and drill, bolt, and solder as in Figure 4. My stakes are 8 feet long, 10 feet apart, and at least 6 feet from the house. They are driven so the tops are a foot below grade; the tubing is also about a foot deep. In addition, my guy anchors, well casing, and power ground augment my shack ground.

Experts recommend you put a no. 2 gauge perimeter wire around the house below the frost line several feet from the house, with ground stakes at the corners. This is primarily to equalize the slab step voltage, but it also augments outside ground. Without this wire around the foundation, any equipment (including insulated cables or a steel desk) within several inches of the slab may side flash to it. Use a wood desk on a slab and keep the cables off the floor!

Experts also bury a grid of no. 6 gauge wires below places where people might walk during a storm. Without this grid, a stroke could produce a "step voltage" gradient in the ground such that the surge current would prefer to take a path through a body — from one foot to the other. Unless you have a fully developed outside ground, stay away from it during storms!

Setting priorities

Your first priority is people protection. This means using increased grounding and taking care to ensure a good, well-integrated ground system. Next, you'll want to provide surge protection on the AC power lines of your expensive electric equipment so you needn't suffer the aggravation that follows surge damage. You'll want to hook up your Amateur gear in such a way that it's immune from surging if properly shut down. You may wish to provide a degree of surge attenuation for your radio equipment in case you are caught unaware of an approaching storm. This, in large measure, will depend on circumstance and, perhaps, your pocketbook. You can obtain the most protection for your money by adding a small ground window in your shack, combined with a modest outside ground. Thereafter, augmenting the outside ground will add still more improvement.

I hope the information I've presented here starts you off in the right direction. Check the bibliography at the end of the article for valuable source material. **hr**

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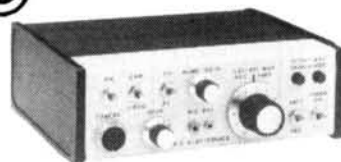
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2522 Paxson Ln Arcadia CA 91006

Maryann (WB6YSS)

Ham Notebook

Finding the source of computer-generated interference

Using a computer system near an Amateur Radio receiver (operating a packet radio station, for example) is likely to cause receiver interference. To pinpoint the source of the interference, go through this quick check list while listening to the noise in the receiver:

1. Disk drive: Does the noise appear only when the disk drive is transferring data? Does the noise disappear when the drive is turned off? Does the noise change in intensity when you move the drive cables?
2. Monitor: Does the noise stop when the monitor is turned off? Does the noise stop if you move the cables?
3. Printer: Does the interference occur only when the printer is running a print job, and stop when the printer is turned off?
4. TNC: Does disconnecting the audio cable solve the problem? Does turning off the TNC solve it?
5. Computer: Does turning off only the computer remove the interference?

If this procedure fails to find your culprit, tune a portable AM radio to an unused portion of the band and use it to sniff out the source of the problem. You'll probably be surprised at the variety of different computer-generated noises the receiver picks up. Concentrate on the type of noise affecting your radio receiver and ignore the rest, since it's not impairing your reception. Move the AM receiver near cables, power cords, and disk drives to find out where the noise originates.

I used this technique and found that my interference problem occurred only when my Commodore 64 was on. The interference was in the form of RF coming from the computer itself. I wrapped a piece of brass window screen and cardboard insulation around the motherboard and soldered the screen to a ground connection. This solved the problem completely and took only about an hour to do.

Dean F. Poeth II, K8TM



HOMEBREW DIPLEXER

There are now several good dual band (144/430 MHz) antennas available. Unfortunately, many of the dual band rigs have separate antenna input sockets for each band. How do you cope with the problem of getting one plug into two sockets? The answer is a simple bit of circuitry called a diplexer. This device sorts out the various frequencies and routes them to the appropriate rig. They are available commercially at a rather high price. But those that I have measured, while safe to use, don't show up too well on separation and also tend to have an unacceptable loss when placed in circuit.

The circuit

The circuit of a homemade diplexer, which is well within the construction capabilities of the newcomer to homebrewing, is shown in Figure 1. It

consists of three coaxial sockets and four series-resonant circuits. I hope you'll remember that a series-resonant circuit has a very low impedance at resonance and a high impedance off resonance. How does the circuit work?

Consider a 144-MHz (2 meter) signal coming in on the antenna socket SK2. The tuned circuit L2/C2 is resonant at 144 MHz and, having a low impedance, passes the signal to the 2-meter output SK1. The tuned circuit L3/C3, being resonant at 433 MHz, exhibits a high impedance at 2 meters and so stops the 144-MHz signal from reaching the 70-cm output socket SK3. On 433 MHz the opposite action takes place.

More protection

The action already described will do a fair job, but it can be improved upon.

PARTS LIST

Capacitors Trimmers

C1,3 5 pF
C2,4 15 pF

Inductors

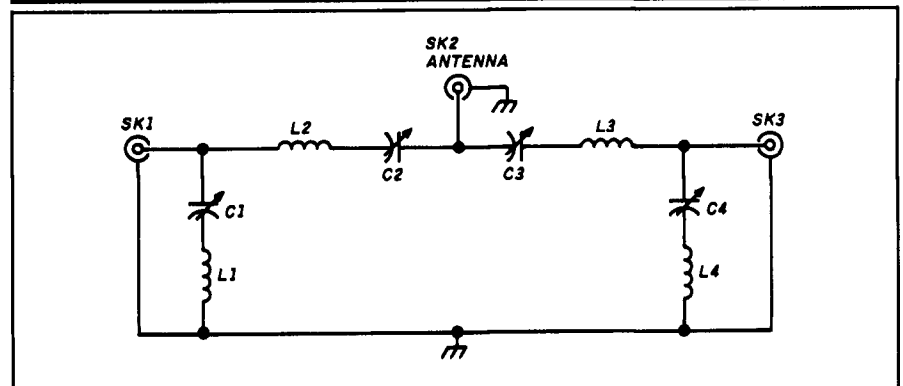
Air spaced, self-supporting

L1,3 3 turns 22 a.w.g., 6 mm diameter, 12.6 mm long
L2,4 5 turns 22 a.w.g., 6 mm diameter, 20 mm long

Miscellaneous

Sockets, BNC, N, etc., as required (3 off); die-cast box; nuts, bolts, washers, and solder tags.

FIGURE 1



Circuit diagram of the 144 MHz/430 MHz diplexer.

The tuned circuit L1/C1, which is connected from the 2-meter output to earth, is series resonant at 433 MHz and so any signal at that frequency which manages to find its way through L2/C2 is shorted to earth. As it has a high impedance off resonance, L1/C1 has no effect on the 144-MHz signals. The tuned circuit L4/C4 is series resonant at 144 MHz and removes any leakage which reaches the 70-cm output socket at that frequency.

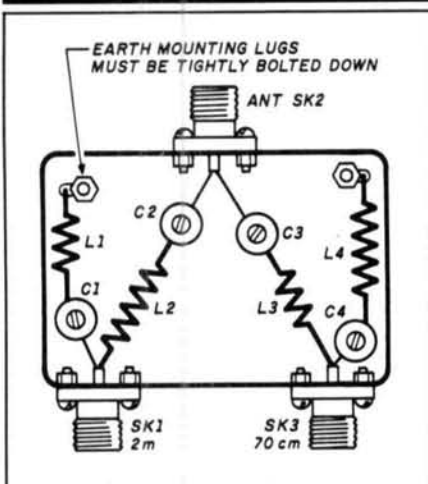
Specification

How well does the circuit do its job? The insertion or through loss was measured at less than 0.1 dB on 144 MHz, and was slightly higher at 0.17 dB on 433 MHz. When you consider that you need a loss of 3 dB to lose one S point of signal strength, these losses can be disregarded. The blocking of 144 MHz at the 70-cm output, and of 433 MHz at the 2-meter output, was greater than 60 dB. This means there's an unwanted output of 1 μ W for every watt of power applied, which is more than satisfactory.

Construction

The unit can be built in a small die-cast box; a suitable layout is shown in Figure 2. The trimmer capacitor types

FIGURE 2



A layout suitable for operation at fairly low powers.

required will depend on the transmitter powers to be used. Ceramic piston and compression types are suitable for low powers; for higher powers air-spaced trimmers (e.g., Jackson C804 series) will be necessary. Ed.

Tuning the unit is simple. First connect the rigs to the correct output sockets. **DO NOT TRANSMIT** until all the following steps are completed.

Tune the 144-MHz rig to a strong signal and adjust C2 for the highest S-meter reading. Tune the 433-MHz rig to a strong signal and adjust C3 for the best S-meter reading.

Now connect the 144-MHz rig to the 70-cm output on the diplexer and the 433-MHz rig to the 2-meter output. Tune to a strong 144-MHz signal and adjust C4 for **minimum** S meter reading. Tune to a strong 433-MHz signal and adjust C1 for **minimum** S-meter reading. For safety, run through all the above steps a second time, then reconnect the rigs to the correct outputs and the job is completed. **hy**

Glen Ross, G8MWR

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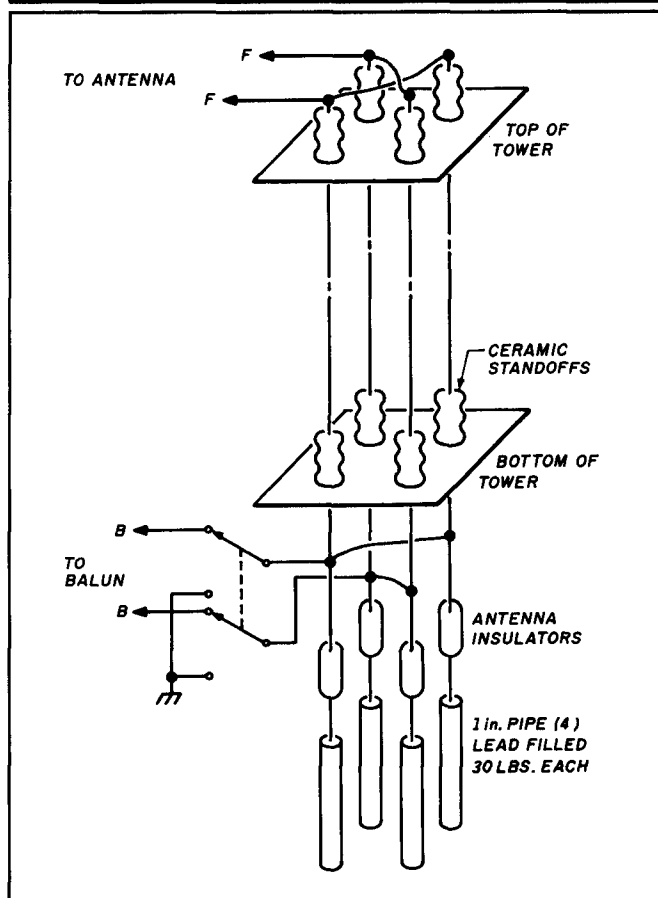
My interest in long wires was sharpened in the mid-1970s when I acquired my first solid-state transceiver that required no tuneup. It seemed to me that transmitter technology had left antenna development behind. Wouldn't it be a great improvement to have a single high performance all band antenna fed with a single coaxial cable? Think of the convenience! When operating in contests you could switch bands with no time lost. During a QSO, you could check quickly to see if another band was open. You'd be free to operate on any Amateur HF frequency, without the limitations imposed by antenna bandwidths and high SWR. You could explore every nook and cranny of our extensive frequency allocation and find new friends who rarely leave "home" frequencies. I felt long wires offered the best opportunity to achieve that ideal.

After many months of testing performance on the air and experimenting with numerous configurations, I came to the following conclusions:

- Under skip conditions, V antennas were vastly superior to straight long wires or dipoles. This wasn't due to azimuth gain — they excelled in any direction. Ground wave measurements weren't at all similar to measurements taken during skip contacts.
- A resonant wire, approximately center fed and an odd number of half waves in length, offered a consistent impedance in the vicinity of 200 ohms. If additional wire legs resonant on other frequencies were added, the impedance varied only slightly. If the feedpoint was moved from the center of the element as much as 1/8 wavelength there was surprisingly little shift in impedance.

These findings suggested a whole family of new antenna designs, but I concentrated on my ideal — all bands, one coax. My final design was highly successful and I published it with the associated test and measurement results in the Amateur literature.¹ The final design had one drawback. It occupied about ten acres; not many urban Amateurs could fit it into their backyards. Despite this, I received letters from

FIGURE 1



Detail of the 4-wire 200-ohm feedline and grounding relay.

rural users in many states, and from as far away as VK-land. The Australians were particularly pleased. The antenna performed flawlessly on the commercial frequencies they used in addition to Amateur bands for communications in remote areas.

These antennas are also appealing because they don't require expensive hardware which would oxidize outdoors. I used a single 40-foot wooden mast and aluminum electric fencing wire, which I bought in quarter-mile rolls from commercial suppliers. Trees provided the only other supports.

Antenna feed

Feeding a 200-ohm antenna is simple. It requires a 4:1 balun and 50-ohm coaxial cable. Of course, because commercial baluns usually aren't perfect, a word of caution is in order. I suffered a 3:1 SWR on 10 meters for a year before a nearby lightning strike caused the balun to explode like a hand grenade, littering the yard with plastic fragments. Many of the letters from users of identical antennas had reported unity SWR. That lightning strike was a great help. A new balun cured my SWR problem. After the strike, I took more precautions. These involved moving the balun from the top of the mast to the bottom, and installing a 200-ohm open wire line with a relay which grounded the antenna and disconnected the balun automatically when the transceiver was turned off. The 12 volts DC for the relay was supplied by the transceiver power supply. I recommend you try this procedure if you're in an area that experiences frequent electrical storms. Figure 1 shows the details. Four no. 10 copper wires are arranged in a square on 2-inch centers and the diagonally opposite wires are joined together at each end of the line. This line has much lower loss than coaxial cable — a worthwhile bonus. I removed the bolts from the ceramic standoffs and fed the wires through the holes, so the insulators acted as guides. The shelves holding the standoffs had 1-inch holes on the wire centers, providing plenty of clearance. I captured the wires above the top insulators with brass washers that I silver soldered to the wire. If this sounds like a lot of work, there's a shortcut. There was 200-ohm twin lead on the surplus market a few years ago, which would work well in this application. However, finding it is difficult.

The Novice license now allows operation on four HF bands. Old-timers, their backyards already bulging with antennas, may not want to add more for WARC bands. It appears there's an urgent need for multiband antennas to gain access to these new bands, without adding significantly to the hardware already in our yards.

I've come up with some antennas which I think get to the heart of this problem. They're all 200-ohm impedance designs which can be fed with 4:1 baluns and 50-ohm coaxial cable. Most can fit into an urban backyard. You'll notice a few monobanders among the designs. They occupy more space than a conventional dipole; so why use them? The answer is performance. They provide more capture area, and a configuration that has proved superior in extensive on-the-air testing.

Another feature of these antennas is the 90-degree apex angle, suggesting a V antenna. A V antenna which yields bidirectional gain is fed with the legs in phase. These are fed out of phase, and this makes them quite different electrically. I couldn't measure any directivity when I used these antennas under skip conditions.

The antenna diagrams in the figures show top views of the antenna wires. Their lengths are identified in feet. The two small circles at the wire ends are the connection points for the 4:1 balun.

Monobanders for the Novice

Perhaps you already have several Novice bands covered and wish to add one more. You may want to operate on just one band. In either case, one of the designs in Figure 2 is for you. These designs require three times the wire of a conventional dipole — and for good reason. The configuration and

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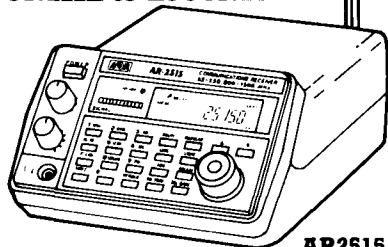
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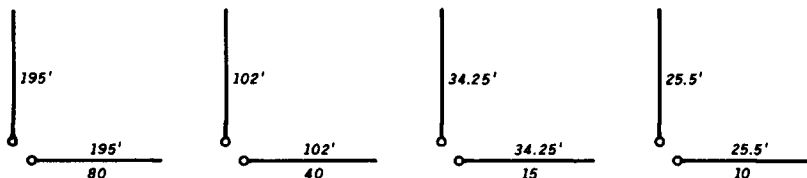
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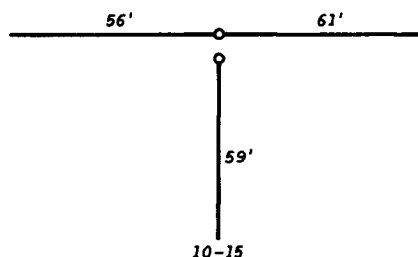
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FIGURE 2



Length of element			Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
Band	Half waves	Feet			
80	3	390	3.72	3.66—3.77	3.70—3.75
40	3	204	7.11	7.00—7.22	7.10—7.15
15	3	68.5	21.18	20.87—21.50	21.10—21.20
10	3	51	28.46	28.03—28.88	28.10—28.50

FIGURE 3



Length of element			Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
Band	Half waves	Feet			
15	5	115	21.18	20.86—21.50	21.10—21.20
10	7	120	28.50	28.07—28.93	28.10—28.50

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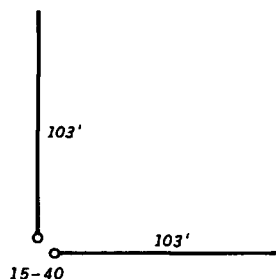
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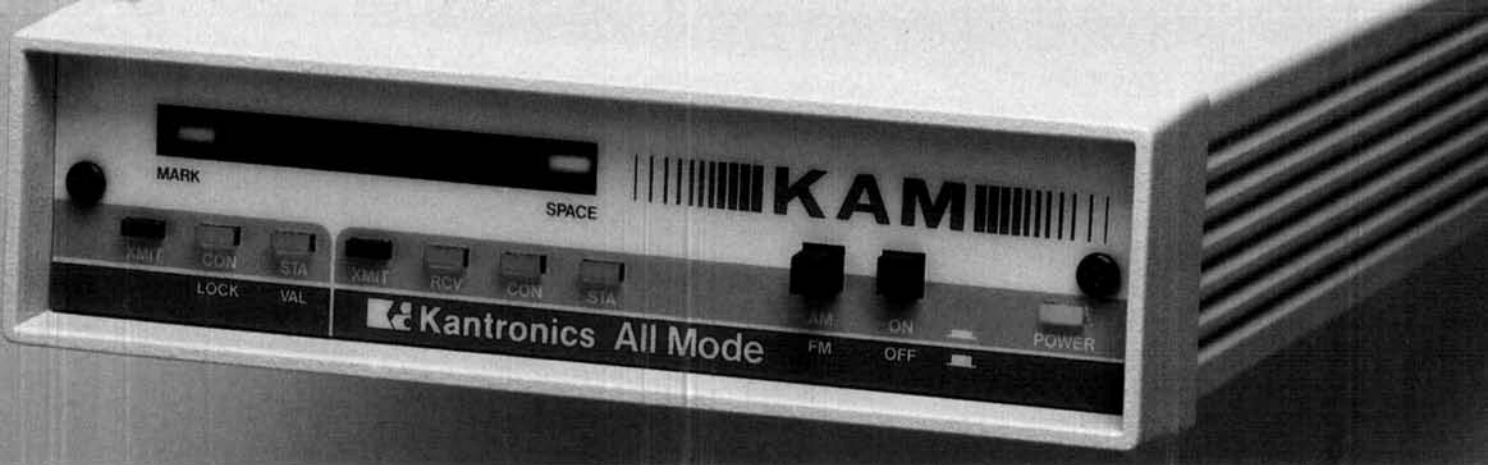
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FIGURE 4



Length of element			Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
Band	Half waves	Feet			
40	3	206	7.05	6.94—7.15	7.10—7.15
15	9	206	21.38	21.05—21.70	21.10—21.20



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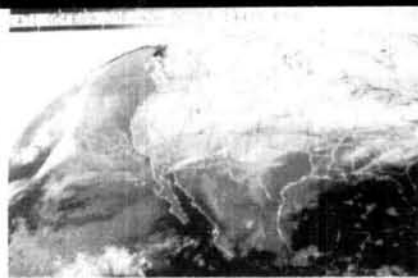
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FIGURE 5

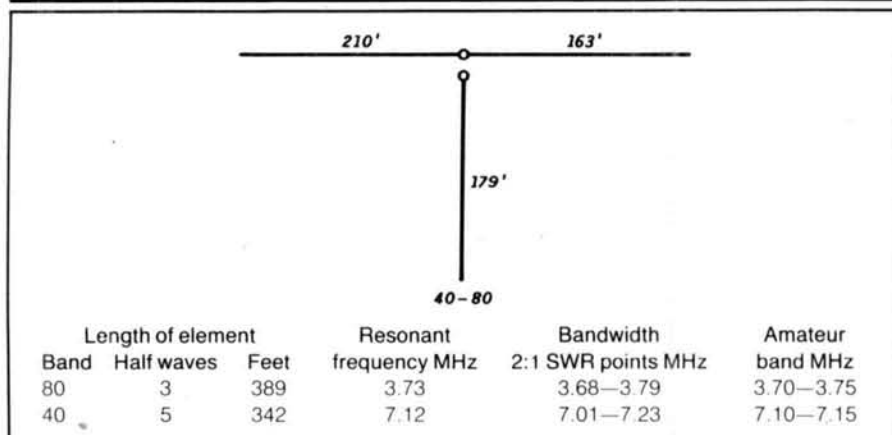


FIGURE 6

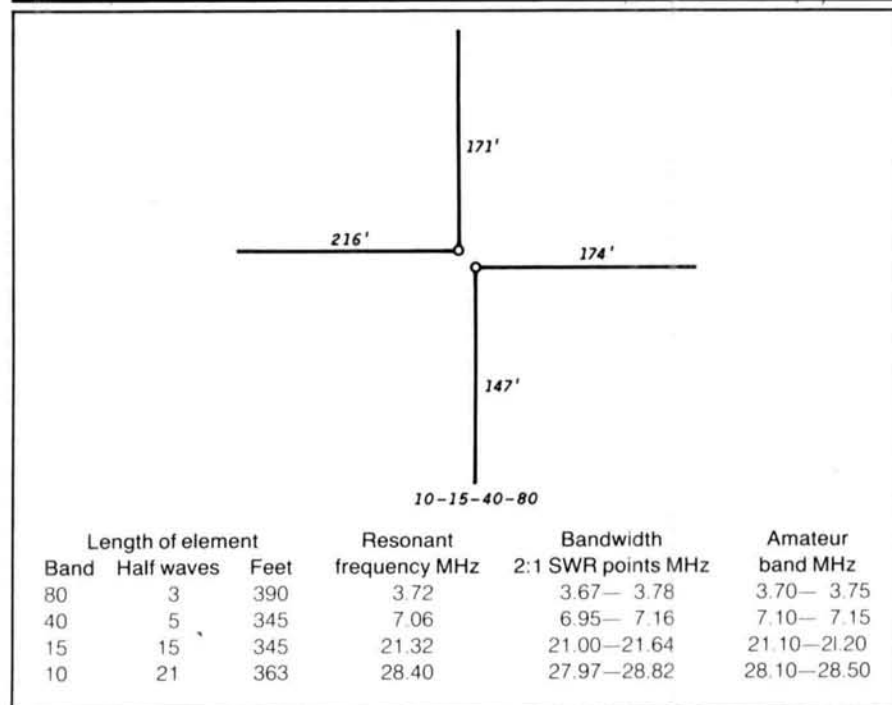
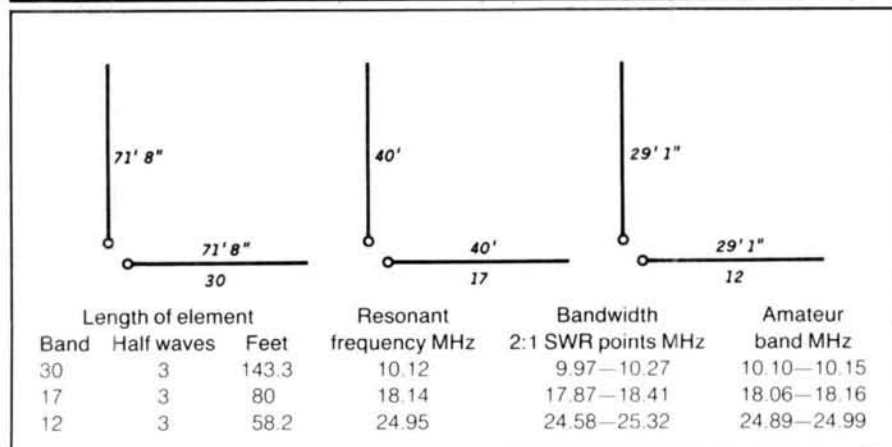


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capture area provide better performance, and they don't have the nulls of a dipole. They are good performers in all directions.

Dual band Novice

This antenna is tailored for the 10 and 15-meter Novice bands (see **Figure 3**). It's compact and will fit into most backyards. Use one band or the other, without any antenna tuning or switching; the SWR remains low. The cost is also low. All you'll need is under 200 feet of inexpensive wire, coaxial cable, and a balun. Total cost, including insulators and rope, can run as little as \$50.

Figure 4 shows an antenna for 15 and 40-meter coverage that uses a little more wire for about the same cost as the preceding design. It's simple to install, and has just two legs. The antenna is resonated in both bands by 206 feet of wire. One antenna does double duty and, like all of these designs, it provides low SWR and excellent performance. If you can't fit the wires onto your property with the 90-degree apex angle, you can make it a straight, center-fed long wire. The SWR will continue to be low; however, the antenna becomes directional and performance suffers on some headings. But this may be your best compromise.

Unfortunately, there isn't a wire length of reasonable dimensions which will resonate on both 80 and 40. The solution is to revert to the three-leg design in **Figure 5**, which provides a different length for each band. The two resonances fall almost in the center of the Novice segments and this, together with the large area of the array, makes it a very efficient performer. It's ironic that resonances also fall in the 15 and 10-meter bands, but the feedpoint is far removed from the current loops resulting in high SWR on these bands.

All band Novice

The antenna in **Figure 6** gives access to all four Novice HF bands. And, when you upgrade to General, it stands ready to serve in other segments. Though I haven't shown it here, the 363-foot element resonates at the high end of 80. This opens 3.9 to 4 MHz up to SSB. In addition, the 345-foot length resonates at the top of the 10-meter band, allowing SSB operation above 29 MHz. This antenna is large, but don't let that deter you. If you have friendly neighbors, you may be able to run unobtrusive wires through the trees over their properties. I did this for a number of years using inexpensive electric fencing wire.

WARC monobanders

The monobanders in **Figure 7** are for the ham who wants to add a WARC band. If you cut the wire lengths carefully to the measurements shown, and your antenna is reasonably in the clear, the resonance will fall almost dead center in the band. This will give you a low SWR from band edge to band edge. These element lengths give no resonances on other HF Amateur bands, and shouldn't interfere with existing antennas.

Dual band WARC

Are you a General who hasn't tried 12 or 17? Here are two antennas which give you both 12 and 17. They are compact and can be erected in the average backyard. I've given two alternatives in **Figures 8A and B**. Choose the one which best suits your layout. If you have a tower available, use it as the main support with the legs coming down like an inverted V. A flat top, however, is preferable. None of the element lengths

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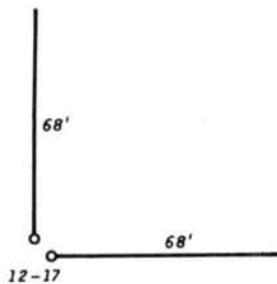


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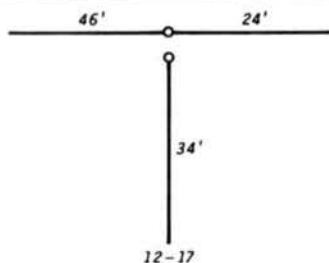
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FIGURE 8A



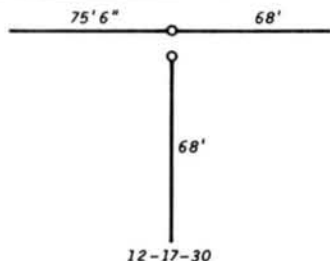
Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
17	5	136	17.90	17.63—18.18	18.06—18.16
12	7	136	25.14	24.76—25.52	24.89—24.99

FIGURE 8B



Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
17	3	80	18.14	17.87—18.41	18.06—18.16
12	3	58	25.02	24.65—25.40	24.89—24.99

FIGURE 9



Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
30	3	143.5	10.11	9.96—10.27	10.10—10.15
17	5	136	17.90	17.63—18.18	18.06—18.16
12	7	136	25.14	24.76—25.52	24.89—24.99

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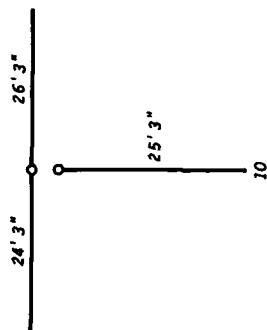


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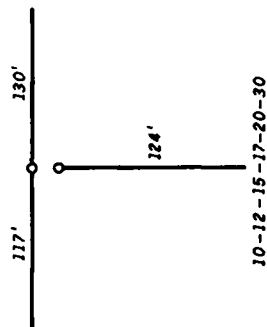


FIGURE 10



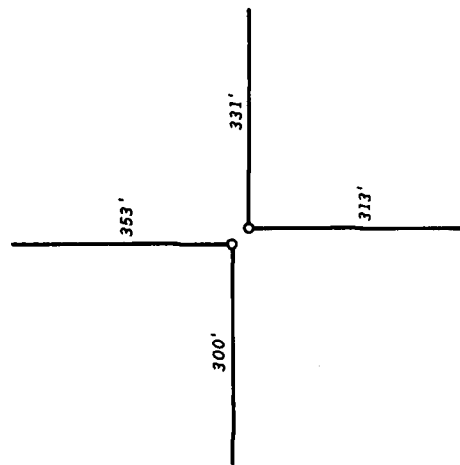
Length of element		Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
Band	Half waves			
10	3	28.18	27.76—29.76	28.00—29.70
		29.32		
	49.5			

FIGURE 11



Length of element		Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
Band	Half waves			
30	5	10.10	9.95—10.26	10.10—10.15
20	7	14.19	13.98—14.40	14.00—14.35
17	9	18.27	18.00—18.54	18.06—18.16
15	11	21.21	20.89—21.53	21.00—21.45
12	13	25.08	24.71—25.46	24.89—24.99
10	15	28.95	28.52—29.30	28.00—29.70

FIGURE 12



Length of element		Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
Band	Half waves			
80	5	3.97	3.50—4.03	3.50—4.00
	5	3.86		
	5	3.66		
	5	3.56		
40	9	7.18	6.80—7.30	7.00—7.30
	9	6.98		
30	13	10.00	9.95—10.25	10.10—10.15
20	19	14.00	13.79—14.35	14.00—14.35
17	23	18.42	17.62—18.70	18.06—18.16
	23	17.89		
12	31	24.84	24.46—25.21	24.89—24.99
10	35	28.05	27.63—29.24	28.00—29.70
	37	28.81		
	39	28.77		
	39	28.02		

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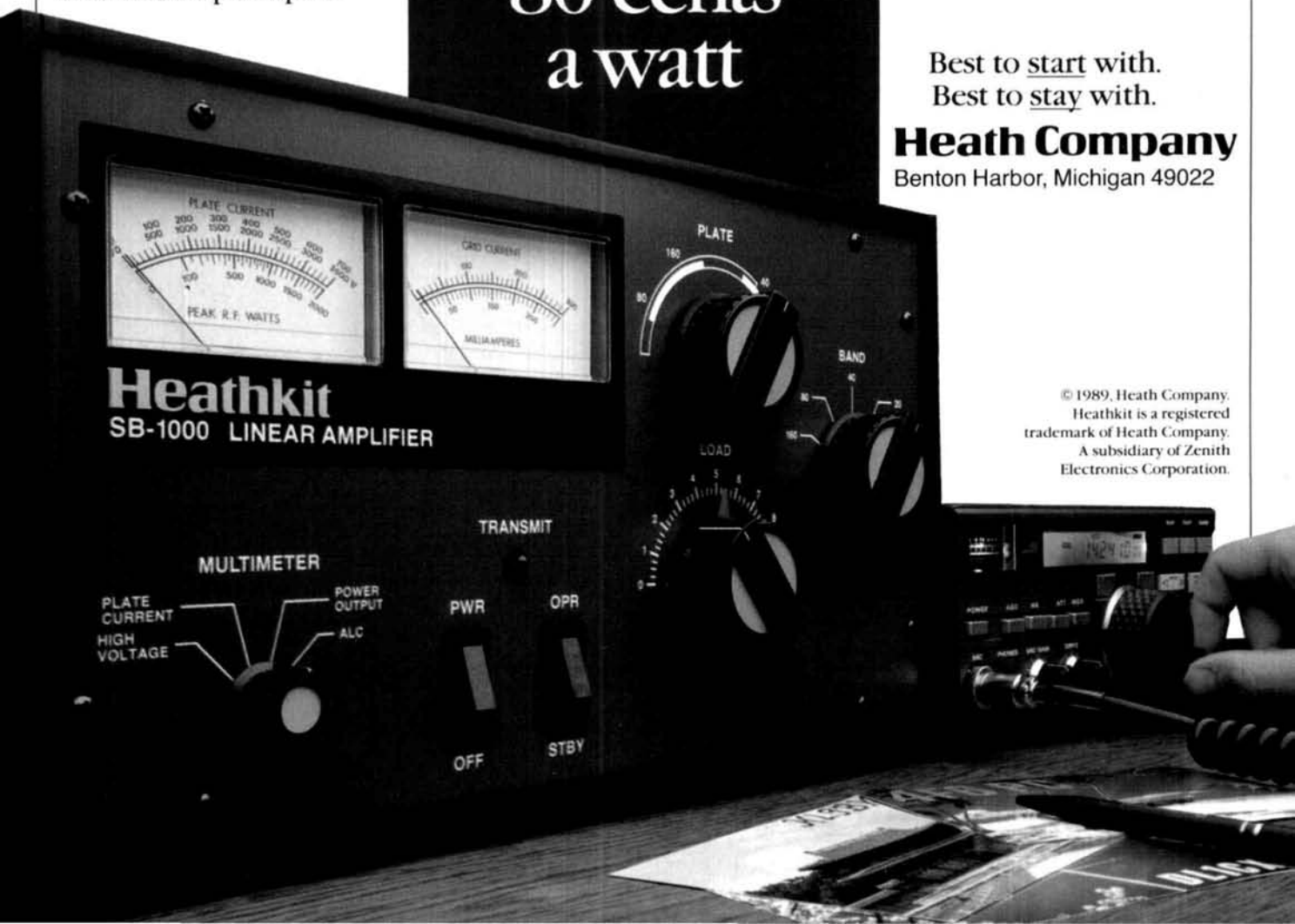
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on the three-leg design resonate on or near other Amateur bands, so it shouldn't pose a problem for your Yagis or other antennas. The three-leg design also provides a somewhat lower SWR. On the other hand, the two-leg design will resonate on 40, 20, and 10 meters, and should be kept clear of other antennas on those bands.

Triband WARC

Here's your chance to put up one antenna with capabilities on all WARC bands! (See Figure 9.) While these designs will function satisfactorily when installed as inverted Vs, it's preferable to make them flat tops. Unlike a dipole, which has a single current loop at the center, these antennas have at least three current loops (including one in the center). The current loops provide maximum radiation.

Broadband 10-meter monobander for general coverage

Because this band is so much wider, it poses problems of band coverage with narrowband antennas. The design shown in Figure 10 will cover the entire band. Don't use a coaxial balun; it will limit your bandwidth. If you wind your own, use the Amidon iron powder kit with eight bifilar turns instead of the usual ten. On this HF band, worry about coaxial cable losses. RG-58, with a run of 100 feet and transceiver output of 100 watts, will deliver only 56 watts to the antenna. By comparison, Belden 9913 or equivalent will deliver 85 watts to the antenna in similar circumstances on 10 meters.

Six band general coverage

The simple antenna in Figure 11 will deliver six of the nine HF bands! It provides the traditional DX bands, plus all WARC frequencies. The resonances fall within all the bands but 17 and 12, where they are slightly on the high side. However, the antenna bandwidth amply covers these two WARC bands with an SWR of less than 2:1. A commercial balun will handle this design; but if you use a kit and wind your own, I suggest once again that you use eight turns instead of the usual ten. The fewer turns will slightly lower SWR on 10 and 12 meters.

Eight band general coverage

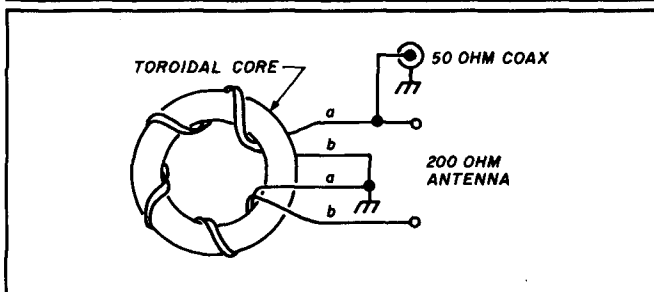
This is the "Monster." It covers about ten acres (see Figure 12). Since the publication of the details of this design¹ it has been used in many states and DX locations. Nearly all users reported SWR readings on each band similar to those I had experienced.

All of the preceding antennas require a 4:1 balun to give a good match with RG-58 or RG-8 type 50-ohm coaxial cable. I have provided several options.

Toroid balun

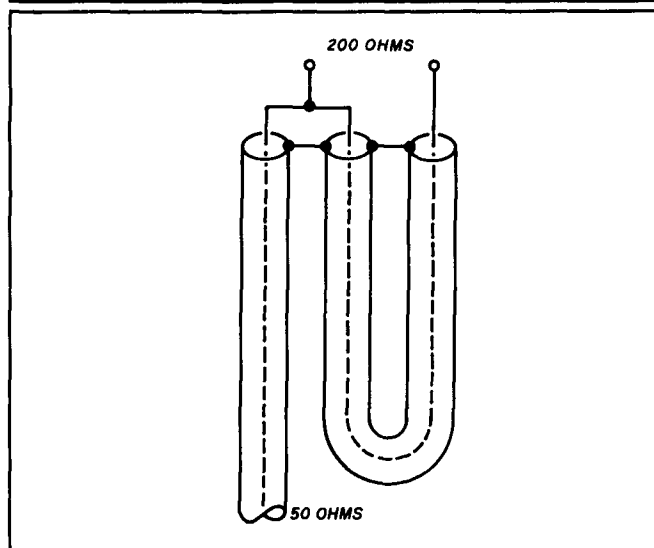
There are a number of commercial baluns available from Amateur equipment distributors. Be sure you get a 4:1, not a 1:1 (see Figure 13). If you'd like to wind your own, you can order a kit from Amidon Associates or Radiokit.* They come with instructions suggesting they be packaged in PVC pipe. I recommend you wrap the core with Scotch® no. 27 glass electrical cloth tape. You can get epoxy potting material from your local electrical supply house and completely encapsulate the unit. The final professional touch for the ultimate in reliability is to do the potting in a high school or college science

FIGURE 13



Detail for winding a 4:1 balun.

FIGURE 14



Detail for making coaxial balun.

lab, and immediately place it in a vacuum jar. This removes all bubbles or moisture.


Coaxial balun

You can make your balun of coaxial cable for **some** of the monoband antenna designs I've described. Details are shown in Figure 14. The U section may be coiled and secured with tape; its length is as follows:

Coaxial cable length U section

Band	Solid	Foam
80 Novice	87'2"	104'4"
40	45'7"	54'7"
30	32'1"	38'5"
17	17'10"	21'6"
15	15'4"	18'5"
12	13'	15'7"
10 Novice	11'5"	13'8"

Conclusion

I hope you'll give one of these long wire antenna designs a try. Pick a band (or bands) that your existing antenna system doesn't cover, and put one to the test. I'll look for you on the air! 

REFERENCES

- 1 E.S. Brown, K4EF, "Antenna Design Using the Long Wire Principle, *Ham Radio*, May 1977, page 10

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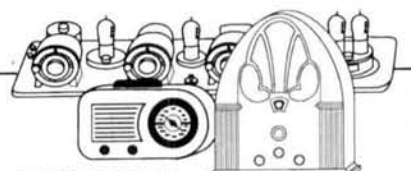
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Practically Speaking

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VERTICALLY POLARIZED HF ANTENNAS: PART 2

Last month I introduced a series on vertical antennas. I discussed the basic theory and configuration of the "standard" quarter-wavelength vertical antenna. This month I'll take a look at some practical issues involving the much-needed ground system for the vertical, and vertical antenna construction details.

Vertical antenna ground systems

The vertical antenna works well only when placed over a good ground system. The usual way to provide a good ground for a vertical is to use a system of radials like that shown in **Figure 1**. A view from above shows 16 quarter-wavelength radials arranged to cover a full circle around the antenna. Each radial is a quarter wavelength, so each will have a length (in feet) of $246/F_{\text{MHz}}$. All the radials are connected together at the base of the antenna, and the ground side of the transmission line is connected to this system. The radials may be placed on the surface or underground. A friend of mine placed an extensive radial system on the bare dirt when his house was being built. When the sod was laid down, he had a very high quality underground radial system.

If you decide to use an above-ground radial system, be sure to make provisions to prevent people from tripping over it. You may be liable if people trip over your radials and injure themselves — even if the person is an intruder or trespasser!

Some experts prefer to place a copper wire screen at the center of the radial system. The minimum screen size is about 2 meters (6 feet) square. Use solder to connect it to the radials at the points shown in **Figure 1**. Other experts drive ground stakes into the ground at these points. Still another

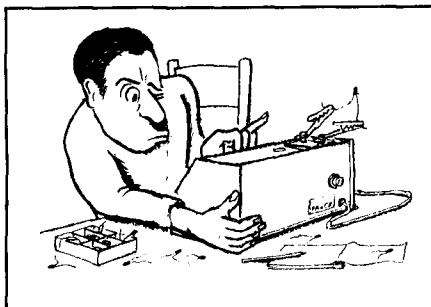
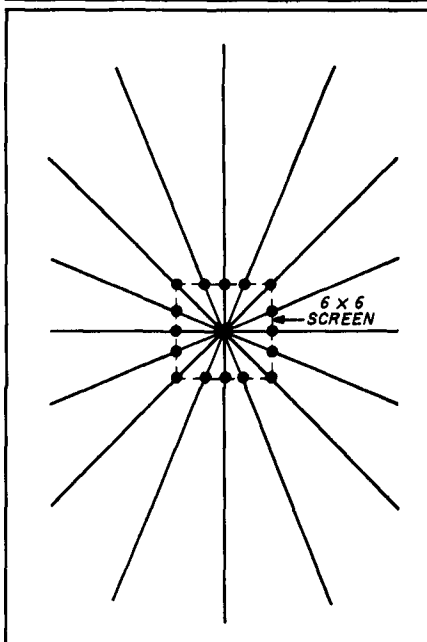


FIGURE 1



Basic ground radial system.

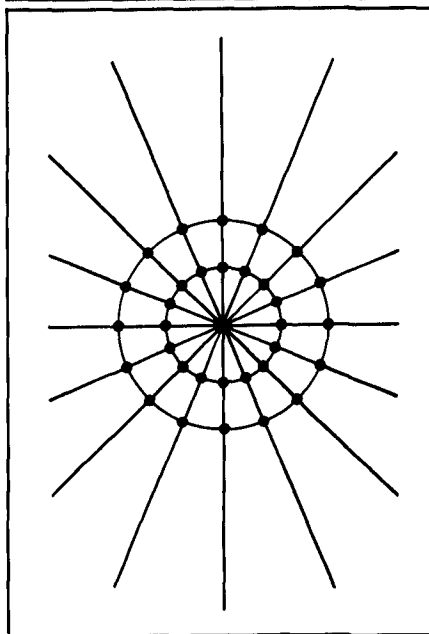
method is shown in **Figure 2**. Here you see a "spider web" of conductors shorting the radials at points a meter or two from the antenna. Again, some authorities recommend that ground rods be driven into the earth at the points indicated.

The exact number of radials you use depends in part on practical matters — like how much money you have to spend, or how many you can physically install. Use at least two radials per band; four per band is preferred for simple, low cost systems. However, be aware that even four radials is considered a compromise. The general rule is: the more radials, the better. But

there's also a law of diminishing returns as the number of radials increases. **Figure 3** shows the approximate field intensity (mV/meter) as a function of the number of radials. Notice that the field intensity doesn't increase as rapidly per extra radial when the total number of radials is above 20 or so. The Federal Communications Commission requires AM band (550 to 1620 KHz) stations to use 120 radials, but that number isn't necessary for Amateur stations. A practical upper limit of 16 radials is usually accepted for Amateur radio work, and your antenna can work well with fewer.

For vertical antennas mounted above ground, there's an optimum height for the base of the antenna. This height is a quarter wavelength above the actual ground plane. Unfortunately, that distance may or may not be the actual physical height above the surface. Depending upon ground conductivity and ground water content, the height may be exactly a quarter wavelength above the surface or

FIGURE 2



Spiderweb ground radial system.

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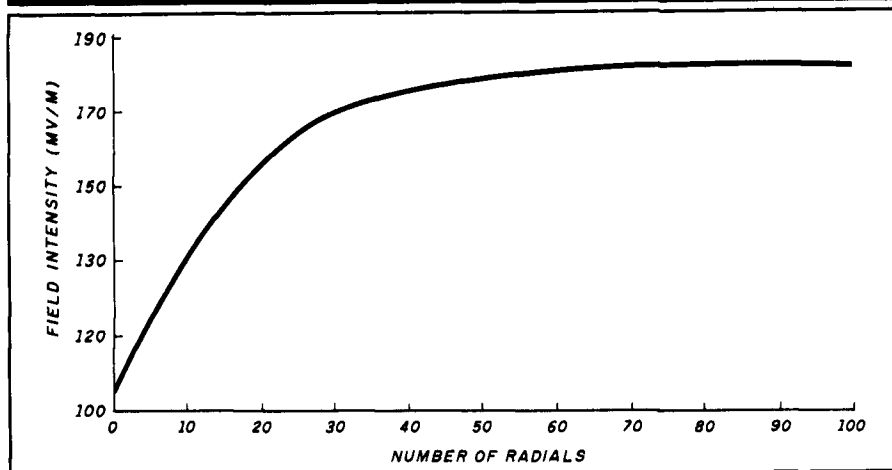
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FIGURE 3



Effect of the number of radials on the effective radiation of the antenna.

slightly lower. Find the optimum height by experimenting; remember that it will vary over the course of the year if climatic changes are the norm in your location.

Vertical antenna variants

So far, the vertical antennas I've considered have been standard quarter-wavelength models. Let's take a look at several variations. Figure 4 shows the vertical half-wavelength dipole. The vertical dipole is constructed in exactly the same manner as the horizontal dipole, but is mounted in the vertical plane. In general, the section of the radiator closest to the ground should be connected to the shield end of the coaxial cable transmission line.

Like the horizontal dipole, the approximate length of the vertical dipole is calculated from:

$$L_{ft} = \frac{468}{F_{MHz}} \quad (1)$$

Where:

L_{ft} is the length in feet, and
 F_{MHz} is the operating frequency in megahertz.

Of course, each leg of the vertical dipole is one-half the calculated length.

The vertical dipole antenna is used in many locations where it's impossible to mount a horizontal dipole properly, or where a roof or mast-mounted antenna is impossible to install because of logistics or a hostile landlord and/or homeowners' association. Some row and townhouse dwellers, for example, have been successful with the vertical dipole. In the 1950s and 1960s, the vertical dipole was popular among European

Amateurs because of space restrictions in many locations.

Vertical dipole construction is relatively straightforward. First, find or build a vertical support structure. In the system shown in Figure 4, the support is a wooden or heavy wall PVC mast. Thin wall PVC pipe whips around too much in the wind and requires more guy line support than is reasonable; so avoid it for this application. Ropes and insulators at either end support the wire elements from the ends and keep the antenna taut. If neighbors are a problem, try to find some white thick wall PVC pipe that you can use to build a fine flagpole (be patriotic), and simply hide a vertical dipole inside it. If your home doesn't have metal siding and is tall enough, a support from the roof structure (or soffits) will make a proper support.

One problem we liability-conscious people need to consider when using a vertical dipole is the high impedance voltage at the ends of a half-wavelength dipole. Anyone touching the antenna is likely to receive a nasty RF burn or shock.

Coaxial vertical construction is similar to that of the vertical dipole in that it uses a pair of vertical radiator elements. It can even be argued that it's a form of vertical dipole. However, with the coaxial vertical antenna, the radiator that's closest to the ground is coaxial with the transmission line and the main radiator element (see the example in Figure 5A). An insulator at the feedpoint separates the two halves of the radiator. In most cases, the top radiator is smaller in diameter than the

coaxial sleeve (also called the "shield pipe" in some publications). For the most part, the reasons for this arrangement are mechanical rather than electrical. The coaxial cable transmission line passes through the sleeve and is itself coaxial to the sleeve.

The overall length of the coaxial vertical antenna is one-half wavelength, consisting of two quarter-wavelength sections. Both the radiator and the sleeve are a quarter wavelength long. The starting length of each is found (approximately) from:

$$L_{ft} = \frac{246}{F_{MHz}} \quad (2)$$

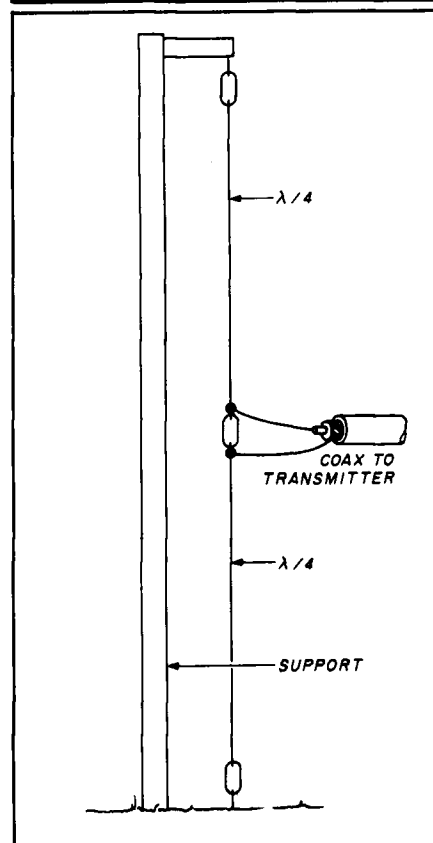
or,

$$L_{meters} = \frac{72}{F_{MHz}} \quad (3)$$

These equations are similar to the one used to calculate half-wavelength antennas, but they are reduced by a factor of 2.

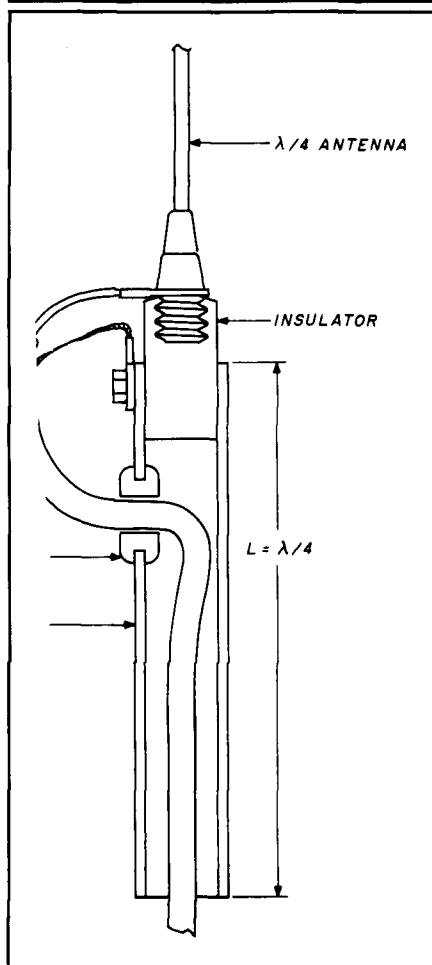
The coaxial vertical antenna was once popular with CB operators and was called the "colinear antenna." You can sometimes find hardware from these antennas at hamfests or surplus

FIGURE 4



Simple half-wave vertical dipole.

FIGURE 5A



Commercially used system for feeding a coaxial half-wave antenna.

markets and modify the pieces for Amateur Radio use. If you're building a 10-meter band antenna, it's a simple matter to cut the 11-meter CB antenna for operation on a slightly higher frequency. But it's a little more difficult for the lower frequency bands, and it's likely that only the insulator and mounting assembly are salvageable. Keep in mind, however, that adjacent sizes of aluminum tubing are designed so that the inner diameter (ID) of the larger piece is a slip fit for the outer diameter (OD) of the smaller piece. This lets you connect adjacent sizes of aluminum tubing together without special couplers. I find that salvaged insulator assemblies with just 6 to 10 inches of the former radiator and sleeve can be cut off, and new radiators from "adjacent size" tubing can be installed.

The configuration in **Figure 5A** is the construction technique used by commercial antenna manufacturers for VHF and CB colinear vertical dipoles.

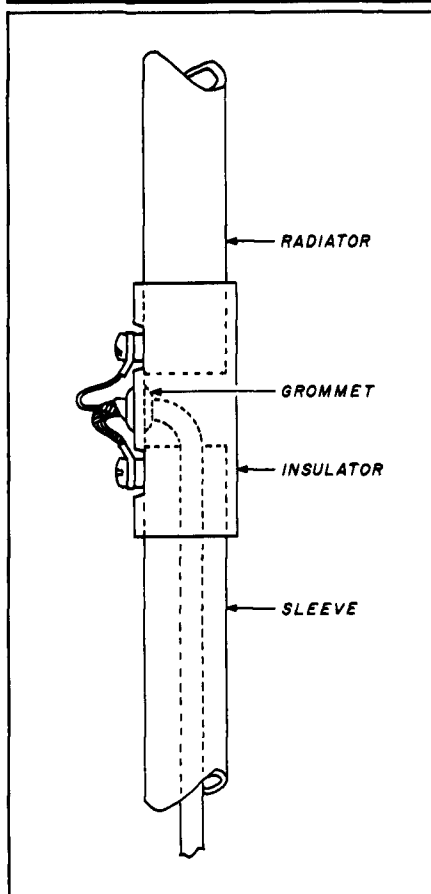
This method is a little difficult for those who don't have access to a machine shop for making the center insulator. You'll need to find another construction method to make this antenna practical.

Figure 5B shows a construction method that has been used by Amateurs with good results. The radiator and shield pipe (sleeve) are joined together in an insulating piece of thick wall PVC plumbing pipe, Lucite™, or Plexiglas™ tubing; 6 to 10 inches of tubing are needed.

Leave a gap of about 2 inches between the bottom end of the radiator pipe and the top end of the shield pipe to keep them electrically insulated from each other, and to allow the coaxial cable to be passed through to the outside world. Drill a hole in the insulator pipe for this purpose.

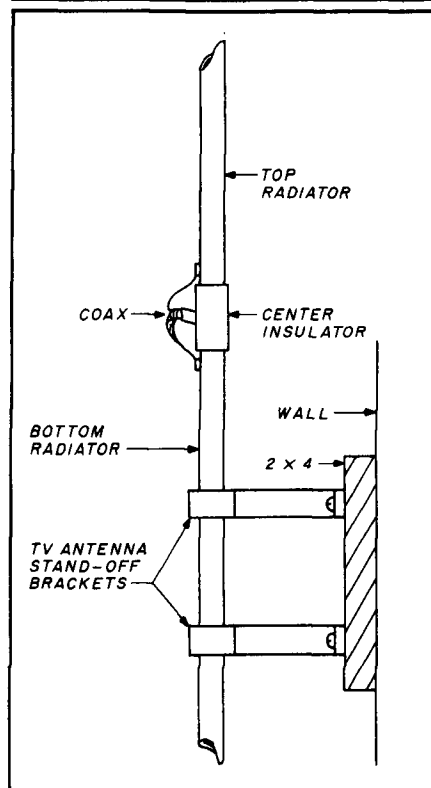
Fasten the aluminum tubing pieces for the radiator and the sleeve to the insulator using at least two heavy machine screws for each. You can use one of the machine screws on each piece as the electrical connection

FIGURE 5B



Homebrew method for feeding a coaxial half-wave vertical.

FIGURE 5C



Antenna mounting scheme.

between the coaxial cable and the pipes, as long as you cut a larger hole in the insulator at that point to admit the washer that provides the electrical pathway between the screw head and the aluminum pipe. If you omit the washer, and depend on the contact between the machine screw and the pipe, your connection will probably be intermittent and cause you quite a bit of aggravation.

Mounting the homebrew coaxial vertical antenna can be a "pain in the neck." Normally this antenna is mounted high in the air, so some form of support is needed. Fortunately, you can use small area metal supports connected to the sleeve. **Figure 5C** shows one popular mounting method that uses a pair of television antenna standoff mounting brackets to support the sleeve. You can buy these brackets in sizes from 6 to 24 inches. Note that a 2 x 4 piece of lumber is used between the building wall and the brackets. This wood serves as an insulator, so it should be varnished or painted. Attach it to the wall with lag bolts, wing bolts, or some other secure anchoring method. Keep in mind that the forces on the brackets increase tremendously during windstorms.



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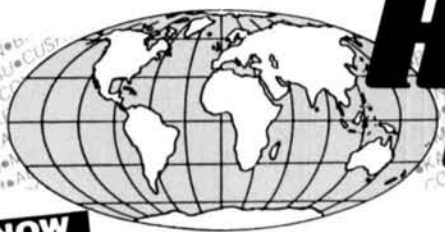
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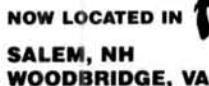
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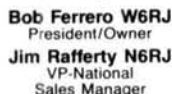
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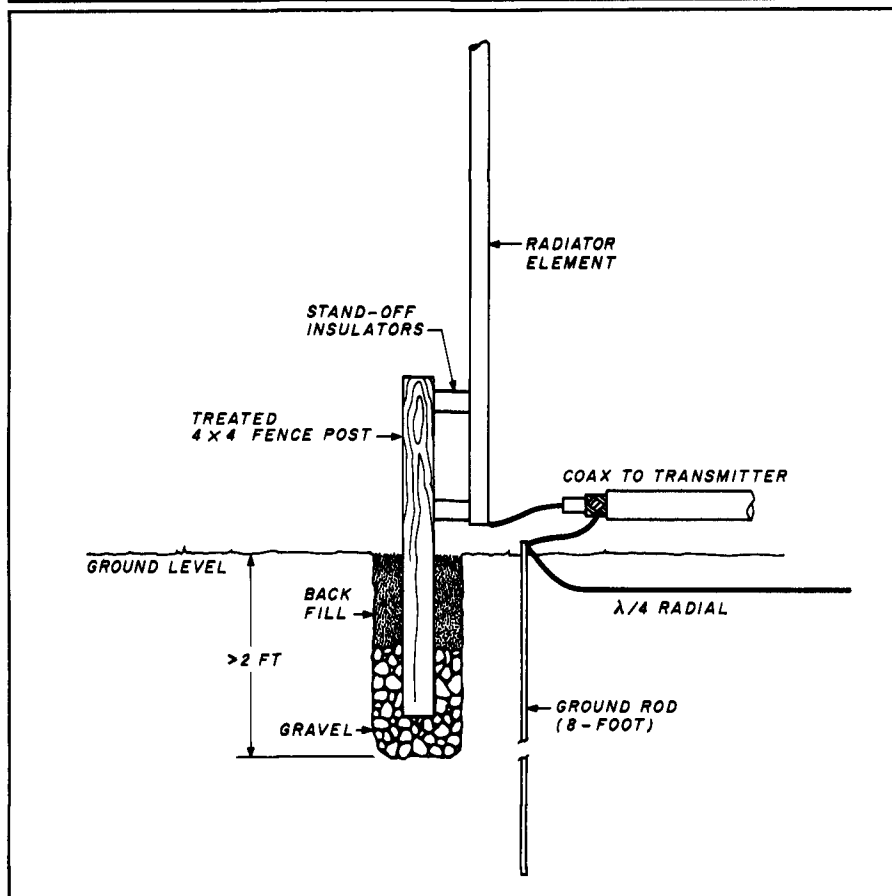


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FIGURE 6



Basic ground installation of a quarter-wave vertical.

The two vertical antennas shown here can present a shock hazard to anyone who touches them. Both of those antennas are half-wavelength radiators and of the dipole form of construction. The center point is used for feeding the antenna, so it forms the low impedance point in the antenna. As a result, the ends of the antenna, one of which is close to the ground, are the high impedance points. This means the voltages at those points can be high, and also within reach of prying hands playing in the yard. It's wise to either mount the antennas so far above ground that they can't be reached, or build a small nonconductive fence around the ends of the antenna.

Vertical antenna construction

Vertical antenna installations are generally ground level or nonground mounted. In this section I'll take a brief look at both forms of mounting, concentrating on the installation of homebrew verticals rather than commercial ones. I assume that the vendors

of these antennas will provide their own instructions.

The ground-level mounted vertical is shown in Figure 6. The typical vertical antenna is 8 to 40 feet high. Thus, although the actual weight of the antenna is small, *the forces applied to the mounting structure can be quite high, especially during windstorms.* Don't be fooled by the apparent light weight of the antenna in this respect.

The mounting structure for the vertical antenna can be a metal or wooden fence post buried in the ground. Make sure at least 2 feet of the fence post are above ground. In Figure 6, a 4 x 4 wooden fence post is used as the mounting, but the principles are similar for all forms of post. Try to make sure you have a fence post hole at least 2 feet deep. In some cases, it may be possible to use 1 foot of gravel fill topped with back-filled dirt. In other cases, especially where a steel fence post is used, place a concrete plug at the bottom of the hole over a 4-inch layer of gravel.

Install the antenna radiator element

to the fence post with standoff insulators. You may have to omit these insulators, as they are difficult to find. Given that varnished or painted wood isn't a very good conductor, it's not unreasonable to bolt the radiator directly to the 4 x 4 fence post. Use 5/16-inch (or larger) bolts; make sure they're long enough to fit through both the antenna element and the 4 x 4 post. Bolts 5/16 inch in diameter and 6 or 8 inches long will probably work best. Use at least two bolts, one at the bottom of the antenna radiator element and one near the top of the fence post. A third bolt, halfway between the other two, wouldn't be out of order.

Generally, no matching is necessary if the antenna is a quarter wavelength. Although the feedpoint impedance isn't exactly 52 ohms, it's close enough (37 ohms) to form a reasonable match for 52-ohm coaxial cable (with VSWR $\approx 1.4:1$). The center conductor of the coaxial cable is connected to the radiator element, while the shield is connected to the ground system. Two ground methods are used in the example shown in Figure 6. The first is an 8-foot ground rod driven into the earth at the base of the antenna; the second is a system of quarter-wavelength radials. Remember that the ground system is absolutely essential.

Figure 7 shows a method for installing a vertical antenna above ground. A wooden support (2 x 4 or 4 x 4) is put up in a manner similar to the one in Figure 6, but a deeper hole is used to counter the longer length. The support can also be affixed to the side of a building wall, shed, or other pre-existing structure. Once you've decided on your support, attach the radiator element using the method described for the previous antenna.

Electrical connections to the antenna are also shown in Figure 7. Because the antenna is above ground level, an electrical counterpoise ground consisting of a system of radials is absolutely essential; provide at least two radials per band. Use a small L bracket to support the radials and provide an SO-239 coaxial connector for the coax. This connector is a chassis-mounted type with its center conductor connected to the radiator element. Fasten the connector shield to the bracket; this connects it to the radial system.

In some installations the antenna support structure will require guy wires

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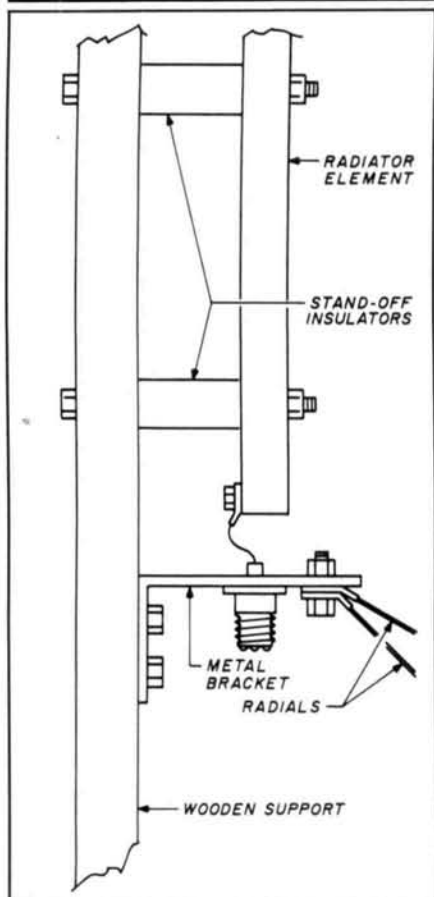
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


Scheme for mounting an elevated vertical with an elevated radial system.

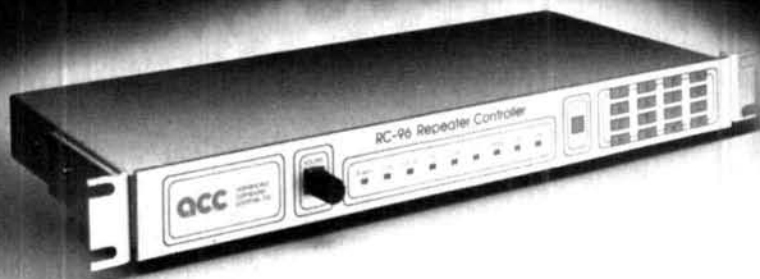
to keep the structure stable. Don't use the radials as guy wires. The type of wire that usually works well for radials is too soft and too easily stretched for guy wire service. Use regular steel guy line, available where TV antenna supplies are sold, for this antenna. Make the lengths nonresonant and break the guy lines up with egg insulators, if necessary, to achieve nonresonance.

Next month...

I'll look at two topics in the final installment of this three-part series. One is the 5/8-wavelength vertical antenna. These verticals have a generally lower angle of radiation than quarter-wavelength antennas, and may offer many Amateurs a superior "DX solution" over the quarter-wavelength model. The second issue that I'll address is safety.

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column. 

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CARD FILE STATION FOR 40 METERS

By Ed Marriner, W6XM, 528 Colima St., La Jolla California 92037

I'd like to tell you about a 40-meter CW transceiver I use for portable QRP. It consists of a direct conversion receiver and a 1-watt transmitter (see **Figure 1**).

A direct conversion receiver is very good for portable use. It has disadvantages as a home station if there are other stations within a mile of you. A strong signal nearby will block and modulate across the band.

The direct conversion receiver VFO is tuned just off frequency from the incoming signal. This difference in frequency produces a clean, strong, and solid audio tone signal.

You'll find when tuning that adjacent signals may superimpose themselves on the received signal if the band is crowded. You could use an audio filter; however, this would add to the complexity of the receiver. Tuning to one side or the other of the received signal sometimes deletes the unwanted signal. Your only other alternative for solving the interference problem is to find a crystal filter for a regular superhetrodyne receiver. Unfortunately, this is almost impossible because parts are becoming hard to get.

Even though the direct conversion receiver has some drawbacks, it gives me a lot of enjoyment during the day when there are few signals on the band. Best of all, these receivers are simple.

Power supply

I'd like to suggest that you start by using a 12-volt battery for the power supply. Doing so solves a lot of problems. You can experiment with a 12-volt regulated supply later. I use a regulated supply built in a Ten-Tec box and keep it at least a foot away from the receiver. It's been recommended that toroid chokes be used in both positive and negative leads when using AC supplies with a direct conversion receiver. I didn't find it necessary. Don't try to build the power supply and transceiver on the same chassis. If you do you're bound to have AC-modulated hum. Transistors love to pick up this hum from the chassis ground.

I built my transceiver in a 3 x 5-inch wooden card file box. You might want to use a larger chassis.

Audio amplifier

I used a Radio Shack telephone amplifier (catalog no. 43-231) which is often on sale for \$7.00. I found it was a great choice. The amplifier contains a 2N2222 audio preamplifier driving an LM386. I was able to use the whole board by removing it from the case. (Just two screws hold it in place.) I also used the loudspeaker; it can be pried from the case. I could have used the amplifier volume control, but I used a standard 10-k potentiometer for panel mounting instead.

PC boards

I made my own circuit board using drafting dots and tape. You can hacksaw the board using two pieces of angle iron for support. Make sure you file the edges until they're smooth. Polish the copper with steel wool before putting on the tape.

I used to put the components on the fiber side of the board. Now I put them on the copper side; this makes it easier to remove or change them. There are times when leads coming through holes are covered with solder and still aren't making contact. It's easier to solder the components if you tin the copper side.

Once the board circuitry tape is pasted on, I put the board in a plastic tray and pour ferric chloride over it. Place a 75-watt lamp over the tray to heat the fluid. The Radio Shack board etches in about 20 minutes. Many military-type boards have thicker copper and are very difficult to etch. The process may take up to an hour. I found both the board and etchant at Radio Shack.

Coil construction

I find winding and tuning the toroid coils the most difficult part of construction. Everyone has various sizes in their junkboxes and this makes a grid dip oscillator (GDO) a must. The T-68 or T-50 coils are the most popular. For 40 meters use the red-painted ones. You can start by winding 35 turns of no. 28 wire on the coil. Fasten the coil to a 50-pF variable capacitor, then put one loop of hookup wire

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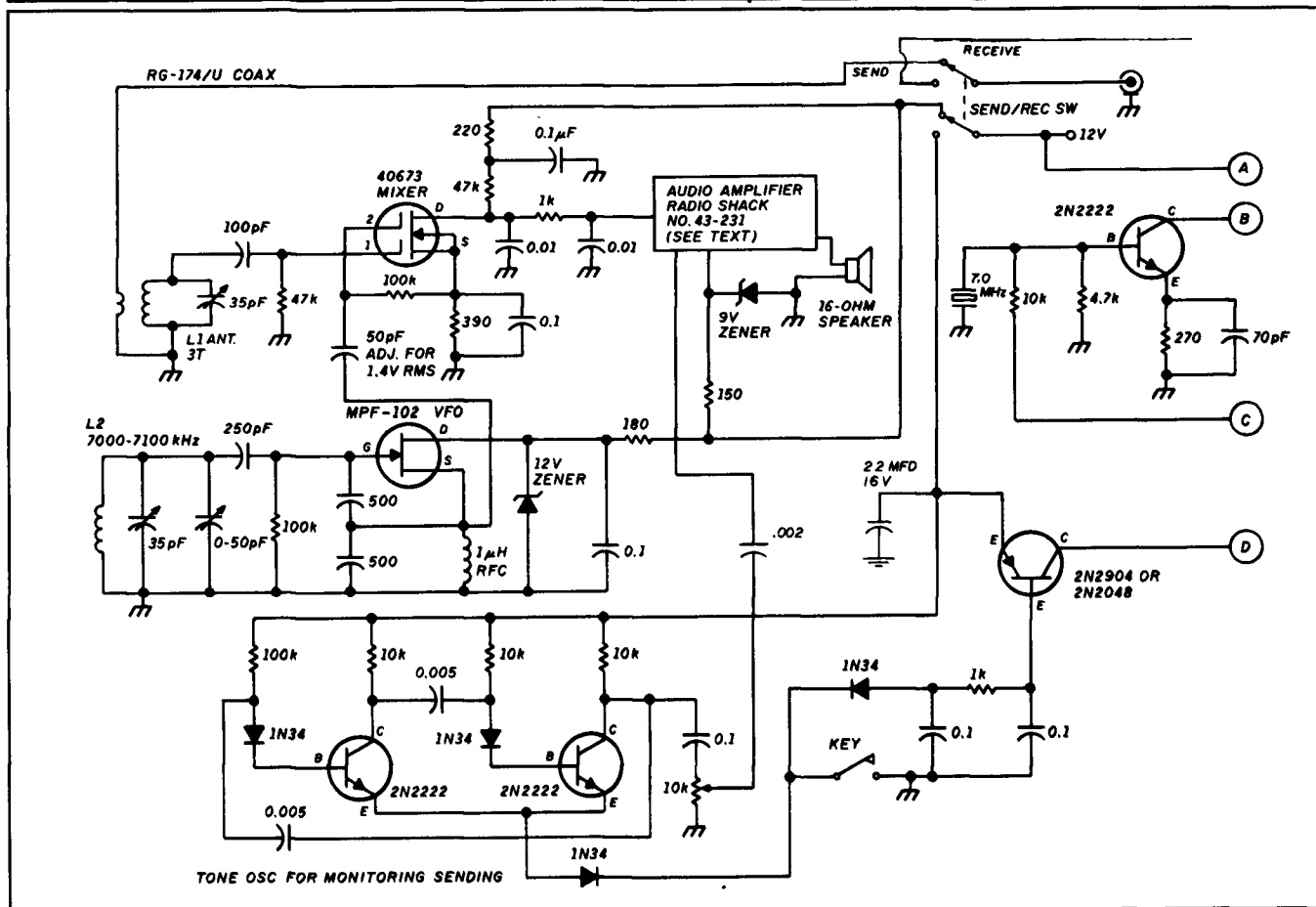
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FIGURE 1



Schematic of the 40-meter direct-conversion receiver and 1-watt transmitter.

(Continued on page 61.)

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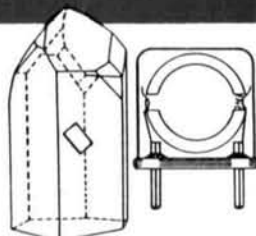
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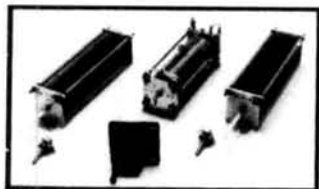
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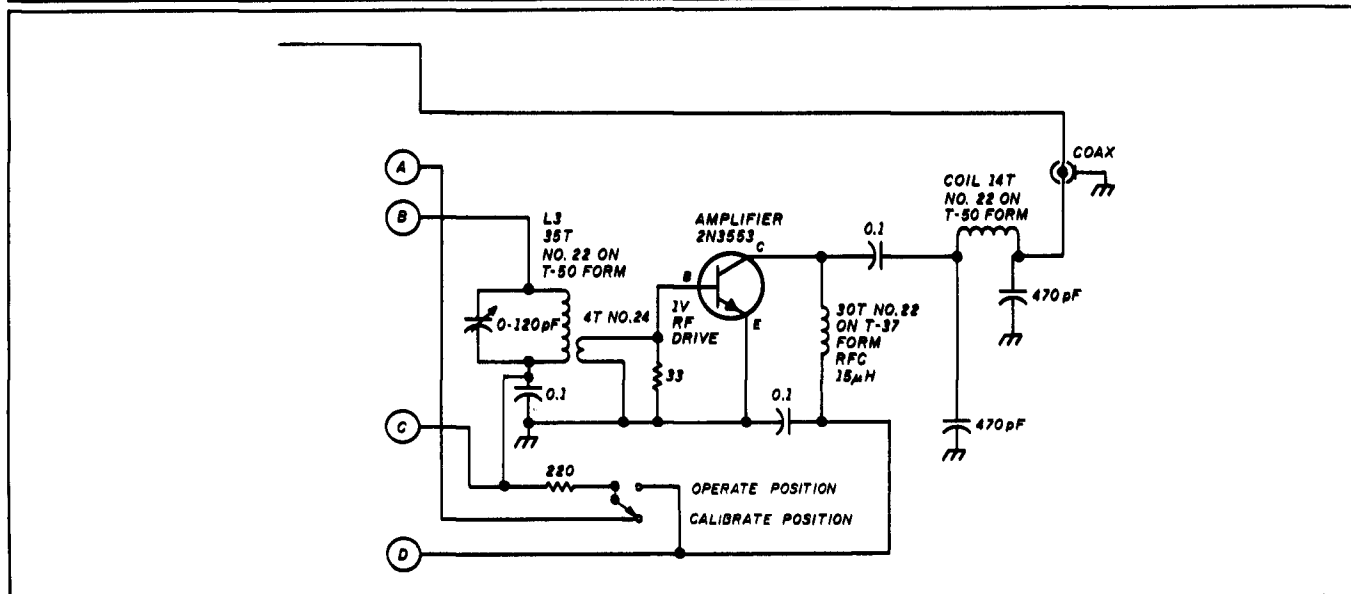
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FIGURE 1



through the hole. Put a loop of wire around the dipper coil and clip to the loop around the toroid coil, which has been set to 50 to 75 pF. Adjust the turns for resonance for 40 meters.

You can detect the resonant frequency of the transmitter variable frequency oscillator (VFO) by using the GDO as a field-strength meter. Because of the large capacitance in the Colpitts VFO, the tuning coil will have less turns than the mixer coil. Use the capacitance shown for the VFO gate to ground (see **Figure 1**) and to the coil. It will affect the frequency and output. You'll need 1.4 volts rms on pin 2 of the mixer to get a good signal from the VFO.

The 1000-ohm resistor and 0.01-μF capacitors act as an RF filter from the mixer output. You can use a 2.5-mH RF choke, but I found it wasn't necessary.

Transmitter

The transmitter is straightforward. The oscillator coil is peaked to obtain 1 volt of RF drive to the 2N3553. The output of the final matches 50-ohm coax line.

Parts are hard to find these days. I've listed some places to try here. Perhaps an ad in *Ham Radio* might net you some hard-to-find parts.

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INTRODUCTION TO WAVEFORM GENERATORS PART 1

By Joseph J. Carr, K4IPV, P.O. Box 1099, Falls Church, Virginia 22041-1099

Waveform generator circuits are used to produce a large variety of waveforms needed in circuits and projects of interest to Amateur operators. The astable (also called free running) multivibrator (AMV) may produce square waves, triangle waves, or other non-sinusoidal waveforms. The AMV is a circuit that produces a periodic waveform (i.e., one that repeats itself).

The monostable multivibrator (MMV), or one-shot, circuit is a class of waveform generator that is not free running. This circuit produces only a single pulse when triggered, so it isn't periodic. (Note: In the strictest sense, astable multivibrator circuits produce only square waves. Current common usage, however, broadens the scope of the term considerably.)

The subclass of AMV and MMV circuits I'll discuss here is based on IC devices like voltage comparators, operational amplifiers, integrators, and so forth. Because these circuits are based on the charge and discharge properties of resistor-capacitor networks, it's prudent to review the operation of simple RC networks. Since they also depend on the properties of the op amp voltage comparator, I'll review comparator theory.

Review of RC networks

Take a look at Figure 1A. Assuming that the initial condition is as shown, switch S1 is in position A and is open circuited. Initially, there's no charge stored in capacitor C (i.e., $V_c = 0$). However, if switch S1 is moved to position B, voltage V is applied to the RC network. The capacitor begins to charge with current from the battery, and V_c begins to rise towards V (see curve V_{cb} in Figure 1B). The instantaneous capacitor voltage is found from:

$$V_c = V[1 - e^{(-T/RC)}] \quad (1)$$

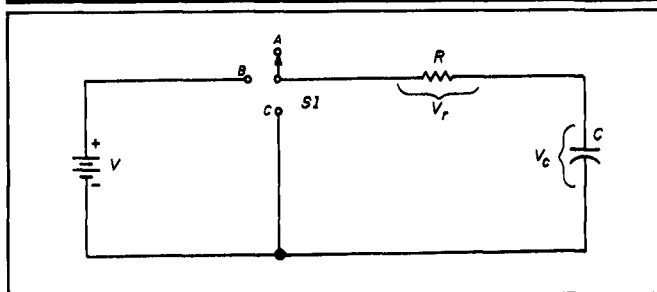
Where:

V_c is the capacitor voltage

V is the applied voltage from the source

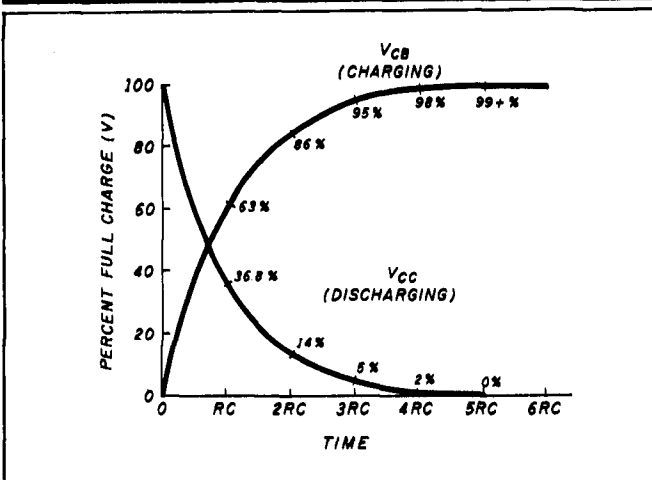
T is the elapsed time (in seconds) after charging begins

FIGURE 1A



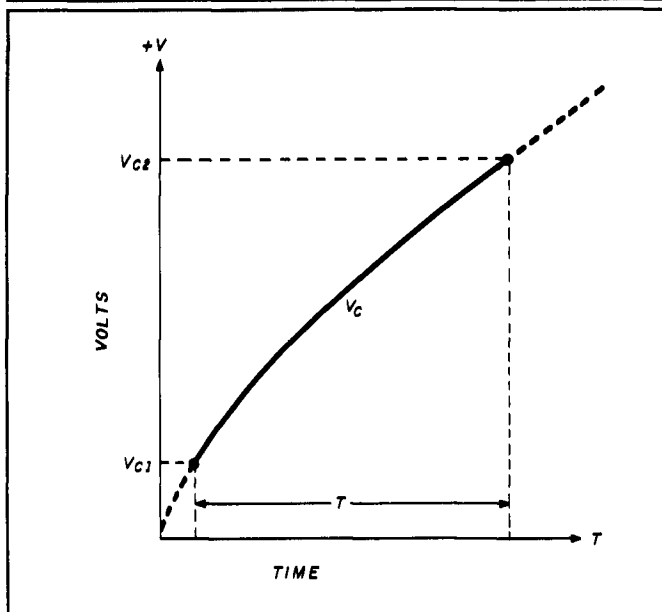
Basic RC network, no voltage applied.

FIGURE 1B



Graph illustrating charge and discharge time constants.

FIGURE 1C



Graph of a common charge cycle encountered in waveform generators.

R is the resistance in ohms

C is the capacitance in farads

The product RC is called the RC time constant of the network. If R is in ohms and C is in farads, then the product RC is specified in seconds. The capacitor voltage rises to approximately 63.2 percent of the final value after 1RC, 86 percent after 2RC, and >99 percent after 5RC. By definition, a capacitor in an RC network is considered "fully charged" after five time constants.

If switch S1 in Figure 1A is next set to position C, the capacitor begins to discharge through the resistor. In the discharge condition:

$$V_c = V[e^{(-T/RC)}] \quad (2)$$

Voltage V_c drops to 36.8 percent of the full charge level after one time constant (1RC), and to very nearly zero after 5RC.

Now look at Figure 1C. This graph represents a situation commonly encountered in waveform generator circuits. In this graph, the capacitor is required to charge from some initial condition (V_{c1}), which may or may not be zero volts, to a final condition (V_{c2}), which may or may not be the fully charged 5RC point. This all occurs in a specified time interval, T. The question is: "What RC time constant will force V_{c1} to rise to V_{c2} in time T? Assuming that $V_{c1} < V_{c2} < V$:

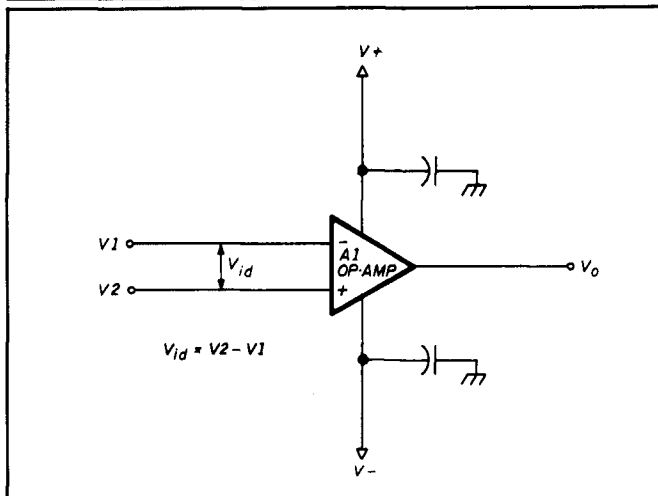
$$V - V_{c2} = (V - V_{c1})[e^{(-T/RC)}] \quad (3)$$

or, doing a little algebra and rearranging terms:

$$RC = \frac{-T}{\ln \left[\frac{V - V_{c2}}{V - V_{c1}} \right]} \quad (4)$$

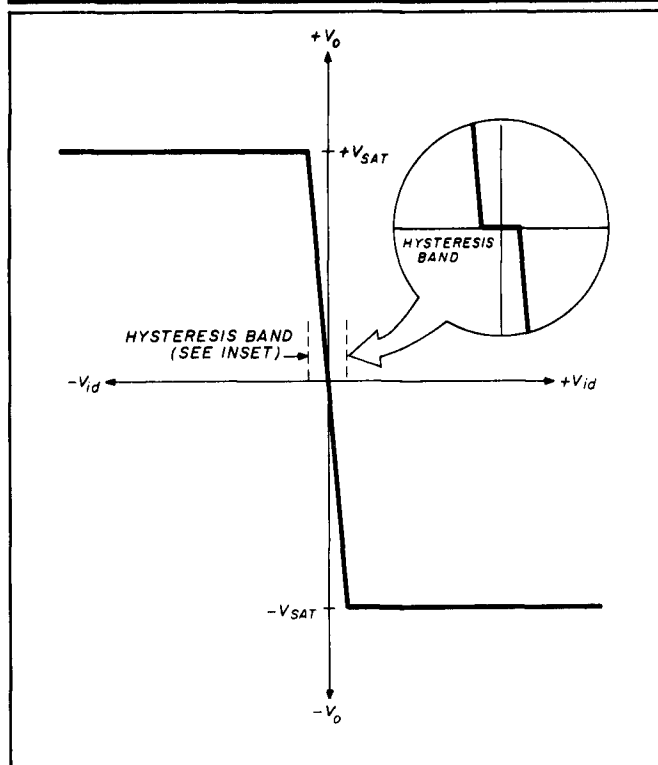
You can use Equation 4 to derive the timing or frequency setting equations of many different RC-based waveform generator circuits. The key voltage levels will most often be comparator trip points, or critical values set by the design of the circuit.

FIGURE 2A



Basic voltage comparator using an op amp.

FIGURE 2B

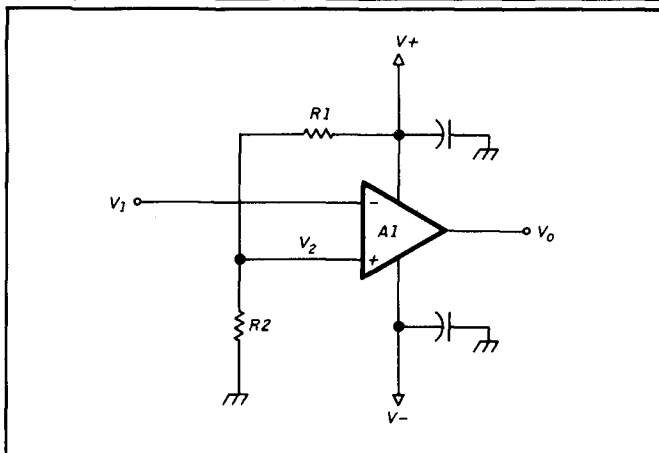


Graph depicting the transfer function of the comparator.

Voltage comparators

A voltage comparator is basically an operational amplifier without a negative feedback network (see Figure 2A). The open loop gain of the operational amplifier is very large, on the order of 200,000 to 300,000 for most common, low cost integrated circuit (IC) devices. Without a negative feedback, the operational amplifier functions as a very high gain DC amplifier with an output that saturates when a very tiny input potential is present.

FIGURE 3A



Simple method for biasing either input to the comparator to a specific voltage.

The voltage comparator is used to compare two input voltages and issue an output signal that indicates their relationship ($V_1 = V_2$, $V_1 > V_2$, or $V_1 < V_2$). In Figure 2A potential V_1 is applied to the inverting input, and V_2 is applied to the noninverting input. If $V_1 = V_2$, then $V_o = 0$. Otherwise, the output voltage obeys the relationships shown in Figure 2B, which is the transfer function of the comparator. According to the normal rules for operational amplifiers, making V_1 larger than V_2 causes the input voltage to look like a positive input to the inverting input, so the output potential is saturated at $-V_{sat}$, just below V_- . Alternatively, when V_1 is smaller than V_2 the input voltage looks like a negative input potential, so the output is saturated at $+V_{sat}$ just below V_+ . In Figure 2B, there's a small hysteresis band around zero where no output changes occur. This is an unfortunate defect in practical operational amplifiers.

The biased comparator

Figure 3A shows a method for biasing either comparator input to a specific reference voltage. This circuit is called a voltage level detector. Although in this case the noninverting input is biased and the inverting input is active, the roles can just as easily be reversed. Bias voltage V_1 is found using the voltage divider equation:

$$V_1 = \frac{R_2 (V_+) }{R_1 + R_2} \quad (5)$$

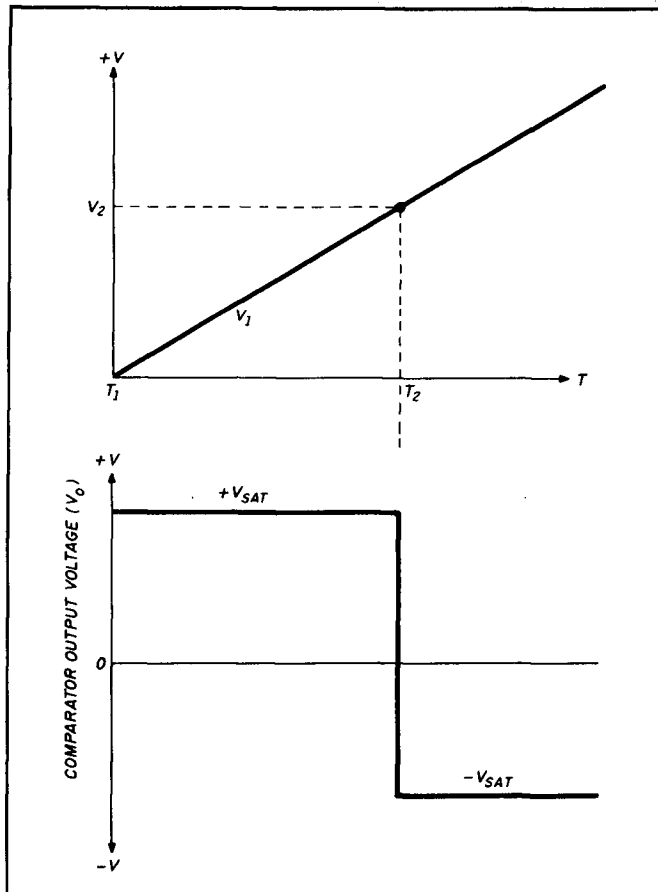
Figure 3B shows what happens when the noninverting input is biased to a positive voltage, V_2 . At time T_1 the voltage applied to the inverting input (V_1) begins to rise, but $V_1 < V_2$, so the output of the comparator is saturated to $+V_{sat}$. The V_1 potential continues rising until time T_2 when $V_1 = V_2$, so the output snaps toward zero; an instant later $V_1 > V_2$, so the output is saturated at $-V_{sat}$.

In the circuit presented in the section that follows, the noninverting input is biased through a resistor voltage divider, but the source potential is V_o . Thus, V_2 will always be a fraction of V_o , and of the same polarity. That configuration (see Figure 3C) is sometimes called a Schmitt trigger.

Monostable multivibrator circuits

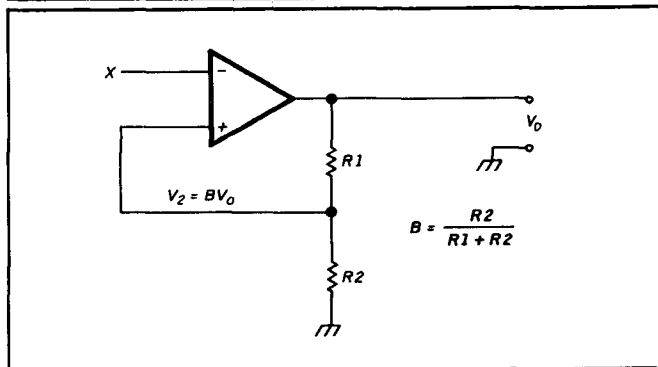
The monostable multivibrator (MMV) has two permissi-

FIGURE 3B



Graph illustrating the output of the comparator as the noninverting input is biased to a positive V_2 .

FIGURE 3C



Basic schematic of a Schmitt trigger.

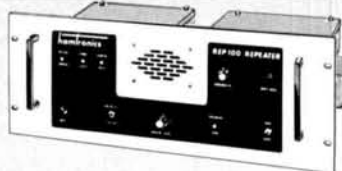
ble output states (HIGH and LOW), but only one of them is stable. The MMV produces one output pulse in response to an input trigger signal (see Figure 4). The output pulse (V_o) has a duration, T , in which the output is in the quasi-stable state. The MMV is also known under several other names: one-shot, pulse generator, and pulse stretcher. The name "pulse stretcher" is derived from the fact that the output duration (T) is longer than the trigger pulse ($T > T_c$).

Monostable multivibrators have a wide variety of applications in electronic circuits. Besides the pulse stretcher, the MMV also serves to lock out unwanted pulses. Photo

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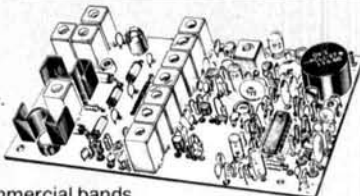
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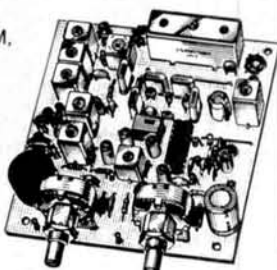
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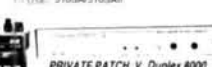


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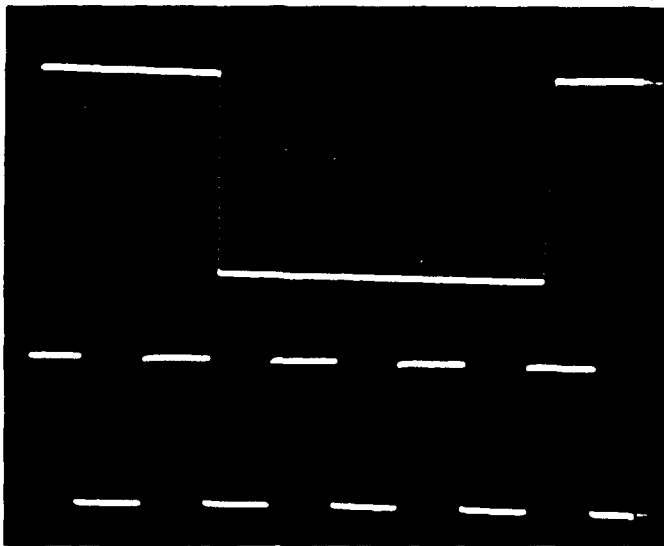
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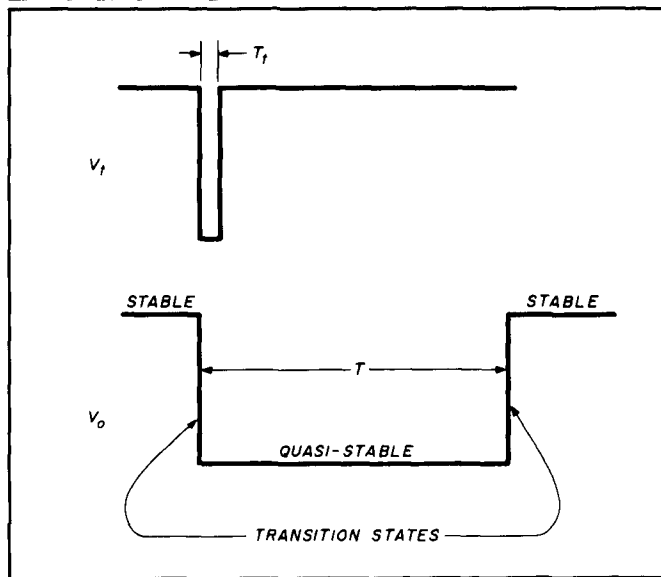
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PHOTO A



The monostable multivibrator responds to only the first triggered input until the MMV is reset.

FIGURE 4



Output of a monostable multivibrator (one shot). V_t is the input trigger voltage and V_o is the output response.

A shows that the output responds to only the first trigger pulse. The next three pulses occur during the active time, T , so are ignored. Such an MMV is said to be "nonretriggerable." A common application of this feature is in switch contact debouncing. All mechanical switch contacts bounce a few times on closure, creating a short run of exponentially decaying pulses. If an MMV is triggered by the first pulse from the switch, and if the MMV remains quasi-active long enough for the bouncing to die out, then the MMV output signal becomes the debounced switch closure. The main requirement is that the MMV duration be longer than the switch contact bounce pulse train; 5 ms is generally considered adequate for most switch types.

Figure 5A shows the circuit for a nonretriggerable monostable multivibrator based on the operational amplifier. This circuit is based on the voltage comparator circuit discussed earlier. When there's no feedback, the effective voltage gain of an op amp is its open loop gain (A_{vol}). When both $-IN$ and $+IN$ are at the same potential, the differential input voltage (V_{id}) is zero, so the output is also zero. But if $V(-IN)$ doesn't equal $V(+IN)$, the high gain of the amplifier forces the output to either its positive or negative saturation values. If $V(-IN) > V(+IN)$, the op amp sees a positive differential input signal, so the output saturates at $-V_{sat}$. However, if $V(-IN) < V(+IN)$, the amplifier sees a negative differential input signal, and the output saturates to $+V_{sat}$. The operation of the MMV depends on the relationship of $V(-IN)$ and $V(+IN)$.

There are four states of the monostable multivibrator that must be considered. They include the stable, transition, quasi-stable, and refractory states.

Stable state

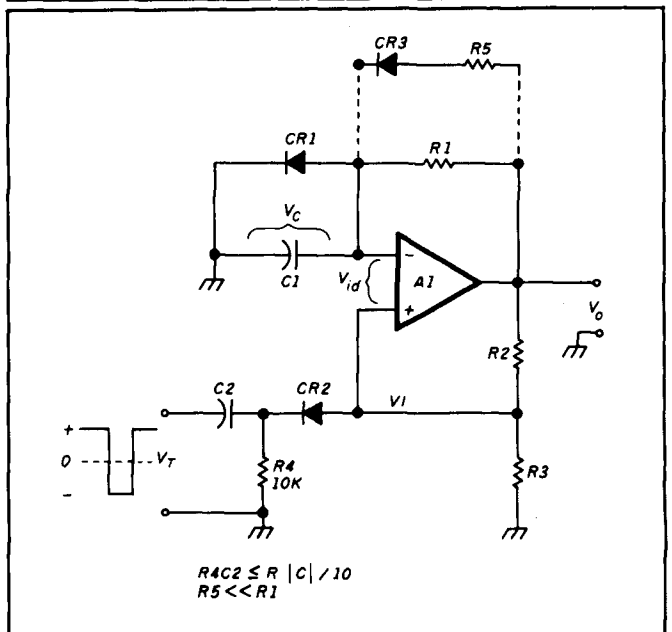
The output voltage V_o is initially at $+V_{sat}$. Capacitor C_1 attempts to charge in the positive-going direction because $+V_{sat}$ is applied to the R_1C_1 network. But because of diode CR_1 shunted across C_1 , the voltage across C_1 is clamped to $+V_{CR1}$ (for a silicon diode like the 1N914 or 1N4148, $+V_{CR1}$ is about $+0.7$ volts DC). Thus, the inverting input ($-IN$) is held to $+0.7$ volts DC during the stable state. The noninverting input ($+IN$) is biased to a level V_1 , which is:

$$V_1 = \frac{R_3 (+V_{sat})}{R_2 + R_3} \quad (6)$$

or, in the special case of $R_2 = R_3$:

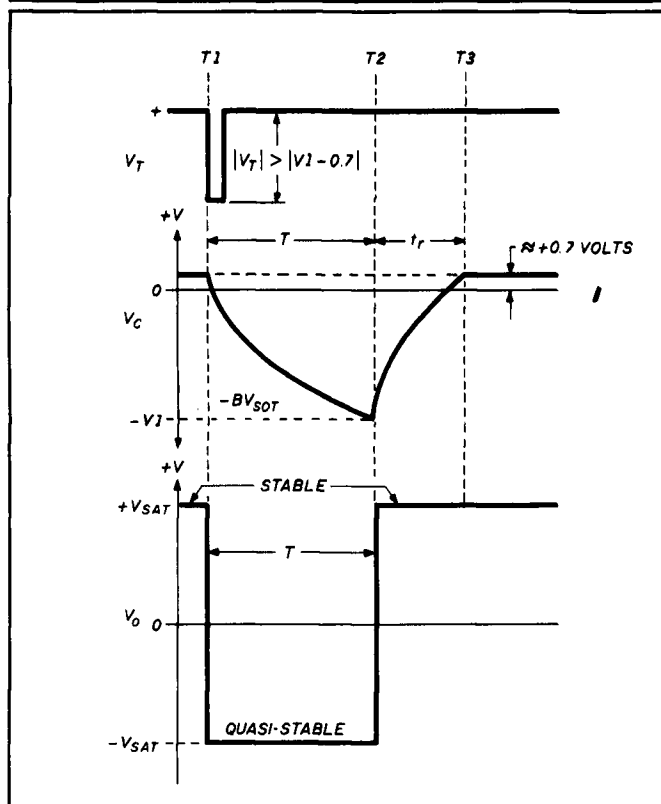
$$V_1 = \frac{+V_{sat}}{2} \quad (7)$$

FIGURE 5A



Schematic of a non-retriggerable monostable multivibrator (one-shot).

FIGURE 5B



Graphical representation of the various voltages associated with the monostable multivibrator.

The amplifier (A1) sees a differential input voltage (V_{id}) of $V_1 - V_{CR1}$, or $V_1 - 0.7$ volts:

$$V_{id} = \frac{R_3(+V_{sat})}{R_2 + R_3} - 0.7 \quad (8)$$

As long as $V_1 > V_{CR1}$, the amplifier effectively sees a negative DC differential voltage at the inverting input, so (with its high open loop gain) A_{vol} will remain saturated at $+V_{sat}$. For this discussion, the amplifier is a type 741 operated at DC power supply potentials of ± 12 volts DC, so V_{sat} will be ± 10 volts.

Transition state

The input trigger signal (V_t) is applied to the MMV of Figure 5A through RC network R_4C_2 . The general design rule for this network is that its time constant should be no more than one-tenth the time constant of the timing network:

$$R_4C_2 < \frac{R_1C_1}{10} \quad (9)$$

At time T_1 (see Figure 5B) trigger signal V_t makes an abrupt HIGH to LOW transition to a peak value less than $V_1 - 0.7$ volts. Under this condition, the polarity of V_{id} is reversed and the inverting input sees a positive voltage: $V_1 + V_t - 0.7 < V_{CR1}$. The output voltage V_o now snaps rapidly to $-V_{sat}$. The fall time of the output signal is dependent upon the slew rate and the open-loop gain of the operational amplifier, A1.

Quasi-stable state

The output signal from the MMV is the quasi-stable state

between T_1 and T_2 in Figure 5B. It's called "quasi-stable" because it doesn't change over $T = T_2 - T_1$. But when T expires, the MMV "times out," and V_o reverts to the stable state ($+V_{sat}$).

During the quasi-stable time, CR_1 is reverse biased and capacitor C_1 discharges from $+0.7$ volt DC to zero, and then recharges towards $-V_{sat}$. However, when $-V_o$ reaches $-V_1$, the value of V_{id} crosses zero, and that change forces V_o to snap once again to $+V_{sat}$.

Equation 4 makes it possible to derive the timing equation for the MMV. The timing capacitor must charge from an initial value (V_{c1}) to a final value (V_{c2}) in time T . What value of R_1C_1 will cause the required transitions? Consider the case $R_2 = R_3$ ($V_1 = 0.5 V_{sat}$):

$$R_1C_1 = \frac{-T}{\ln \left[\frac{V_{sat} - V_{c2}}{V_{sat} - V_{c1}} \right]} \quad (10)$$

$$R_1C_1 = \frac{-T}{\ln \left[\frac{V_{sat} - ((0.5)(V_{sat} + 0.7))}{V_{sat} - 0.7} \right]} \quad (11)$$

and, for the case $V_{sat} = 10$ volts DC:

$$R_1C_1 = \frac{-T}{\ln \left[\frac{10 \text{ V} - ((0.5)(10 + 0.7))}{10 \text{ V} - 0.7 \text{ volts}} \right]} \quad (12)$$

Thus,

$$T = 0.69R_1C_1 \quad (13)$$

Equation 10 represents the special case in which $B = 1/2$ (i.e., $R_2 = R_3$). Although $R_2 = R_3$ may be the usual case for this class of circuit, R_2 and R_3 might not be equal in other cases. A more generalized expression is:

$$RC = \ln \left[\frac{1 + 0.7/V_{sat}}{1 - B} \right] \quad (14)$$

In which:

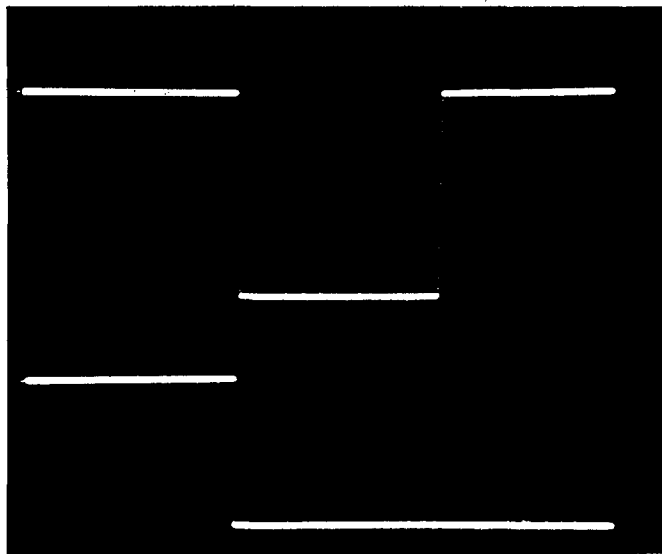
$$B = \frac{R_3}{R_2 + R_3} \quad (15)$$

When the quasi-stable state times out, the circuit status returns to the stable state, where it remains dormant until triggered again.

Refractory period

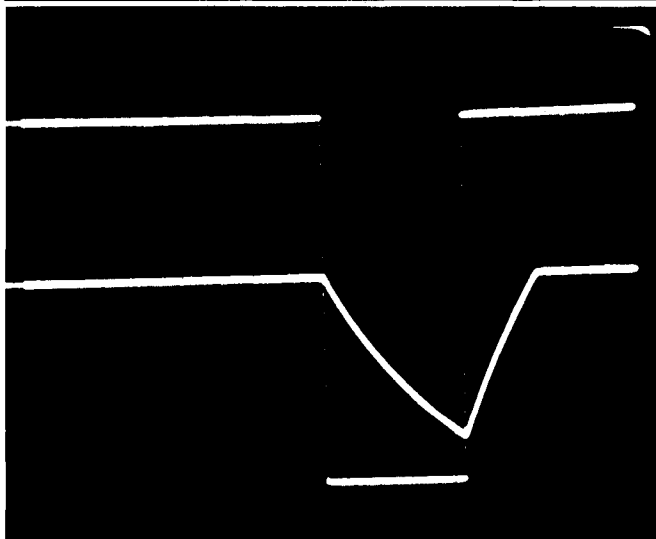
At time T_2 , the output signal voltage V_o switches from $-V_{sat}$ to $+V_{sat}$. Although the output has timed out, the MMV isn't ready to accept another trigger pulse. The refractory state between T_2 and T_3 is characterized by the output being in the stable state, but the input is unable to accept a new trigger input stimulus. The refractory period must wait for the discharge of C_1 under the influence of the output voltage to satisfy $V_1 < (V_1 - 0.7 \text{ volts})$. In preparing this article, I built several MMV circuits using 741 op

PHOTO B



Top trace shows the output voltage (V_o) and the bottom trace shows the trigger voltage (V_t).

PHOTO C



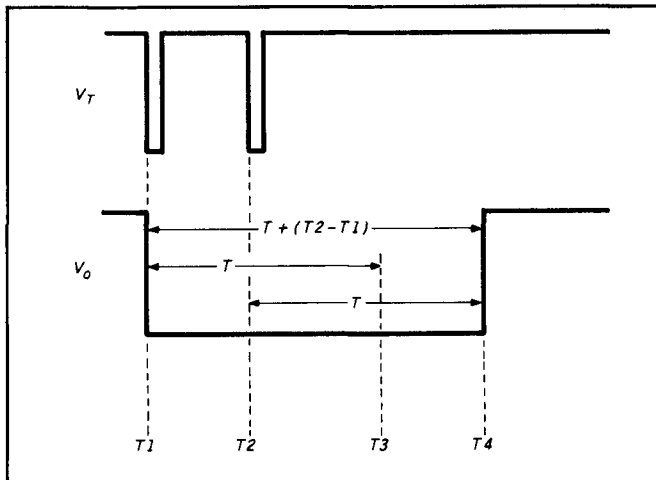
V_o is superimposed on the capacitor voltage (V_c).

amps operated from ± 12 volt DC power supplies. Photo B shows the output voltage (V_o) and trigger pulses (V_t). In Photo C the output pulse is superimposed on the capacitor voltage (V_c). The refractory period is shown as the increasing segment of V_c .

Retriggerable monostable multivibrators

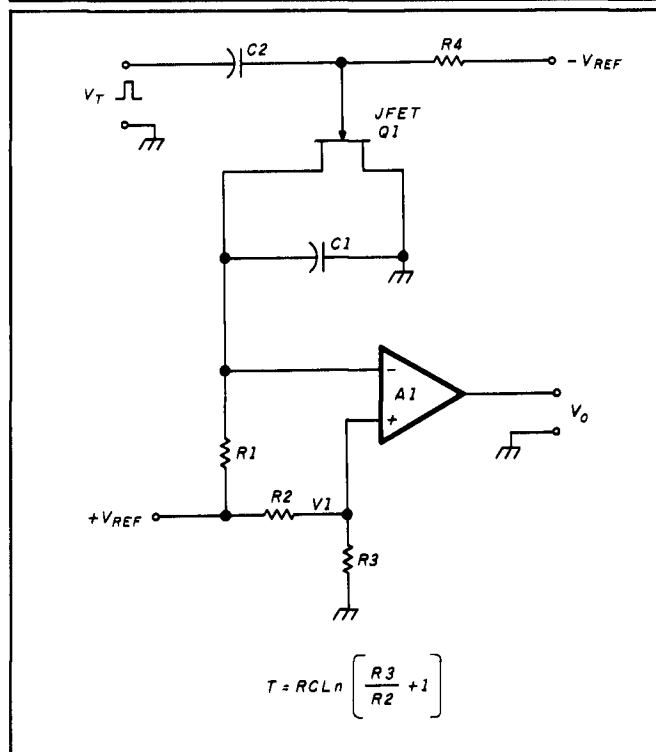
The circuit in Figure 5A is a nonretriggerable MMV. Once it's triggered, the circuit won't respond to further trigger inputs until after both the quasi-stable and refractory states are completed. A retriggerable monostable multivibrator (RMMV) will respond to further trigger signals.

FIGURE 6



Response of the retriggerable monostable multivibrator.

FIGURE 7A



Schematic of a basic retriggerable monostable multivibrator.

Figure 6 shows the response for the retriggerable MMV. An initial trigger signal (V_t) is received at time T_1 . The output snaps LOW and, under normal circumstances, would remain in this quasi-stable state until time T_3 , when the duration T expires. But at time T_2 , a second trigger pulse is received. The circuit is now retriggered for another duration T , so it won't time out until T_4 . The total time that the RMMV is in the quasi-stable state is $[T + (T_2 - T_1)]$. In other words, the RMMV output is active for the entire duration T , plus that portion of the previous active time which expired when the next trigger pulse was received.

Figure 7A shows the circuit for a simple RMMV based

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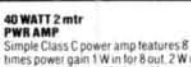
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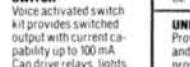
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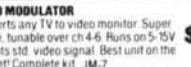
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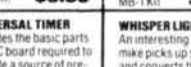
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FM-1 Kit \$5.95
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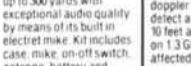
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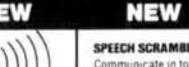
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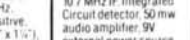
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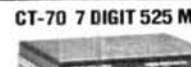
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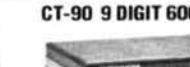
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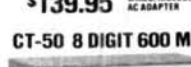
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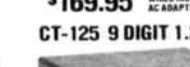
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CT-90	10 Hz-600 MHz	< 10mV to 150 MHz < 150mV to 600 MHz	1 PPM	9	0.1 Hz, 10 Hz, 100 Hz	169.95
CT-50	5 Hz-600 MHz	LESS THAN 25 mV	1 PPM	8	1 Hz, 10 Hz	189.95
CT-125	10 Hz-1.25 GHz	< 25mV @ 50 MHz < 5mV @ 500 MHz < 100mV @ 800 MHz	1 PPM	9	0.1 Hz, 1 Hz, 10 Hz	189.95
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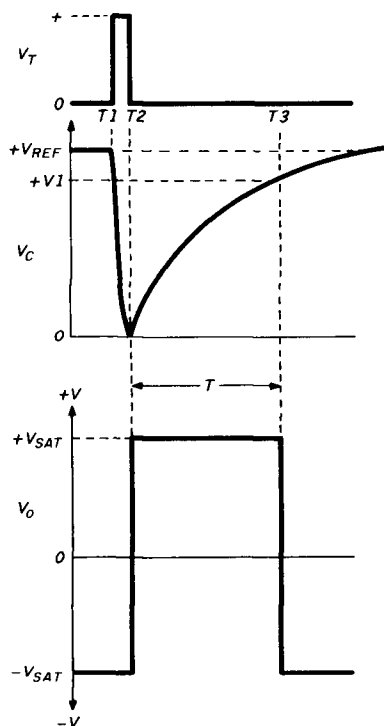


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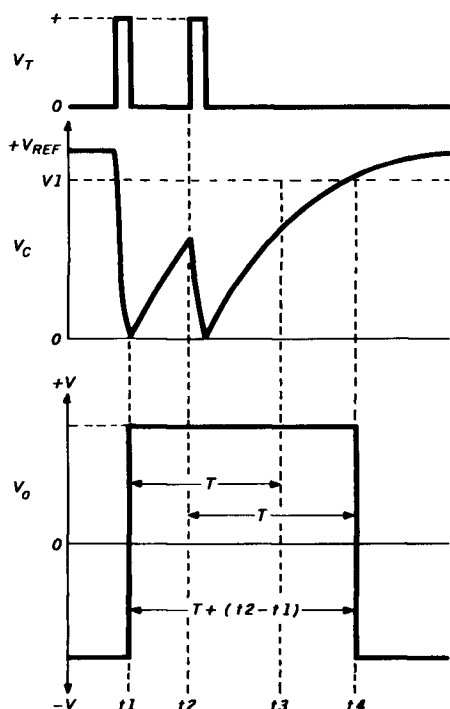
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FIGURE 7B



Response graph of the non-retriggerable monostable multivibrator.

FIGURE 7C



Response graph of the retriggerable monostable multivibrator.

on an operational amplifier. The two inputs are biased from a reference voltage source, $+V_{REF}$. The potential applied to $+IN$ is a fraction of $+V_{REF}$. That is, $[(R3)(+V_{REF})/(R2 + R3)]$. The potential applied to $-IN$ is a function of $+V_{REF}$ and time constant $R1C1$. If the circuit isn't triggered at turn on, capacitor $C1$ charges up to $+V_{REF}$, so $-IN$ is more positive than $+IN$. This situation forces V_O to $-V_{SAT}$, which is the stable state. When a positive-going trigger pulse (V_T) is received (see Figure 7B), it biases junction field effect transistor (JFET) $Q1$ hard on. The JFET drain source channel resistance drops very low, causing $C1$ to discharge rapidly between $T1$ and $T2$. With V_C close to 0 volts DC, $+IN$ is more positive than $-IN$, so the output snaps abruptly to $+V_{SAT}$ at time $T1$. During the interval $T2$ to $T3$, capacitor $C1$ begins charging towards $+V_{REF}$, and V_O remains at $+V_{SAT}$. However, once V_C reaches $+V1$, the output of $A1$ snaps back to $-V_{SAT}$.

The duration, T , is found from:

$$T = R1C1 \ln \left[\frac{R3}{R2} + 1 \right] \quad (16)$$

The operation I just discussed, which is depicted in Figure 7B, is for normal nonretriggered operation. Figure 7C shows the retriggered case. Here the RMMV receives a second trigger pulse at time $T2$, which forces the JFET $Q1$ to turn on again, and rapidly discharge $C1$. The charging process then starts over again, and continues until the circuit times out — unless a further trigger pulse is received.

The RMMV is commonly used in alarm or sensing circuits. It's triggered by some external event, and will continually retrigger as long as that event keeps occurring. If no event is sensed prior to time-out, the RMMV returns to the stable state, and the following circuitry will be triggered to alarm status. For example, the timer MMV is retriggered every time a carrier drop is sensed. But if the same carrier stays on too long, the MMV "times out" and sends a signal to the circuit that turns off the transmitter for a short "rest period."

Part Two...

Now that you've had a refresher on RC networks, voltage comparators, and monostable multivibrators, it's time to move on to astable multivibrators. But, alas, the Editor's MMV "timed out" for this month, and we'll have to wait for part 2 to talk about the AMV circuit. *hrr*

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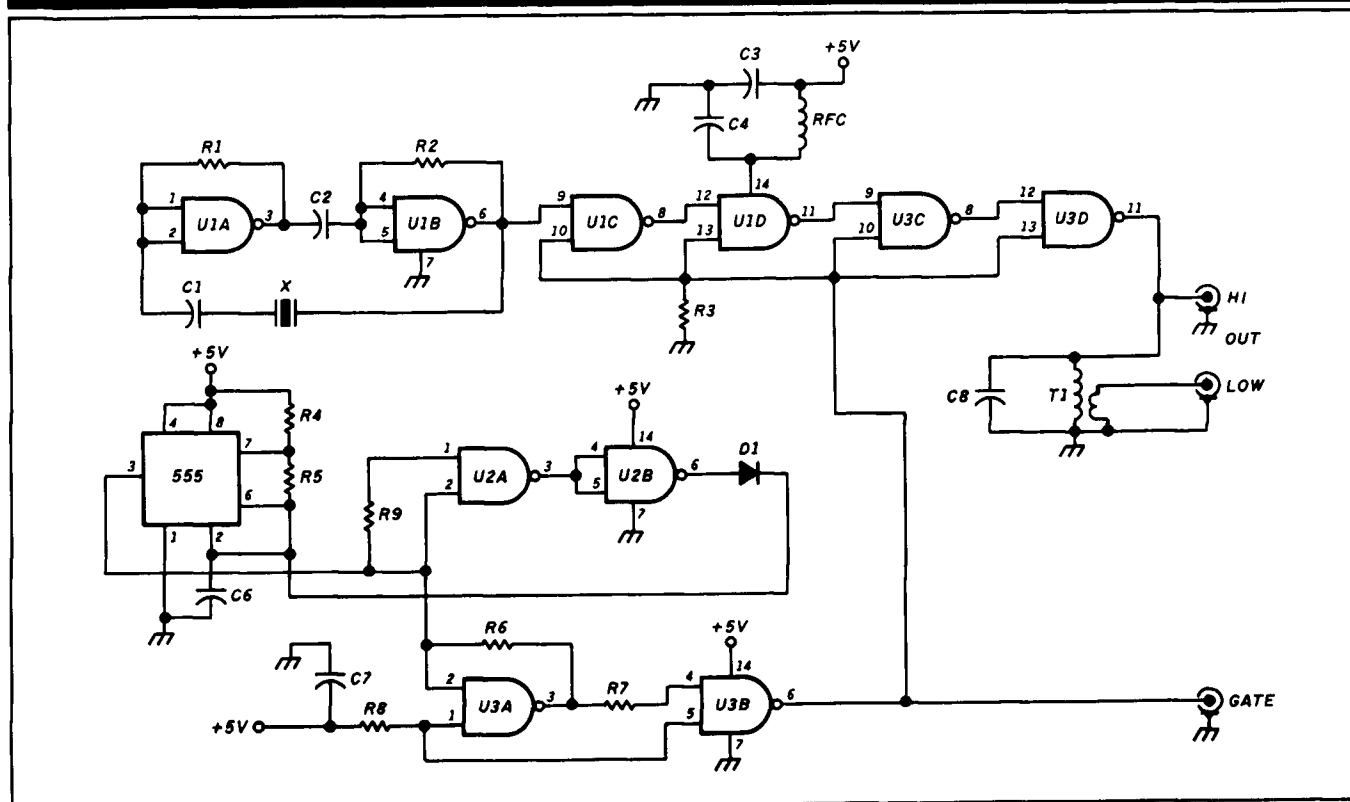
AN IMPROVED AGC CIRCUIT

Add this circuit to your
Kenwood TS-940S or TS-930S
for DATA/RTTY reception

By W. C. Loudon, W8WFH, 1915 Templethurst
Road, S. Euclid, Ohio 44121

Automatic gain control (AGC) circuits are used in receivers to adjust the gain of RF and IF amplifiers automatically. This prevents overdriving of the amplifier stages and maintains audio that's nearly constant with the varying strength of the input signal. When propagation conditions are good, interference from

FIGURE 1



7.5-MHz pulse generator.

atmospheric noise is minimal, and adjacent channel chatter from other signals is low, any AGC circuitry will provide satisfactory results for most modes of reception. However, when fading is prevalent, or atmospheric noise increases due to summer electrical storms and adjacent channel chatter builds up, it's important to improve the design of the AGC system. While even a well-designed AGC system won't take the place of an effective noise blanker, it will supplement the blanker and let you receive information you'd lose in the presence of adverse conditions.

I realize that many of you may question the efficacy of changing an AGC system like the one in the TS-940S. Since the system doesn't generate any clicks or pops and works satisfactorily for SSB, AM, and CW, consider that changing it runs contrary to the old adage "If it ain't broke don't fix it." My question to you is: does it work well enough for data communications — RTTY, AMTOR, and packet? After a year or more of careful record keeping and diagnosis, I concluded the system wasn't effective enough. I found that nearly every case of an RTTY "hit" or error in the copy had occurred on days when there was static from electrical storms. The major portion of the static was in the form of short duration noise pulses. While you might expect that such static errors would result from the addition of bits of data, most of the hits were caused by a loss of bits. I determined this by referring to the *Teletypewriter Code and Garble Table*.

I found these hits puzzling. If the receiver was blanking on or after noise pulses, why couldn't the blanking action be heard as it occurred? I reasoned that if the blanking action was of short duration, it could be "seen" even though it couldn't be "heard." I connected an oscilloscope to the audio output, tuned the receiver to a vacant frequency, and watched the static pulses. I saw nothing of significance until I inserted a data signal using the 100-kHz calibration standard. I tuned the receiver to obtain a 2300-Hz audio tone and synchronized the scope to the tone. As I watched a static pulse, I could see the noise peak. But there was a loss of audio information immediately following the peak which lasted from 4.5 to 12 ms, depending on the position

PARTS LIST

C1	20-pF silver mica
C2	0.001
C3,C4	0.01
C6	0.47 μ F
C7	0.1
C8	33-pF silver mica
CR1	1N914
R1,R2,R3, R4,R8	1 k
R5	1.5 meg
R6,R7,R9	470
T1	primary—30 turns no. 24 on 1/2", OD toroid—Amidon T-50-2, secondary - 2 turns no. 24
U1,U2,U3	7400
Xtal	7.5-MHz crystal
RFC	220 μ H

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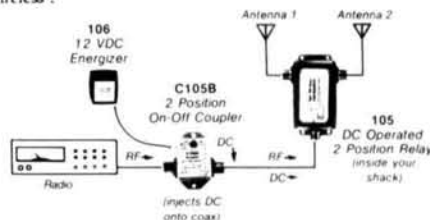
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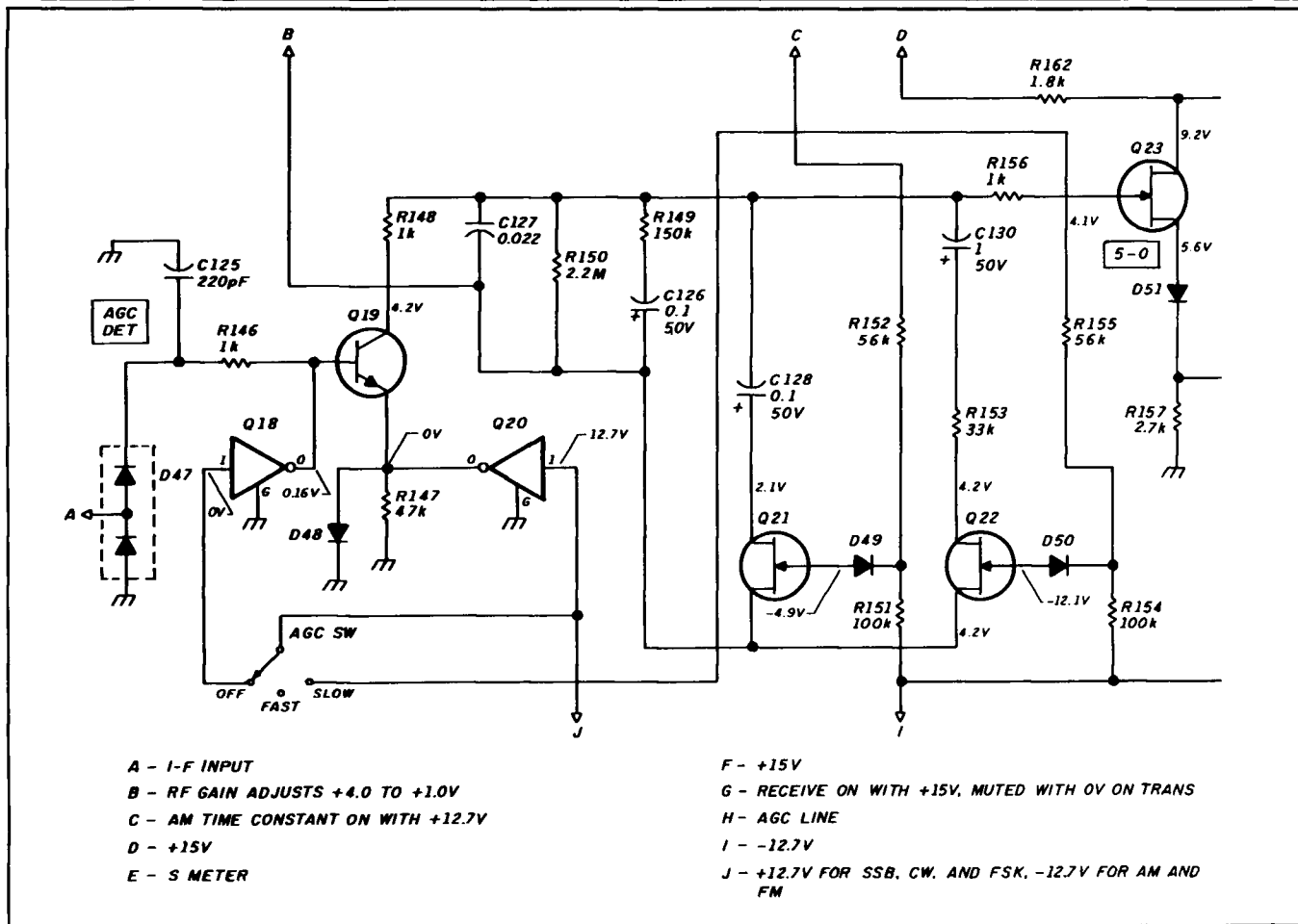
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FIGURE 2



TS 940S AGC system.

of the AGC switch. I found that the "fast" position AGC was slower in recovering than the "slow" position.

The data loss period is made up of the sum of three time intervals. The first is due to the duration of the noise pulse. The second is the circuit group delay (the time it takes the AGC to start to react to the noise pulse), which is about 1 ms according to Rohde.¹ The third interval is the recovery time of the AGC. When the total of these three intervals is an appreciable part of the length of time it takes for a bit to be sent, the bit is lost. The duration of the noise pulse is an act of nature and, unfortunately, uncontrollable. The circuit group delay depends upon the number of resonators, and varies inversely with the bandwidth. It can't be changed without making sacrifices. But you *can* modify the AGC's recovery time.

Once I understood the problem, I listened closely to the receiver and noted that the lag in AGC recovery immediately following the static pulse caused a momentary quieting of the receiver. This, in turn, caused the loss of data bits. I decided that a reduction of the AGC's recovery time was required. It was necessary to come up with a reproducible test in order to work on the problem. I needed a

test that would provide a pulse duplicating the effect of a static pulse on the receiver, so I wouldn't have to rely on electrical storms to measure my progress.

I devised the pulse generator shown in **Figure 1**. It has a 7.5-MHz crystal oscillator gated on for 2.5 ms at 2 Hz. The low pulse rate allows the AGC system to recover between pulses. None of the other parameters are critical.

The 7.5-MHz crystal came from my junkbox; the circuits are from QST² and *The 555 Timer Applications Sourcebook with Experiments*.³ There's a broadly tuned circuit in the output which transforms the TTL voltage down to a usable value. I've provided outputs for the high and low level 7.5-MHz RF pulse and for the gate pulse. I built the generator on a Radio Shack perforated circuit board and mounted it in an aluminum box. I used a commercial 60-dB T pad attenuator with it to further reduce the generator low output.

The generator provided a calibrated "noise" pulse, similar to a static pulse in its effect on the receiver when connected to the antenna input. I observed considerable rounding off of the pulse envelope with the oscilloscope connected to the output of the 8.83-MHz, 455-kHz, and 100-kHz IF. This

[illegible]

TS-940S AGC circuits		
Section	Components	Function
1	R148 (1.0 k)	attack and fast AGC circuit
	C127 (0.22 μ F)	
	R149 (68 k)	
	C126 (0.1 μ F)	
	R150 (2.2 meg)	Q19 load resistor
2	C128 (0.1 μ F)	AM AGC time constant
3	C130 (1.0 μ F)	slow AGC
	R153 (33 k)	
4	Q23 FET	AGC RC net isolation
	Q24	AGC amplifier/driver
	Q25	AGC line driver, T/R

After I made my preliminary observations, I decided to make some changes in the AGC circuit and get some on-the-air experience. Details of the TS-940S AGC circuitry (reprinted with permission from the *Kenwood Service Manual*) are shown in **Figure 2**. I've found it convenient to think of this part of the AGC system as being made up of four "sections" of related components. **Table 1** lists the key components used in the various sections, along with their nominal functions.

These measurements don't include the time required for the IF stages to respond to the AGC voltage, so I also made measurements with the 7.5-MHz pulse applied to the receiver antenna. They indicated that the RF output of the 100-kHz fourth IF followed the curves in **Figure 3** closely. Test procedures maintained the signal below S9. Your operating procedures can also keep the input signal below S9 most of the time if you use the 30-dB input attenuator — an important part of the TS-940S.

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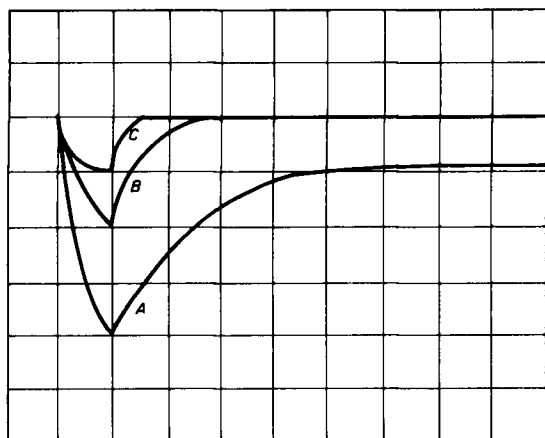
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FIGURE 3



A - "FAST" AGC
B - "SLOW" AGC
C - NEW "FAST" AGC

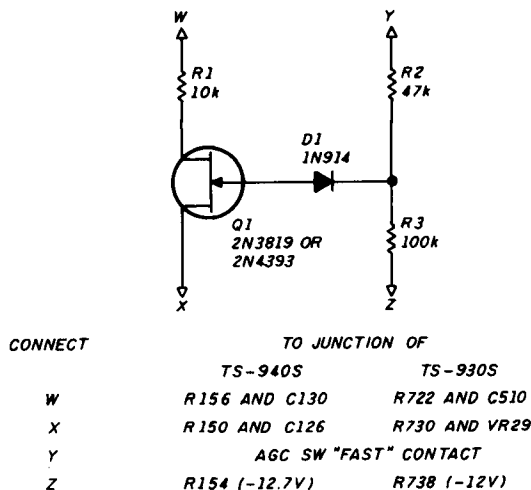
HORIZONTAL SCALE = 2 ms / DIV

VERTICAL SCALE = 0.5 V / DIV

2.5 ms SQUARE-WAVE PULSE of 2 Hz APPLIED TO BASE OF Q19

Graphic display of oscillogram of AGC voltage developed with applied 2.5-ms pulse.

FIGURE 4



New FAST AGC circuit for TS-940S and TS-930S.

In accordance with the design approach to reduce the AGC recovery time, I examined the RC time constants of section 1. Q19 load resistor R150 controls the recovery rate or discharge time for C127 and R149, the fast AGC circuit. Reducing the value of this resistor decreases the recovery time. I chose a value of 10 k. Figure 3 shows the recovery time when it's paralleled with R150. When the AGC RF-IF amplifier loop circuit is closed, the amplitude of the AGC voltage tends to be normalized due to the gain of the loop, and curves A, B, and C fall on top of one another — except for the recovery times.

Before I go on, I'd like to note that I found an error in my

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Kenwood Service Manual. The circuit diagram for the IF unit (X48-1430-00) doesn't agree with the pc board in my transceiver. The position of R150 was interchanged with R149 on the diagram in the manual. **Figure 2** in this article shows them correctly. Some serial numbers of the 940 show R149 changed from 150 k to 68 k.

You could change R150 to 10 k permanently but this would also affect the slow AGC, and that circuit is satisfactory for all other modes of operation. I used an approach which didn't alter the original circuit or circuit board. There's an unused contact on the AGC switch in the fast position (see **Figure 2**). I used this to actuate the circuit shown in **Figure 4**. I've included a table of connections for application to the TS-940S that you can make without removing the IF circuit board.

When you move the AGC switch to the fast position, the gate of switching FET Q1 is made positive and R1 is connected in parallel with R150. With the AGC switch in the slow position, the circuit is unaltered. Inserting a single pin connector in the Y lead lets you return the entire system to the original configuration by disconnecting that lead.

Construction and installation

The parts for the circuit in **Figure 4** are mounted on a piece of Radio Shack circuit board slightly larger than a postage stamp. This is fastened to the IF unit with foam mounting tape.

Remove the bottom cover to access the IF unit, X48-1430-00. The location of every component is marked. You can make all connections to the IF unit on the exposed side of the board. Carefully clean the paint from the resistor leads and tack solder the wires of the new circuit to the exposed leads as indicated.

Remove the top and bottom covers to gain access to the contact on the AGC switch. Then remove two flat-head screws from each side of the front hinges so the front panel swings away from the chassis. Provide support for the front panel during this step to prevent damage to the panel or controls. Solder the wire lead Y shown in **Figure 4** to the spare contact using a small iron and low heat. Use the TS-940S service manual to locate the IF unit and the component parts.

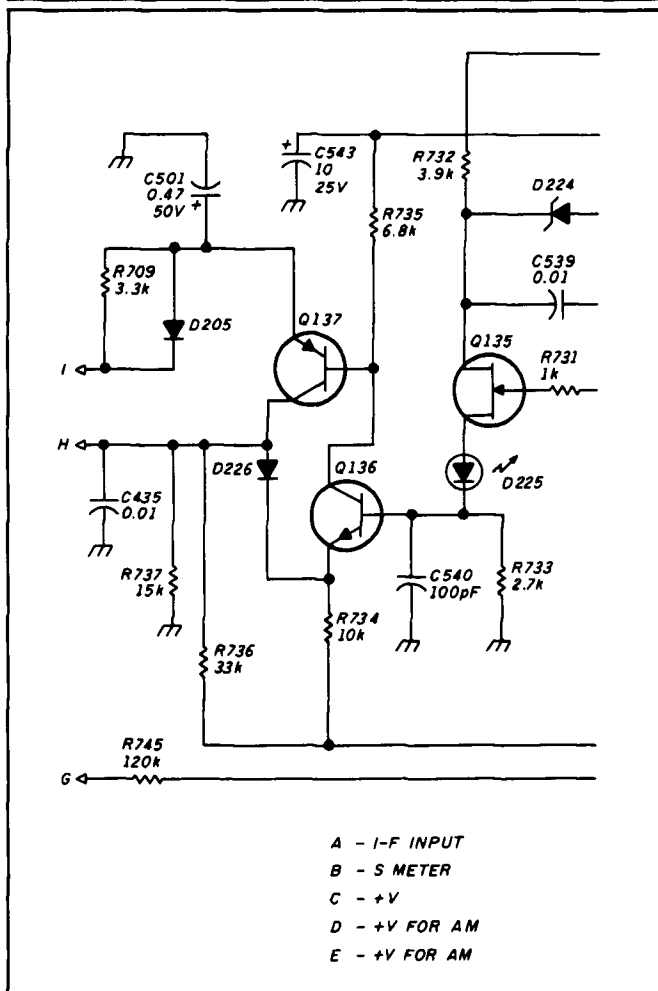
Recommendations for modifying the TS-930S

I did much of my initial work and record keeping with the TS-930S, before the TS-940S became available. As far as recovery time is concerned, I found the performances of the AGC systems much the same. The TS-930S AGC system may be modified using the same principles I used for the TS-940S. **Figure 5** is the TS-930S AGC system shown in the service manual. This system is very similar to the TS-940S. Operation is the same as that of the TS-940S and doesn't warrant additional explanation. The AGC switch is the same in the two models, so there is a spare blank contact available to operate the new fast AGC circuit. The table in **Figure 4** shows the connections to the TS-930S for the new circuit.

On-the-air testing

Preliminary tests showed that the 8.83-MHz filter is "shock" excited to oscillation at its resonant frequency by the 7.5-MHz pulse applied to the receiver antenna. This

FIGURE 5



TS-930S AGC system.

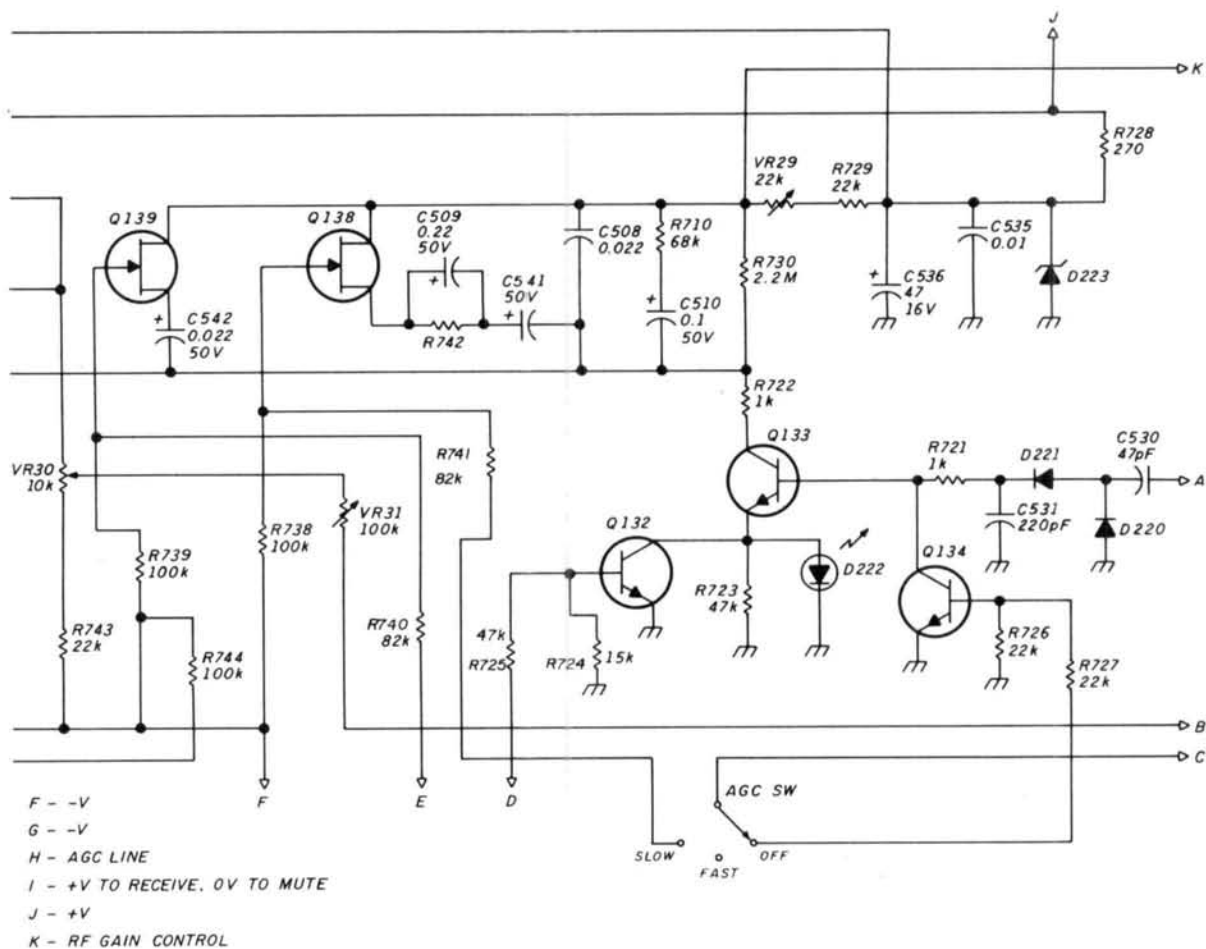
lengthened the pulse and countered the short recovery time by increasing it. Oscillation occurs whether the slow AGC is on or the AGC is off; it just becomes more obvious with the new fast AGC. Static pulses act in the same manner to cause oscillation.

I then investigated the noise blanker to determine if it would act to blank such pulses and prevent the oscillation from degrading the recovery time. (Noise blanking occurs before the 8.83-MHz filter.) NB2 was very effective in blanking the repetitive 7.5 MHz-pulse and in blanking similar single static pulses. Not all static was blanked, but not all static causes ringing. The noise blanker does act to prevent oscillation; set the level control between 0 and 2 for best results.

The slow AGC figure of merit, the change in audio output with increased signal strength,⁴ is 0 dB for signal levels from 1.55 μ V to 1.55 μ V + 110 dB. The new fast AGC causes an increase of 3 dB for the same signal range. This isn't significant.


My RTTY reception improves dramatically when I use the new fast circuit during the noisy summer months. Fast fading effects are reduced — the circuit recovers fast enough to compensate. I do notice a raspy quality on voice communications. This isn't a problem on RTTY because the

FIGURE 5



signal is like a continuous carrier. When an adjacent SSB signal tends to control the AGC and prevent reception of the wanted on-channel signal, I can switch on the new fast AGC. This allows copy between voice peaks of the other signal, and generally works unless the other station turns on its voice processor. If conditions are good, I switch on the slow AGC for the best voice quality. However, the new fast AGC outperforms the slow one for DATA/RTTY reception.

Acknowledgments

I'd like to thank Allen P. Haase, W2ECA, and John A. Kiener, W8AVH, for their expert assistance in the preparation of this article. 

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
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The minimum system requirements to run the PC FAX program are:

- MS-DOS compatible computer with 384K memory
- CGA, EGA, HGA, or VGA card and monitor
- One serial port
- Optional printer for hard copies
- MS-DOS Version 2.1, or higher
- A good HF receiver

The A/D demodulator has a 1/8-inch phone jack on one end that connects to the earphone or speaker output of your radio; the other end has a female DB25 connector, which is connected directly to the serial port of the PC. (The software supports either COM1 or COM2). You also get a cassette tape to help you recognize FAX signals and check out the PC FAX program.

The software will run from a floppy or can be installed on a hard disk. Either way, once you've loaded the program, the interactive menus make using the PC FAX program a snap. I first used PC FAX with a CGA card and monitor and was quite impressed. Later, I replaced my CGA system with an EGA card and monitor. It made a great difference — especially on the satellite photos.



The 80-page user's manual included in the package is well written and makes it easy to be up, running, and capturing your first image in less than a half hour. It was truly exciting when I got my reception system going the first time. Using the Autostart feature, which lets the program run unattended, was even better. The program can be configured to wait for a start tone, capture a frame, write the frame to disk, wait for the next frame, and so on.

The morning after I first used the Autostart feature, I reviewed the 12 frames captured from the previous night's operation. Among them I found a photo of the entire Earth taken with infrared sensors. It showed a newly formed tropical storm. Later that morning, the weather men

announced its formation for the first time!

Once images are captured, they can be displayed in a variety of ways. Images can be viewed in color or 16 shades of grey (EGA or VGA), lightened or darkened, zoomed in on, or converted to PCX format files for editing by Paint programs or importing to many other programs, like desktop publishing.

For more information on PC FAX Facsimile Version 4.0, call or write John Hoot, N6NHP, at Software Systems Consulting, 1303 S. Ola Vista, San Clemente, California 92672. Phone (714)498-5784.

de N1GCF

S-COM 5K Repeater Controller

I'd been planning to buy an S-COM 5K Repeater Controller ever since my friend Joel, WA1ZYX, got one for his 443.800 repeater.

Once I saw Joel's 5K, I couldn't wait to order my own. It finally arrived, and I opened the box with great anticipation. One box contained the new display rack-mount cabinet with 5K controller (v1.3, S/N 681) and the audio delay module mounted inside it, one RS232 connector 25P male plug and hood, and the power connector to provide +12 to 15 volts to the cabinet. The second box held a custom 3-ring notebook with documentation on the 5K, schematics, and instructions for hooking the 5K controller to three different repeaters (more in the making I understand). It also had information using the 5K as a beacon and a circuit for positive voltage TX keying.

The front display rack-mount panel (1-3/4" x 19") is covered in chip-resistant black anodized paint. There are twelve red Hewlett-Packard AlGaAs LEDs to track important circuit status data like: receiver COR (RX), transmitter PTT (TX), CTCSS decoder (PL), control receiver COR (CT), DTMF data valid (DV), power on (ON), logic inputs 1, 2, and 3 (I1, I2, I3), and logic outputs 1, 2, and 3 (O1, O2, O3). These LEDs feature high light output while consuming only 1 mA each, which makes them perfect for natural power sites. Should you experience a power failure, all data except time and date is saved in non-volatile memory.

A conductive iridium-plated chassis box reduces RFI and houses the 5K board, display board, and audio delay module. I removed the six metal screws and took a look inside. The audio delay board is mounted to the lid of the box, the 5K board on the bottom, and the display module on the front panel. The two boards

and the module are connected by ribbon cables and connectors. A DB25S input/output connector (female) and a 2.5-mm DC power jack are mounted on the rear of the 5K board and project through the back of the chassis box. The power input has a Tranzorb™ suppressor and a ferrite bead, there are bypass capacitors on all inputs and outputs, and all power MOSFETS (logic outputs) have Tranzorbs connected to them.

All the commands can be implemented without a lot of work. Take Send ID, for instance. 99 55 * causes the ID to come on. In this case it's "ID" because I haven't programmed my callsign in yet. (The 5K is good, but not that good.) 99 11 * causes the next message to be sent at a slow rate — default, 15 wpm. The normal rate is 20 wpm. Both can be changed. A page in the CW section gives every letter and number a number code; each punctuation mark and CW speed is also assigned a number. Each com-

(Continued on page 84.)

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MEASURING THE ACCURACY OF A PARABOLIC ANTENNA

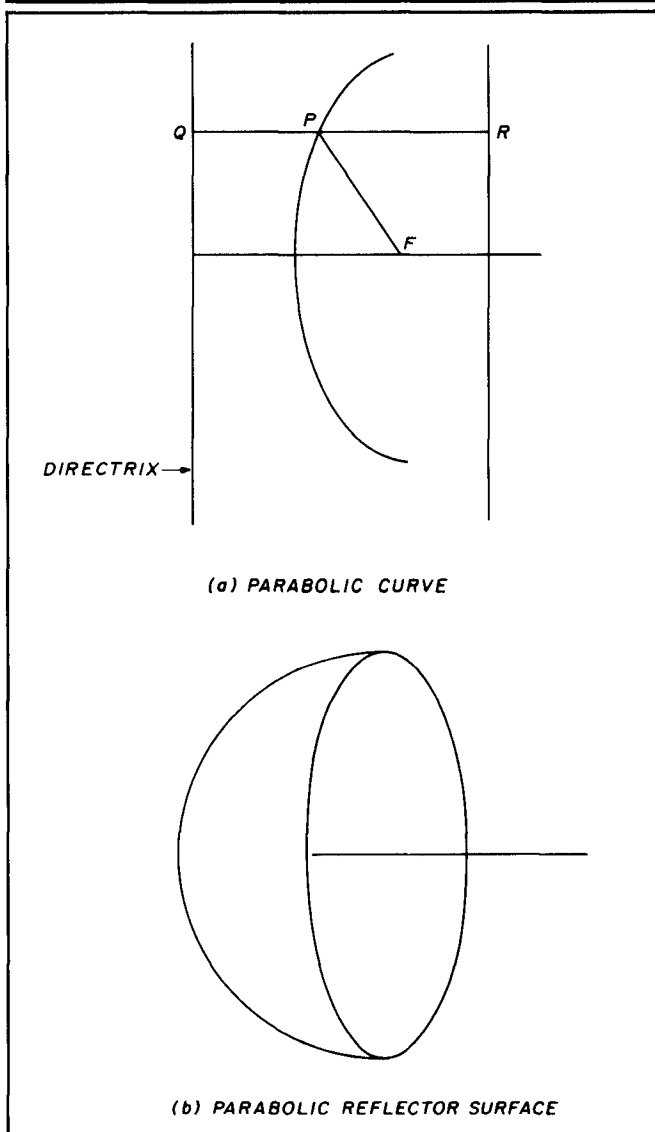
By Lester A. Wagner, WA8BJO, 463 S. Tecumseh Road, Springfield, Ohio 45506 and Glen Grewell, W8FP, 251 Estelle Avenue, Enon, Ohio 45323

The parabolic antenna is a useful design when you consider the use of the higher frequency bands and the increased interest in satellite TV and Amateur Radio reception. This type of antenna offers higher gain than other conventional antennas. Also, when you look at the fairly high cost of commercial dish antennas, a homebrew parabolic antenna seems more practical, if not a necessity for the Radio Amateur. You can make the reflector out of a mesh or screen at frequencies in the range of 1 to 5 GHz. Because a parabola isn't a simple shape like a circle or a flat plate, you'll find you have some difficulty measuring the shape of the surface. This article describes a simple method of measuring the surface of a parabolic reflector. We used a BASIC computer program to calculate the parameters necessary to determine the accuracy of the surface. We constructed a special measuring rod to ascertain, from the focus, the distance of points on the surface as determined by the computer program. This method of accuracy determination eliminates the need for a large template, which is difficult to use because of its size.

The parabolic surface

The parabolic reflector is probably the most widely used high-gain antenna. Reflecting antennas achieve gains in excess of 30 dB in the microwave region. The simplest reflector consists of two components — a large reflection surface and a much smaller feed source. According to the definition of the parabolic curve in **Figure 1A**, the distance from any point P on the parabolic curve to the focus is equal to the perpendicular distance from that point to a line called the directrix. The directrix is a line perpendicular to the axis, passing through the point which is the virtual image of the focus. Thus, in **Figure 1A**, $PF = PQ$. The parabolic reflector has a very unique property: all the waves originating from a point source at the focus arrive at a line perpendicular to the axis with equal phase. A parabolic surface is formed by rotating the top half of the curve in **Figure 1A** around the axis forming the surface as shown in **Figure 1B**.

FIGURE 1



Parabolic reflector antenna: (A) parabolic curve, (B) parabolic reflector surface.

TABLE 1

Parameters for measuring the parabolic antenna surface.
(Dimensions are in inches.)

S	L
0	58.91
2	58.93
4	58.98
6	59.06
8	59.18
10	59.33
12	59.52
14	59.74
16	59.99
18	60.28
20	60.59
22	60.95
24	61.33
26	61.74
28	62.19
30	62.67
32	63.18
34	63.72
36	64.29
38	64.89
40	65.51
42	66.17
44	66.86
46	67.57
48	68.31
50	69.08
52	69.87
54	70.69
56	71.54
58	72.41
60	73.31
62	74.23
64	75.17
66	76.14
68	77.12
70	78.14
72	79.17
74	80.22
76	81.29

The parameters which define the parabolic surface are somewhat difficult to measure. You can solve this measurement problem by defining two other measurable parameters.

We decided that determining the parameters of S and L would make surface measurement easy. These dimensions are defined in **Figure 2**. Length S is the straight line distance from the center of the parabola to the point on the surface to be measured. Length L is the distance from the focal point to a specific point on the surface of the parabola. Note that distance L isn't a simple constant radius. Distance L from the focus increases as distance S from the center of the parabola increases.

We determined parameters S and L for a 12-foot diameter parabolic antenna with a 58.9-inch focal length. We calculated value L for each 2-inch increment in distance S . We chose these dimensions because they were easy to measure. **Table 1** shows the values for S and L in inches. The

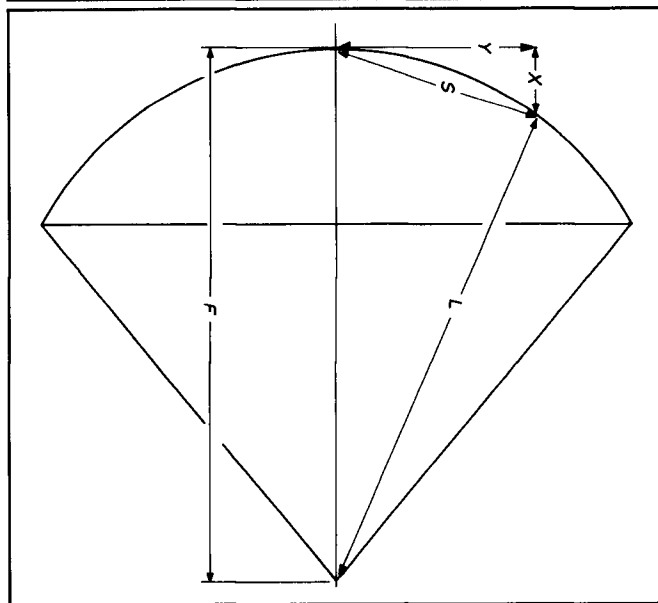
simple BASIC computer program used to calculate these values is given in the appendix so that you can compute the parameters for larger or smaller dish antennas.

The measuring element

The 12-foot diameter parabolic antenna with a focal length of 58.91 inches shown in **Figure 2** was built to receive satellite signals in the 4-GHz frequency range. The frame for the antenna was constructed from thin wall 1/2-inch conduit welded together. The conduit frame was covered with coated steel insect screening to form the parabolic reflector surface. The technique developed here is used to determine the accuracy of the surface.

As mentioned before, we designed a special measuring element to find distance L . The device is shown in **Figure 3**. Our design makes it easy to adjust its length. We built this measuring rod primarily from parts found in our junk-boxes. We used the following parts: a 39-inch length of 1/2-inch diameter PVC pipe, part of a telescoping car antenna, a flexible coupler, and a piece of 1/4-inch metal rod 35 inches long. First we cut a 1/8-inch wide, 30-inch long slot in one wall of the PVC pipe (see **Figure 3**). This slot permits the pointer to slide back and forth, indicating the total length of the measuring rod. The internal part of the device is made from the 1/4-inch rod, the telescoping antenna section, and the end cap. We connected the end cap to one end of the telescoping section. Then we attached the end cap to one end of the PVC pipe. We then fastened the other end of the telescoping section to one end of the 1/4-inch rod and soldered a short pointer to the junction of the rod and the telescoping section. The pointer can stick up out of the slot in the PVC pipe and slide back and forth as the rod is extended and shortened. We inserted the extendable rod assembly into the PVC pipe until the end cap fit

FIGURE 2



Basic geometry of a parabola.

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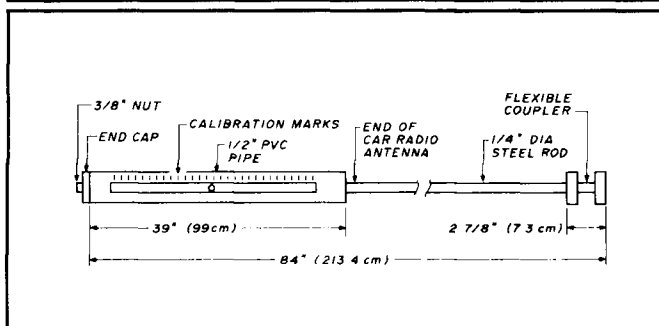
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FIGURE 3



Measuring rod.

onto the end of the pipe. **Figure 3** shows the final assembly of the measuring rod. We put calibration marks on the outside of the PVC pipe to indicate the length of the rod assembly. These marks show the total length of the measuring rod, making it easy to use. You must be able to extend the measuring device from approximately 58 to 82 inches in length in order to measure the distance to any point on the parabolic surface.

We used our measuring rod to calculate the accuracy of the parabolic surface of our antenna. First, we removed the low noise amplifier (LNA) from the antenna feed. Next, we attached a connector, which mates with the connector on the flexible couple on the end of the measuring rod, to the end of the pipe that holds the LNA in place. Then we loosened the clamps holding the piece of pipe, slid the pipe toward the parabolic dish until the connector was at the focal point, and tightened the clamps to hold the pipe in place. Fastening the flexible coupler on the measuring rod to the connector on the pipe was the next step. This holds one end of the measuring rod at the focal point, leaving the other end free to be placed at any point on the surface of the parabola. You can read distance *L* directly from the calibrations on the measuring rod when you slide the end of the measuring rod to a point on the parabola. The most accurate position for antenna measurement is a horizontal one; that is, with the antenna pointed at the zenith.

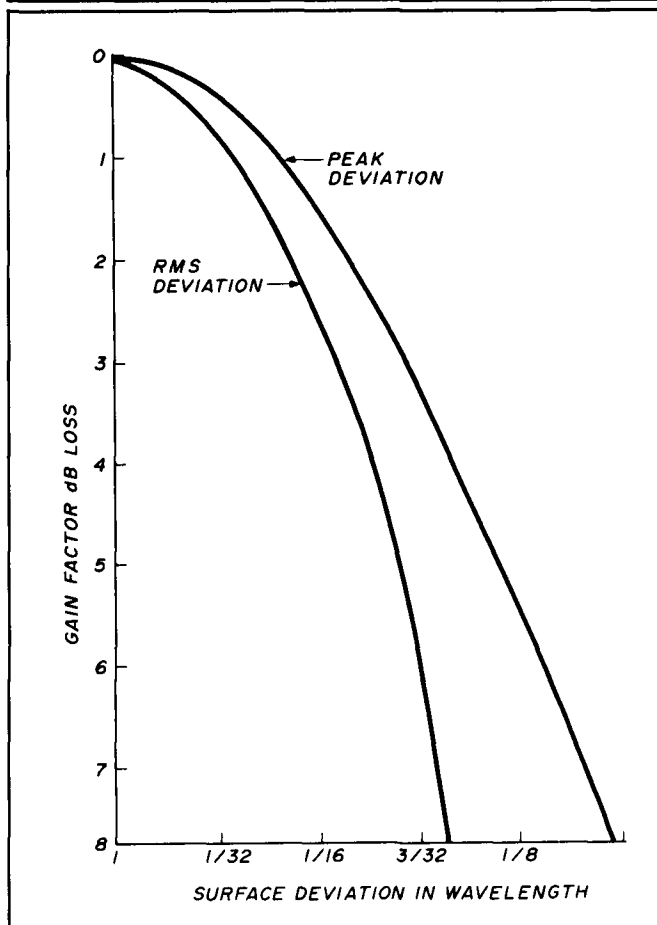
Effect of surface accuracy on performance

You may wonder how accurate the surface of a parabolic reflector antenna should be and why this accuracy is important. The accuracy of the reflector surface is important because it indicates the specifications to which the antenna must be built; it also gives an indication of the antenna's gain reduction. The surface roughness causes phase distortions in the reflected energy and this can reduce the overall antenna gain. The phase error (which can be tolerated because of surface roughness) is directly proportional to the frequency. Larger surface errors can be better tolerated at lower frequencies than at the higher ones. Ruze provides a mathematical expression which relates the surface tolerance to a reduction in gain. Deviation from the true surface can be expressed in peak deviation or in RMS deviation. The graph in **Figure 4** shows the reduction of gain as a function of surface error. One curve is for peak deviation from the surface; the other is for the RMS deviation from the surface. For a peak deviation of 1/16 wavelength, the

reduction in gain is approximately 1.5 dB; for an RMS deviation of 1/16 wavelength, the reduction is approximately 2.7 dB. The loss in antenna gain quickly increases as the surface error exceeds 1/16 wavelength RMS. Surface irregularities are caused by construction errors and external forces acting on the structure. As the frequency at which the antenna is used increases, the tolerances of the parabola become tighter. For example, a 1/16 wavelength is 0.55 inches at 1296 MHz, 0.32 inches at 2300 MHz and 0.18 inches at 4000 MHz.

Any corrections you make to the surface must be made in terms of the frame, because the surface is made of window screen. Make sure all the spokes are well fitted to the center plate. The spokes should be laid out and bent into shape before you attach them to the center plate. Once you've connected them to the center plate, check to make sure that each spoke has the correct shape. You can use the measuring element to measure points on the spokes. If the position is off, bend the spoke to bring the point into line. Changing the frame is a tedious process because bending the frame to change one point may affect other points on the frame. The measuring element lets you determine the accuracy of different points on the frame. You'll find this much easier than holding a 12-foot template in place to measure several points. The measuring and bend-

FIGURE 4



Reduction of gain due to surface errors.

ing procedure is an iterative process; repeat it until the surface's accuracy is acceptable. Our antenna's surface is within $\pm 1/8$ inch tolerance.

Conclusions

We've provided a simple method for determining the accuracy of the parabolic surface and for calculating the parameters used to check the surface accuracy. The parameters given here are for a 12-foot diameter parabolic antenna with a 58.91-inch focal length; however, you can change the computer program's parameters easily to provide data for checking parabolic antennas of other sizes. The BASIC program is written for a Commodore 64 computer, but can be applied to other home computers and programmable calculators. With increased accuracy, your parabolic antenna will provide better performance than other types of antennas at the higher frequencies.

Appendix

The surface of a paraboloid is described by the equation:

$$Y^2 = 4FX \quad (1)$$

where F is the focal length of the parabola.

To simplify surface measurement, determine the parameters of S and L. These dimensions are defined in Figure 2. Values X and Y are the rectangular coordinates of the points on the paraboloid.

Use the following procedure to calculate distance L (see Figure 2). The distance S is given in terms of F, X, and Y as:

$$S = \sqrt{X^2 + Y^2} = \sqrt{X^2 + 4FX} \quad (2)$$

By using Equation 2 and applying the quadratic equation from algebra, you can solve for X as:

$$X = \sqrt{4F^2 + S^2} - 2F \quad (3)$$

Once you've determined X, you can find distance L using the Pythagorean theorem as in Equation 4:

$$L = \sqrt{Y^2 + (F-X)^2} = \sqrt{4FX + (F-X)^2} \quad (4)$$

With a specific distance S, you can calculate distance L by using the focal length. Distance L is the same for all points located at a specific distance from the center of the parabola. This describes a locus of points which fall in a circle on the parabola's surface.

We've included a listing of the computer program to calculate the parameters used in the measurements. We wrote the program to obtain the values in Table 1 in BASIC for use on a C-64 computer. You can use this program to compute the parameters for dish antennas of different sizes.


BASIC COMPUTER PROGRAM

```
10 F= 58.909
20 FOR S= 0 TO 76 STEP 2
30 X=SQR(4*F*S+S*S)-2*F
40 L=SQR(4*F*X+(F-X)*(F-X))
50 PRINT S,L
60 NEXT S
70 END
```

where:

F is the focal length of the parabola,

L is the distance from the focus to the point on the parabola, and

S is the distance from the center of the parabola to the point of concern on the parabola. 

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(Continued from page 4.)

awards for his work, has authored numerous articles, and is associate chief of staff for research and development at Jerry L. Pettis Memorial Veterans Administration Medical Center, Loma Linda, California. He will discuss the basic science that supports our current knowledge of radiation hazards.

- Samuel Milham, Jr., M.D., Washington state epidemiologist. Dr. Milham, you'll remember, did the study that showed that hams, as well as electrical/electronic workers, suffered from higher than normal rates of certain leukemias and lymphomas (types of cancer).
- Ivan Shulman, M.D., WC2S, cancer surgeon. Shulman will discuss how the Amateur can take preventive steps to minimize the risk of exposure to the harmful effects of electromagnetic radiation.
- David Rodman, M.D., KN2M, ophthalmologist and writer for *Ham Radio* magazine. Rodman will cover his extensive work to quantify field strength measurements of both RF and 60-Hz field levels.

Again, it is important to stress that there is no "smoking gun" showing a clear, definable link between electromagnetic radiation and cancer or other diseases. There seldom is, at this early awareness stage of what may be a serious health problem. The latest reporting in the media, while prone to sensationalism and exaggeration, does emphasize the need to research this potential hazard further. In the words of one authority, "Something is going on here."

One must wonder why the ARRL's Bioeffects Committee has said almost nothing since its formation and Dr. Milham's first mention of his study of California and Washington state Amateur mortality rates in *Lancet*, April 6, 1985. (*Lancet* is a highly regarded British medical journal.) Hopefully, the ARRL will publish its policy and its findings soon. Silence, in this case, is not golden. It smacks of being afraid to "fess up" to a problem and admit that it might exist.

Is there a problem? It's likely that there is, but time, money, and thousands of hours of meticulous research are necessary to arrive at the final answers. *HR* is working on a number of different projects and will report its findings as they become known. Our intent is to inform — not fall prey to sensationalism, or blindly deny that a problem exists in the face of emerging evidence. We'll keep you, our readers, fully informed and up to date on all the latest developments.

Craig Clark, NX1G

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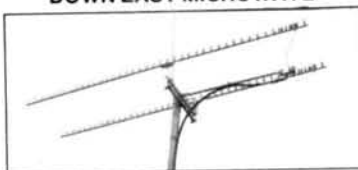
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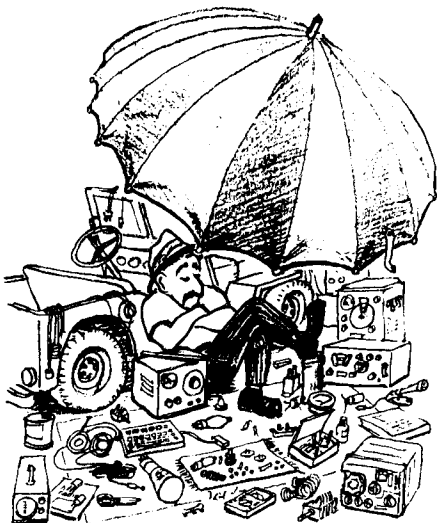
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CANCELLATION NOTICE. The BARC Packet Radio Symposium scheduled for September 16 at Georgian College, Barrie, Ontario has been cancelled.

ALABAMA: September 9-10. **Mobile Hamfest '89.** Sponsored by the Mobile ARC, Texas Street Recreation Center. For information: Larry Early, PO Box 8404, Mobile, AL 36689. (205) 342-7601 after 6 PM.

PENNSYLVANIA: September 9. 40th annual W3Pie Gabfest sponsored by the Uniontown ARC, Club Grounds, Old Pittsburgh Road, Uniontown. For information contact UARC c/o John Cermak, WB3DOD, PO Box 433, Republic, PA 15475. (412) 246-2870.

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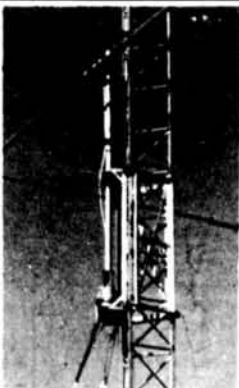
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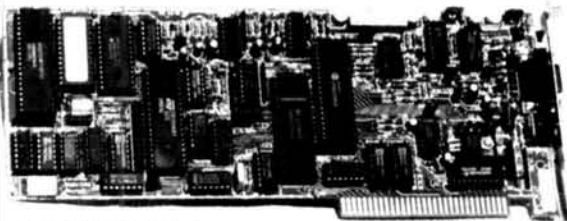
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EQUINOX SEASON DXING

The two equinox seasons are March-April and September-October. During these two periods of a few short weeks, the maximum usable frequencies (MUFs) make fairly rapid seasonal changes. For the spring equinox, the MUFs daily curve changes from a high peak near midday to a lower, broader one across the longer daylight hours of summer. The problems caused by these changes are magnified by a more direct alignment of the solar wind stream of charged particles into the polar region and from those stored in the earth's tail, which perturb the earth's magnetic field and, therefore, the ionosphere. As a result, the signals propagating between two points via the ionospheric mode can become weakened and variable in the mid- to high latitudes and near (± 20 degrees) the geomagnetic equator.

The high latitude propagation is applicable to east-west paths like the US to EU or JA because the great circle of the path reaches as high as 67 degrees north latitude. The MUFs and the signal's amplitude variations usually decrease there. Both can be estimated from the geomagnetic A and K figures. In the equatorial region, the propagation is applicable to transequatorial path openings. Here the MUFs usually increase during the disturbance, but the signal is still weaker and variable. However, the variability is different because it's lower in amplitude changes and at a faster frequency — like flutter.

The disturbed period of last March-April is a good example of equinox season changes. The spring season is often more disturbed than the fall. This is probably because the solar flux is

more often on a decreasing trend in the spring while it tends to increase in the fall, holding the earth's magnetosphere steadier from increasing solar radiation pressure. Therefore, solar flux and geomagnetic disturbance intensity tend to have opposite trends. Several large solar flares started off the month of March with some proton events and geomagnetic disturbances indicated by the A figure of 20 to 30 units. Another on the 10th at 1922 UTC started a polar cap signal absorption, followed by a big geomagnetic disturbance of 248 A units — the largest recorded in the United States since 1960. Numerous reports of aurora, some as far south as Key West, Florida, showed the extent and intensity of this disturbance. Later in the month, another large flare on the 23rd at 1959 UTC caused a proton event in 41 minutes, and a sudden geomagnetic disturbance on the 27th at 1342 UTC. Large flares on the 24th and 26th kept the disturbance going until April 5th. A large flare at 0105 UTC on April 9th had little effect, until another occurred on the 23rd at 2155 UTC. This probably caused the geomagnetic disturbance of April 25th at 1859 UTC, which continued with minor flaring until May 7th. These are the major geophysical events of a typical high

sunspot number equinox season. I'll report the propagation problems next month.

Last-minute forecast

The higher frequency bands are expected to be best, with longer openings the second and third weeks of September. The cause will be higher MUFs resulting from the expected high solar flux. These higher MUFs also cause a decrease in signal strength. A return of transequatorial one long hop openings in late evenings, especially during geomagnetic disturbances, can really enhance signal strengths. The disturbed periods may fall on the 6th and 7th, 13th through 15th, and 22nd and 23rd. Because this is the fall equinox season, there may be more periods of disturbance than those listed. The lower bands should improve with less thunderstorm noise and summer signal absorption both day and night. Expect better openings, especially from unique DX locations, in east-west directions during the disturbances. The full moon is on the 15th and perigee on the 16th. The autumnal equinox occurs on the 23rd at 0120 UTC.

Band-by-band summary

Ten, 12, 15, 17, and 20 meters provide many openings during the daytime. The openings will be shorter as you go up in frequency, centered around noon, and mainly in southerly directions. Fifteen meters is only a transition band between 12 and 17. Twenty meters, the mainstay daytime band for northerly directions, will be useful towards the south in the evenings.

Thirty, 40, 80, and 160 meters are all good for nighttime DX. Thirty and 40 meters are the night frequencies for the east-west and northerly directions, and for distances of 1600 miles. **7p**

WESTERN USA									
GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	5:00	12	30	12	10	10	10	10	10
0100	6:00	12	30	15	10	10	10	10	10
0200	7:00	12	30	15	10	10	10	10	10
0300	8:00	15	30	15	10	10	10	10	12
0400	9:00	15	30	17	12	12	10	10	15
0500	10:00	20	20	15	12	15	10	10	17
0600	11:00	20	30	15	15	20	10	10	20
0700	12:00	30	30	15	15	20	10	10	20
0800	1:00	30	30	17	15	20	12	12	20
0900	2:00	30	30	17	17	20	12	12	20
1000	3:00	30	30	17	17	20	15	15	30
1100	4:00	30	20	17	17	20	15	15	30
1200	5:00	30	15	10	17	20	15	15	30
1300	6:00	20	15	10	12	20	17	17	30
1400	7:00	20	12	10	10	20	17	17	20
1500	8:00	20	10	10	10	17	17	15	30
1600	9:00	30	10	10	10	12	17	15	30
1700	10:00	30	12	10	10	12	15	17	30
1800	11:00	30	12	10	10	10	12	17	20
1900	12:00	30	15	10	10	10	10	12	15
2000	1:00	30	15	10	10	10	10	10	12
2100	2:00	30	17	10	10	10	10	10	12
2200	3:00	17	20	10	10	10	10	10	10
2300	4:00	15	20	12	10	10	10	10	10

MID USA									
GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	6:00	15	30	12	10	10	10	10	10
0100	7:00	15	30	15	10	10	10	10	12
0200	8:00	15	30	15	10	10	10	10	15
0300	9:00	20	30	15	10	12	10	10	15
0400	10:00	20	30	15	12	15	10	10	17
0500	11:00	30	20	17	15	17	10	10	20
0600	12:00	30	30	15	15	20	10	12	20
0700	1:00	30	30	17	17	20	12	15	20
0800	2:00	30	30	17	17	20	12	15	30
0900	3:00	30	30	17	17	20	15	17	30
1000	4:00	30	30	15	17	20	15	17	30
1100	5:00	17	20	10	12	20	15	15	30
1200	6:00	15	15	10	10	20	17	15	20
1300	7:00	12	15	10	10	20	17	15	20
1400	8:00	12	12	10	10	20	17	17	30
1500	9:00	15	10	10	10	17	17	17	30
1600	10:00	15	12	10	10	15	17	17	30
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1900	1:00	20	15	10	10	10	10	12	15
2000	2:00	30	17	10	10	10	10	10	15
2100	3:00	30	20	10	10	10	10	10	12
2200	4:00	30	20	10	10	10	10	10	12
2300	5:00	17	30	12	10	10	10	10	10

EASTERN USA									
GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	8:00	17	30	15	10	10	10	10	15
0100	9:00	20	30	15	10	10	10	10	15
0200	10:00	20	30	15	10	12	10	10	20
0300	11:00	30	30	15	10	12	10	10	20
0400	12:00	30	30	17	12	15	10	10	20
0500	1:00	30	30	15	15	17	15	12	30
0600	2:00	30	30	15	15	20	15	12	30
0700	3:00	30	30	17	15	20	15	15	30
0800	4:00	30	20	17	17	20	15	15	30
0900	5:00	17	15	15	17	20	15	15	30
1000	6:00	15	15	10	17	20	17	17	20
1100	7:00	12	12	10	12	20	17	17	20
1200	8:00	12	12	10	10	20	15	12	20
1300	9:00	15	12	10	10	20	15	12	20
1400	10:00	15	10	10	10	15	15	15	30
1500	11:00	20	12	10	10	12	17	15	30
1600	12:00	20	12	10	10	12	17	17	30
1700	1:00	20	12	10	10	10	12	17	30
1800	2:00	30	12	10	10	10	10	17	20
1900	3:00	30	15	10	10	10	10	12	15
2000	4:00	30	15	10	10	10	10	10	15
2100	5:00	30	17	10	10	10	10	10	12
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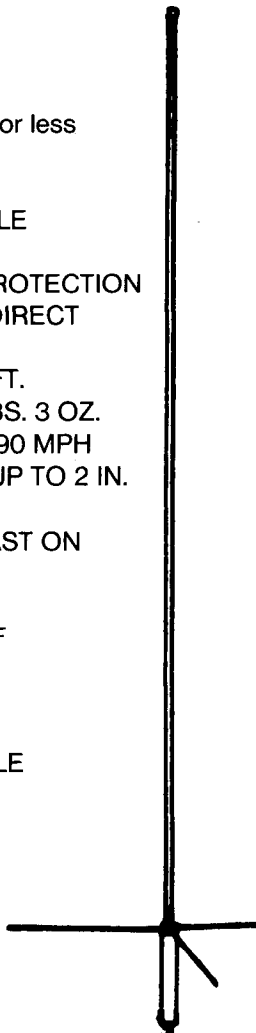
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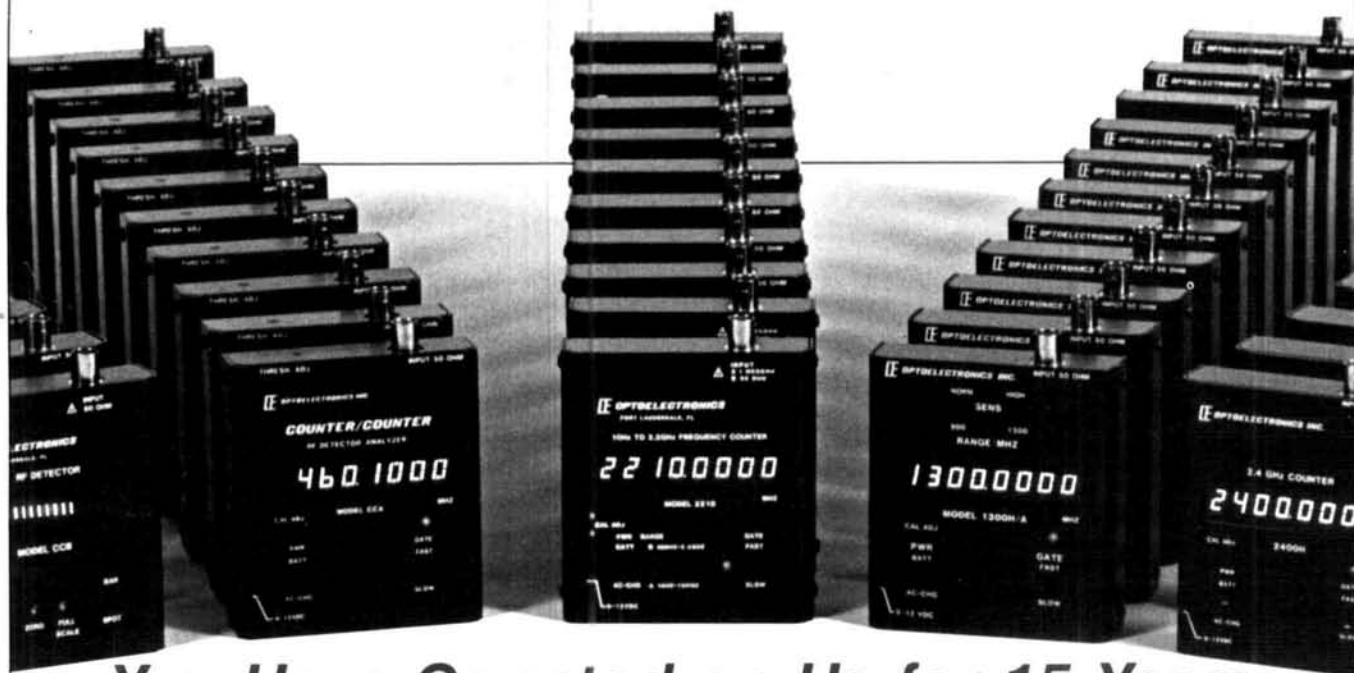
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APPLICATIONS	General Purpose Audio-Microwave	RF	Microwave	Security	Security
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100 MHz	< 3 mv	< 1 mv	< 3 mv	< .5 mv	< 5 mv
450 MHz	< 3 mv	< 5 mv	< 3 mv	< 1 mv	< 5 mv
850 MHz	< 3 mv	< 20 mv	< 5 mv	NA	< 5 mv
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...pacesetter in Amateur Radio

All-mode
tri-bander!

Warp Drive!



TS-790A Satellite Transceiver

The new Kenwood TS-790A VHF/UHF all-mode tri-band transceiver is designed for the VHF/UHF and satellite "power user." The new TS-790A is an all-mode 144/450/1200 MHz transceiver with many special enhancements such as automatic uplink/downlink tracking. Other features include dual receive, automatic mode selection, automatic repeater offset selection for FM repeater use, VFO or quick step channel tuning, direct keyboard frequency entry, 59 memory channels (10 channels for separate receive and transmit frequency storage), multiple scanning and multiple scan stop modes. The Automatic Lock Tuning (ALT) on 1200 MHz eliminates frequency drift. Power output is 45 watts on 144 MHz, 40 watts on 450 MHz, and 10 watts on 1200 MHz. (The 1200 MHz section is an optional module.)

- **High stability VFO.** The dual digital VFOs feature rock-stable TCXO (temperature compensated crystal oscillator) circuitry, with frequency stability of ± 3 ppm.
- **Operates on 13.8 VDC.** Perfect for mountain-top DXpeditions!
- **The mode switches confirm USB, LSB, CW, or FM selection with Morse Code.**
- **Dual Watch** allows reception of two bands at the same time.
- **Automatic mode and automatic repeater offset selection.**
- **Direct keyboard frequency entry.**
- **59 multi-function memory channels.** Store frequency, mode, tone information, offset, and quick step function. Ten memory channels for "odd split."
- **CTCSS encoder built-in.** Optional TSU-5 enables sub-tone decode.
- **Memory scroll function.** This feature allows you to check memory contents without changing the VFO frequency.

- **Multiple scanning functions.** Memory channel lock-out is also provided.
- **ALT—Automatic Lock Tuning—on 1200 MHz eliminates drift!**
- **500 Hz CW filter built-in.**
- **Packet radio connector.**
- **Interference reduction controls:** 10 dB RF attenuator on 2m, noise blanker, IF shift, selectable AGC, all mode squelch.
- **Other useful controls:** RF power output control, speech processor, dual muting, frequency lock switch, RIT.
- **Voice synthesizer option.**
- **Computer control option.**

Optional Accessories:

- **PS-31** Power supply • **SP-31** External speaker
- **UT-10** 1200 MHz module • **VS-2** Voice synthesizer unit
- **TSU-5** Programmable CTCSS decoder
- **IF-232C** Computer interface • **MC-60A/MC-80/MC-85** Desk mics • **HS-5/HS-6** Headphones
- **MC-43S** Hand mic • **PG-2S** Extra DC cable

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KENWOOD U.S.A. CORPORATION
COMMUNICATIONS & TEST EQUIPMENT GROUP
P.O. BOX 22745, 2201 E. Dominguez Street
Long Beach, CA 90801-5745
KENWOOD ELECTRONICS CANADA INC.
P.O. BOX 1075, 959 Gana Court
Mississauga, Ontario, Canada L4T 4C2

Complete service manuals are available for all Kenwood transceivers and most accessories. Specifications, features, and prices are subject to change without notice or obligation.



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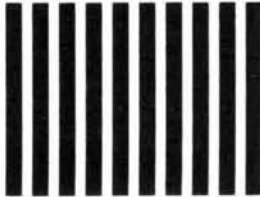
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