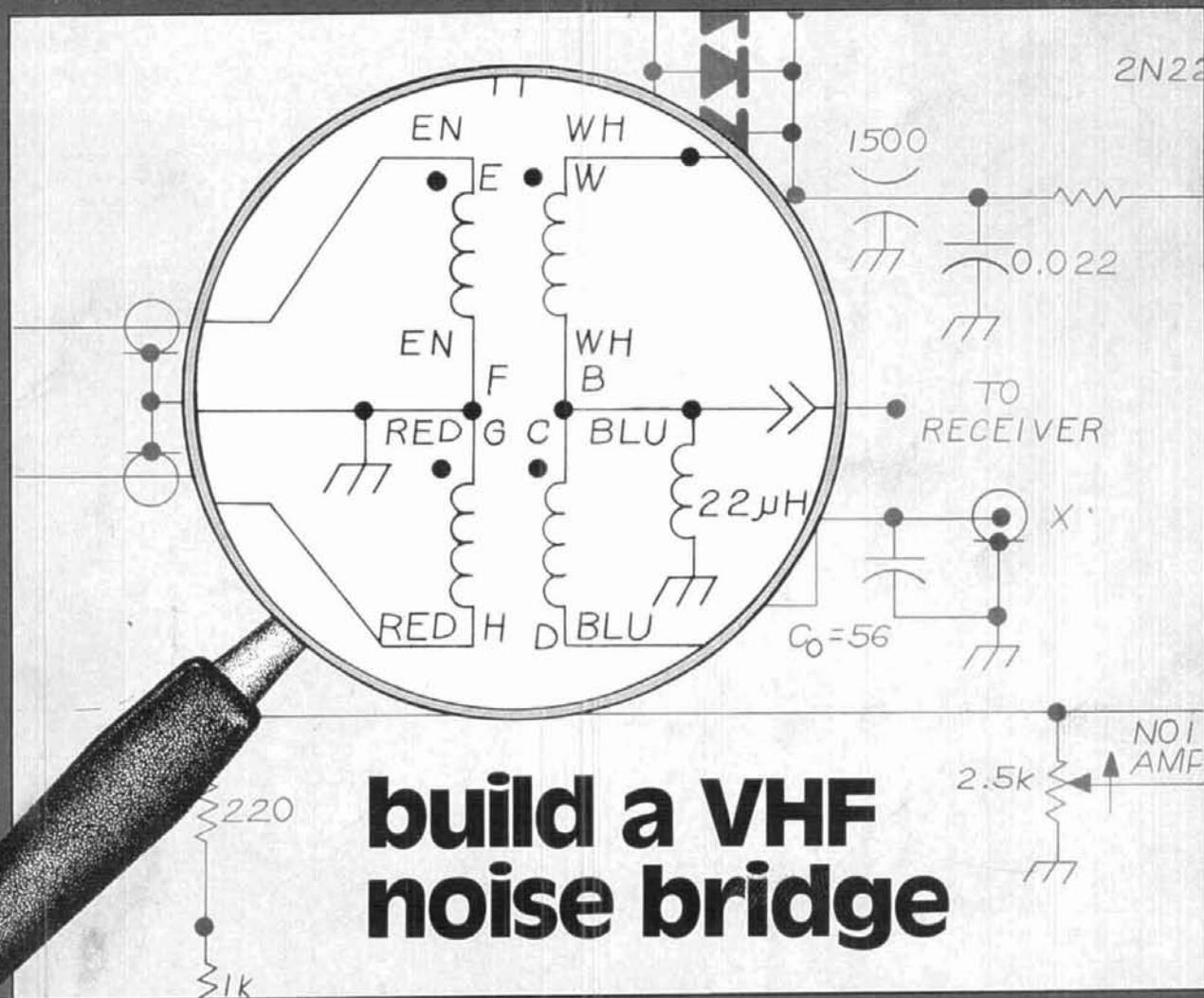


ham radio

magazine





ICOM IC-28H

THE ONE FOR THE ROAD

- Compact Size
- Simple to Operate
- Large LCD Readout
- 25 or 45 Watts
- Packet Compatible
- 21 Memory Channels

The IC-28H has all the features you need for carefree 2-meter mobile operation. The only thing it doesn't have is a big price.

45 Watts. The IC-28H provides a full 45 watts of powerful output. The **IC-28A** 25-watt version is also available. Both units have a selectable low power.

Large LCD readout. A wide-view LCD readout can be easily read even in bright sunlight. An automatic dimmer circuit reduces the brightness for evening operation.

Wideband Coverage. The IC-28H performs from 138-174MHz (specifications guaranteed from 144.00-148MHz) and includes weather channels. Ideal for MARS and CAP operation.

Compact Size. The IC-28H measures only 2 inches high by 5½ inches wide by 7¼ inches deep (IC-28A is 5¼



The IC-27H 45 watt and IC-27A 25 watt ultra compact 2-meter mobiles continue to be available.

inches deep). Great for mobile installations where space is limited.

21 Memory Channels. Store 21 frequencies into memory, or lock out certain memory channels. All memories are backed up with a lithium battery.

Scanning. Scan the entire band or the memory channels from the provided HM-12 mic.

Easy to Operate. With only 11 front panel controls, the IC-28H is simple to operate.

Available Options. IC-HM14 DTMF mic, PS-45 13.8V 8A power supply, UT-29 tone squelch unit, SP-10 external speaker, IC-HM16 speaker mic and HS-15/HS-15SB flexible boom mic and PTT switchbox.

ICOM
First in Communications

Kantronics "SMARTS"

Presenting three intelligent, versatile, compatible terminal units.

"SMART" means an internal microprocessor is used to improve performance and add versatility. The "Smart" Kantronics TU's can transmit and receive CW/RTTY/ASCII/AMTOR or Packet when combined with your computer and transceiver.

Any computer with a serial RS232 or TTL port can connect directly to a Kantronics TU. A simple terminal program, like one used with a telephone modem, is the only additional program required. Kantronics currently offers Pac-term and UTU Terminal Programs for IBM, Kaypro, Commodore 64, VIC 20, and TRS-80 Models III, IV, and IVP. Disk version \$19.95. Cartridge \$24.95.

UTU The Universal Terminal unit (UTU) is the original "Smart" amateur TU. CW, RTTY, ASCII, and AMTOR can all be worked with this single unit. Switched capacitance filters and LED display tuning make using the UTU easy for even the Novice. 12 Vdc 300mv power supply required. Suggested retail \$199.95.

UTU-XT The UTU-XT is an enhanced version of the UTU. Programmable baud rates, tone frequencies, and tone shifts give special versatility. Automatic Gain Control and Threshold Correction circuits greatly enhance sensitivity and selectivity. A RTTY signal detect circuit mutes copy with no carrier, and the CW filter center frequency and bandwidth are programmable. Power supply is provided. Suggested retail \$359.95.



NEW!

KPC-2 Kantronics AX.25 Version 2 TNC features a built-in HF modem, full duplex operation, multiple connects, and over 100 software commands. A serial RS-232 or TTL (C-64/VIC-20) port gives universal compatibility. The enhanced generic command structure fits any computer, even PC compatibles. All this combines to make KPC-2 the only TNC you'll ever need. Suggested retail \$219.00.

For more information contact your local Kantronics dealer or write:

✓ 199

Kantronics

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Lawrence, Kansas 66046

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All New Compact HF

“DX-citing!”

TS-440S Compact high performance HF transceiver with general coverage receiver

Kenwood's advanced digital know-how brings Amateurs world-wide "big-rig" performance in a compact package. We call it "Digital DX-citement"—that special feeling you get every time you turn the power on!

- Covers All Amateur bands
General coverage receiver tunes from 100 kHz—30 MHz. Easily modified for HF MARS operation.
- Direct keyboard entry of frequency
- All modes built-in
USB, LSB, CW, AM, FM, and AFSK. Mode selection is verified in Morse Code.
- Built-in automatic antenna tuner (optional)
Covers 80-10 meters.
- VS-1 voice synthesizer (optional)



- Superior receiver dynamic range
Kenwood DynaMix™ high sensitivity direct mixing system ensures true 102 dB receiver dynamic range. (500Hz bandwidth on 20 m)
- 100% duty cycle transmitter
Super efficient cooling permits continuous key-down for periods exceeding one hour. RF input power is rated at 200 W PEP on SSB, 200 W DC on CW, AFSK, FM, and 110 W DC AM. (The PS-50 power supply is needed for continuous duty.)



- Adjustable dial torque
- 100 memory channels
Frequency and mode may be stored in 10 groups of 10 channels each. Split frequencies may be stored in 10 channels for repeater operation.
- TU-8 CTCSS unit (optional)
Subtone is memorized when TU-8 is installed.
- Superb interference reduction
IF shift, tuneable notch filter, noise blanker, all-mode squelch, RF attenuator, RIT/XIT, and optional filters fight QRM.
- MC-42S UP/DOWN mic. included
- Computer interface port
- 5 IF filter functions
- Dual SSB IF filtering
A built-in SSB filter is standard. When an optional SSB filter (YK-88S or YK-88SN) is installed, **dual** filtering is provided.
- VOX, full or semi break-in CW; AMTOR compatible.



Optional accessories:

- AT-440 internal auto. antenna tuner (80 m—10 m)
- AT-250 external auto. tuner (160 m—10 m)
- AT-130 compact mobile antenna tuner (160 m—10 m)
- IF-232C/IC-10 level translator and modem IC kit
- PS-50 heavy duty power supply
- PS-430/PS-30 DC power supply
- SP-430 external speaker
- MB-430 mobile mounting bracket
- YK-88C/88CN 500 Hz/270 Hz CW filters
- YK-88S/88SN 2.4 kHz/1.8 kHz SSB filters
- MC-60A/80/85 desk microphones
- MC-55 (BP) mobile microphone
- HS-4/5/6/7 headphones
- SP-40/50 mobile speakers
- MA-5/VP-1 HF 5 band mobile helical antenna and bumper mount
- TL-922A 2 kw PEP linear amplifier
- SM-220 station monitor
- VS-1 voice synthesizer
- SW-100A/200A/2000 SWR/power meters
- TU-8 CTCSS tone unit
- PG-2C extra DC cable.

Kenwood takes you from HF to OSCAR!



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

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JULY 1986

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REFLECTIONS REFLECTIONS

the phone call

It took a late-night, long-distance phone call to remind me of what I used to easily perceive as the excitement of ham radio. The call came from a good friend who'd gotten into Amateur Radio at about the same time as I did, approximately 28 years ago. Catching up on recent history, I couldn't help noticing not only his present and continuing enthusiasm for the hobby, but also his accomplishments over the years. His interests included, but weren't limited to, antenna and propagation experimentation, modification of commercial equipment, the design and construction of new equipment, operation on the newer specialized communications modes, as well as teaching and helping other Amateurs. But what impressed me the most was his intensity — his desire to do the very best he could while enjoying what he was doing.

Not long ago I found myself feeling discouraged about the future of Amateur Radio. It's not difficult to get into this mood. Just listen to discussions on the air, at hamfests and at other meetings. . . or open up to the editorial page of any ham magazine. There you'll no doubt hear, or read, that the average age of Radio Amateurs in this country is rising steadily. If you really want to get discouraged, tune any of the HF bands (and the most popular VHF band). What do you hear?

- *"CQ DX, CQ DX."* (Translated, this means "I want to contact you, the rare station, as fast as I can and get your QSL card and then goodbye!")
- Or *"Hey, Goofball, this is my frequency and I'm not moving!"* (Translation: "I've been on this frequency for the past three hours and I own it.")
- Or *"Hey, Joe, are you sure I'm only 37.5 dB stronger than that other W1? By my figuring I should be at least 40 dB up from him!"* (Somewhere along the line many of us forgot that the FCC didn't intend for us to turn Amateur Radio into a horsepower race.)
- Or, as heard on 2 meters not too long ago, *"Tom, I just got this new Loudenboomer amplifier. It's wired for 110 volts. How do ya wire it for 220?"* (I guess that question wasn't on his Advanced class exam).

Is this what Amateur Radio is all about?

There are those who say we need some stimulation and that the solution is obvious: get more youth involved. Presto! Amateur Radio — if not the world itself — is saved. Quite frankly, I don't believe in simplistic cures and single-answer solutions. But it is true that in order for any organization to self-perpetuate, a constant influx of "newness" is required, be it youth itself or just youthful energy and spirit.

Even if we manage to attract young people to our hobby, it will still take Amateurs (like my friend) willing to share their enthusiasm and knowledge with them. By helping young people pursue their own interests, these Amateurs will encourage young people not only to enter Amateur Radio, but stay there. It won't be just young people who "save" Amateur Radio, but those hams like my friend who make that special effort.

Rich Rosen, K2RR
Editor-in-Chief

KENWOOD

...pacesetter in Amateur radio

Just arrived!

All-Mode Mobility!

TR-751A

Compact 2-m all mode transceiver

It's the "New Sound" on the 2 meter band—Kenwood's TR-751A! Automatic mode selection, versatile scanning functions, illuminated multi-function LCD and status lights all contribute to the rig's ease-of-operation. All this and more in a compact package for VHF stations on-the-go!

- Automatic mode selection, plus LSB
- 144.0 144.1 144.5 145.8 146.0 148.0 MHz

CW	USB	FM	USB	FM
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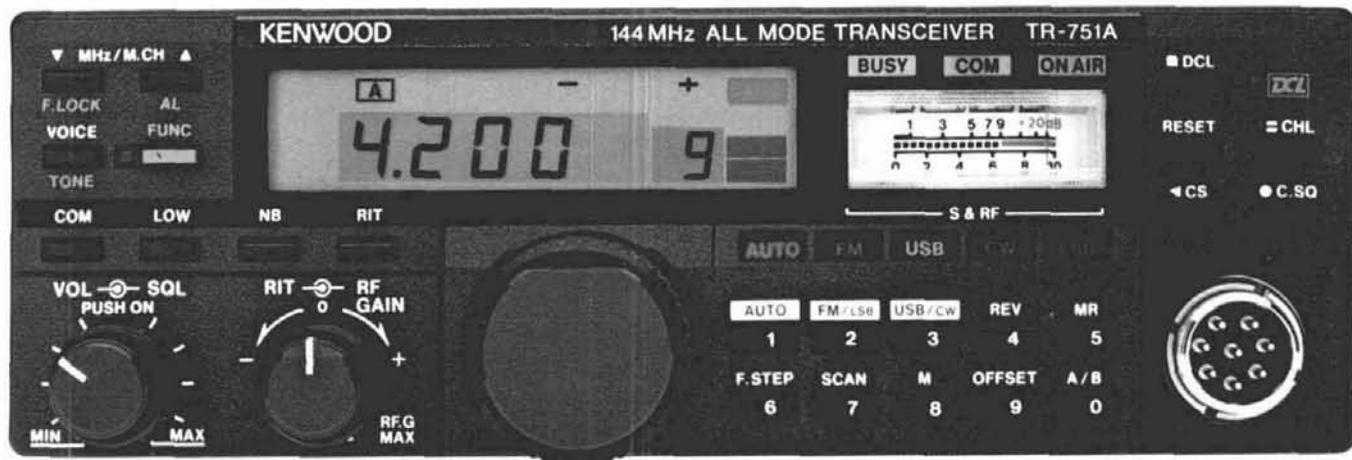
- Optional front panel-selectable 38-tone CTCSS encoder
- Frequency range 142-149 MHz (modifiable to cover 141-151 MHz)
- High performance receiver with GaAs FET front end
- VS-1 voice synthesizer option

- 25 watts high/5 watts adjustable low
- Programmable scanning—memory, band, or mode scan with "COM" channel and priority alert
- 10 memory channels for frequency, mode, CTCSS tone, offset. Two channels for odd splits.
- All mode squelch, noise blanker, and RIT
- Easy-to-read analog S & RF meter

- Dual digital VFOs
- Semi break-in CW with side tone
- MC-48 16-key DTMF hand microphone included
- Frequency lock, offset, reverse switches
- Digital Channel Link (DCL) option

Optional accessories:

- CD-10 call sign display
- PS-430, PS-30 DC power supplies
- SW-100A/B SWR/power meter
- SW-200A/B SWR/power meter
- SWT-1 2-m antenna tuner
- TU-7 38-tone CTCSS encoder
- MU-1 modem unit for DCL system
- VS-1 voice synthesizer
- MB-10 extra mobile mount
- SP-40, SP-50 mobile speakers
- PG-2K extra DC cable
- PG-3A DC line noise filter
- MC-60A, MC-80, MC-85 deluxe base station mics.
- MC-42S UP/DOWN mic.
- MC-55 (8-pin) mobile mic.



Actual size front panel

TR-9500 70 CM SSB/CW/FM transceiver

- Covers 430-440 MHz, in steps of 100-Hz, 1-kHz, 5-kHz, 25-kHz or 1-MHz.
- CW-FM Hi—10W, Low—1W. SSB 10W.
- Automatic band/memory scan. Search of selected 10-kHz segments on SSB/CW.
- 6 memory channels.



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Compton, California 90220

Complete service manuals are available for all Trio Kenwood transceivers and most accessories. Specifications and prices are subject to change without notice or obligation. Specifications guaranteed for the 144-148 MHz Amateur band only.

SEVERE SANCTIONS AGAINST CASUAL SWL'ING STILL REMAIN in the latest version of the "Electronic Communications Privacy Act of 1986" adopted unanimously by Rep. Kastenmeier's subcommittee May 14. Though the Act specifically exempts any station transmitting in an Amateur band, it is still based on the negative philosophy that a U.S. citizen has no right to tune to any radio transmission except as permitted by the government (see the editorial in February's Ham Radio). Furthermore, this latest version now defines "interception" of radio or other electronic communications as the interception of the transmission itself rather than its content! The Act provides for fines up to \$10,000 and a year in jail for tuning in remote broadcast pickups, possibly any ship-to-shore communications, any kind of encoded transmissions, RCCs (older type car phones), and any FM subcarriers.

The Cellular Telephone Industry Didn't Get Exactly what it wanted; the penalty for receiving cellular would be only \$500 and/or six months in jail. However, when Rep. Mike DeWine (R-Ohio) offered an amendment to limit the Act to encrypted communications or the disclosure of the contents of protected but unencrypted communications, Rep. Kastenmeier responded saying he wanted his bill to discourage casual listening -- even though the Justice Department has said it couldn't and wouldn't enforce the Act against casual listeners. That amendment, and another by DeWine to eliminate the six-month penalty for eavesdropping on cellular communications, were both voted down.

The Act (HR-3378) Now Goes To The House Judiciary Committee where it is expected to meet with little opposition. At the same time hearings on the Senate's version of the bill, S-1667, are expected to be scheduled in the very near future.

A 30-DAY WAIT BEFORE RETAKING AN AMATEUR EXAM IS INDEED UNNECESSARY, the FCC affirmed in deciding against ARRL's Petition for Reconsideration in PR Docket 85-31. The League had argued for retaining the delay because its program is set up so that ARRL VEs can use the same exam for some period of time, but the FCC said in its decision, "We will not retain it [the wait] merely to accommodate the administrative choices made by one or more VECs. It is far more important to eliminate unnecessary and outdated government regulations."

PRB-1 HAS APPARENTLY RESOLVED KA7TVC'S ANTENNA PROBLEM with Kirkland, Washington authorities (see June Presstop). His 2-meter vertical had been cited under a city ordinance restricting transmitting antennas, but Kirkland is considering its law firm's advice to revise its ordinance to agree with PRB-1 and has dropped its action against KA7TVC.

An Ordinance Limiting Antennas To Six Feet Above Roof Line in the District of Columbia was up for first hearing at presstime; ARRL has prepared a strong presentation against the proposal. Bills limiting all towers in New York State to 50 feet or tree-top height, whichever is lower, have been introduced in that state's legislature.

SUGGESTIONS AND COMMENTS FOR THE VEC PROGRAM ARE BEING SOUGHT by the Council for Amateur Radio Examining (CARE) in preparation for a meeting with the FCC tentatively set for August. The Washington meeting, for all accredited VECs, will review how well the program is working and how it might be improved. Write CARE, Box 688, Glenview, Illinois 60025.

A NEW BAND PLAN FOR 10-METER FM WAS SUPPORTED by nearly 100 Amateurs attending the 10-Meter FM Forum at the Dayton Hamvention. In brief it would change the repeater offset to 400 kHz instead of 100 kHz and use 29.50-29.68 MHz for the repeater outputs. Repeater inputs would then be 29.10-29.28, on 20 kHz centers. 29.3-29.4 MHz would be used for FM simplex, with 29.4-29.5 a "No-FM" slot for OSCAR downlinks so long as any Amateur 10-meter satellites remain operational. A formal Petition for Rule Making is being planned; Bob Heil, K9EID, would appreciate comments; write Bob at Box 78, Marissa, Illinois 62257.

Revision of 10-Meter Beacon Operation into a system similar to the 20-meter beacon system operating on 14.100 MHz has been proposed by the IARU. In Resolution 85-1 the Union would set aside 28.190-28.200 MHz for beacons, with a worldwide beacon network on 28.200 and regional networks from 28.190 to 28.199. Almost all 10-meter beacons now on the air operate between 28.200 and 28.300, but if the proposed expansion of 10-meter Novice privileges is adopted, the usefulness of these beacons -- most running low power -- would be seriously compromised. G3DME coordinates the International Beacon Project for IARU.

LABELS SPECIFYING RFI SUSCEPTIBILITY ON HOME ENTERTAINMENT EQUIPMENT are being sought by the ARRL in a Petition for Rule Making filed with the FCC. If adopted, the proposal would require every such device to carry an FCC-mandated label or tag that would specify just how susceptible that device is to interference from nearby transmitters.

In Canada VE3SR Has Decided To Fight The Judge's Decision that put him off the air as a "nuisance" to his neighbors' home entertainment equipment (see June Presstop). Though it now looks as if he may receive some support from commercial two-way users who are concerned about the possible impact of the decision on their operations, he'll still need help from the Amateur community to meet the estimated \$15,000 cost of the appeal.

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Accessories



TL-922A 160-15 m 2 kW PEP/1 kW DC Input Linear Amplifier. Pair of EIMAC 3-500Z tubes and excellent IMD characteristics. Perfect safety protection with blower turn-off delay circuit.



PC-1A Phone Patch (FCC Part 68 registered).



VB-2530 25 W RF Power Amplifier (for TR-2600A). BNC-BNC cable, and mounting bracket supplied.



MC-85 (8-pin) Multi-function desk-top microphone (8-pin) 700 Ω unidirectional electret condenser mic. Built-in audio level compensation with output and tone control, meter, and UP/DOWN switch. Selector switch for up to three transceivers. (Additional 4, 6, or 8-pin cables optional.)

MA-5 80/40/20/15/10 meter mobile antenna. All resonators supplied. 200 W PEP max., VSWR 1.5:1 or less. Easily adjustable for center frequencies.

VP-1 Bumper mount for above.



MC-60A (8-pin) Deluxe desk-top microphone. Pre-amp built-in, PTT, LOCK and UP/DOWN switches. Hi/Lo Z selector switch.



SM-220 Station monitor/10 MHz oscilloscope Pan display capability with optional BS-8 (for TS-940S, TS-830S). Monitor transmitted waveforms and/or received signal waveforms. Built-in 2-tone generator.



HS-5 Deluxe headphones.

HS-6 Lightweight headphones.



LF-30A Low pass filter. 1 kW, 50 Ω . Insertion loss: less than 0.5dB at 30 MHz.

MA-4000 2 m/70 cm dual band mobile gain antenna. Duplexer supplied. Ideal for use with the TW-4000A "Dual Bander" and TM-211A/TM-411A. (Mount not supplied.)

AL-2 Lightning and static arrester. 1 kW, 50 Ω .



Not Shown:

MC-50 Desk-top microphone. Hi/Lo Z, 4-pin connector.

MC-80 Desk-top microphone. 700 Ω unidirectional electret element with flexible boom. Built-in mic, pre-amp and UP/DOWN switch, with lock. (8-pin).

MC-48 Hand microphone with 16-key DTMF pad and UP/DOWN switches. (8-pin).

MC-46 As above, but with 6-pin connector.

MC-42S Hand microphone with UP/DOWN switches. (8-pin).

MC-35S Noise cancelling hand microphone, 50 k Ω (4-pin).

MC-30S As above, but 500 Ω .

PG-4A Microphone cable for MC-60A. Converts MC-60A to 4-pin connector.

PG-4B As above, but 6-pin.

PG-4C As above, but 8-pin, as supplied with MC-60A.

PG-4D Extra 4-pin cable for MC-85.

PG-4E As above, but 6-pin.

PG-4F As above, but 8-pin.

HS-7 Micro-headphones.

KPS-7A 13.8 V DC, 7.5 A intermittent DC power supply.

RA-3 2 m, $\frac{3}{8}$ λ telescoping antenna with BNC connector.

RA-5 2 m $\frac{1}{4}$ λ / 170 cm $\frac{3}{8}$ λ telescoping antenna with BNC connector.

RA-8B 2 m StubbyDuk[®] with BNC connector.

RA-9B As above, for 220 MHz.

RA-10B As above, for 440 MHz.

RD-20 Dummy load, 50 Ω DC-500 MHz 20 W continuous, 50 W intermittent.

PG-3A DC line filter for mobile use.

Service manuals are available for all Kenwood transceivers and most accessories.

SP-40 Compact mobile speaker.

SP-50 Mobile speaker.

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BEST OF MFJ

MFJ 24 HOUR LCD CLOCKS

These MFJ 24 hour clocks make your DXing, contesting, logging and SKEDing easier, more precise.

Read both UTC and local time at a glance with the MFJ-108, \$19.95, dual clock that displays 24 and 12 hour time simultaneously. Or choose the MFJ-107, \$9.95 single clock for 24 hour UTC time.

Both are mounted in a brushed aluminum frame, feature huge easy-to-see 5/8 inch LCD numerals and a sloped face that makes reading across-the-shack easy and pleasant.



LOCAL MFJ UTC
MFJ-12/24 HOUR DUAL LCD CLOCK
MODEL MFJ-108

MFJ-108
\$19.95

MFJ-107
\$9.95



MFJ 24 HOUR LCD CLOCK
MODEL MFJ-107

You can read hour, minute, second, month and day and operate them in an alternating time-date display mode. You can also synchronize them to WWV for split-second timing. Both are quartz controlled for excellent accuracy.

They are battery operated so you don't have to reset them after a power failure, and battery operation makes them suitable for mobile and portable use. Long life battery included.

MFJ-108 is 4 1/2 x 1 x 2 in. MFJ-107 is 2 1/4 x 1 x 2 in.

RTTY/ASCII/AMTOR/CW MFJ-1229 COMPUTER INTERFACE \$179.95



Everything you need is included for sending and receiving RTTY/ASCII/CW on a Commodore 64 or VIC-20 and your ham rig. You get MFJ's most advanced computer interface, software on tape and all cables. Just plug in and operate.

The MFJ-1229 is a general purpose computer interface that will never be obsolete. An internal DIP switch, TTL and RS-232C ports lets you adapt the MFJ-1229 to nearly any home computer and even operate AMTOR with appropriate software.

A crosshair "scope" LED tuning aid makes accurate tuning fast, easy and precise.

You can transmit both narrow (170 Hz) and wide (850 Hz) shift while the variable shift tuning lets you copy any shift (100-1000 Hz) and any speed (5-100 wpm, 0-300 baud ASCII).

Automatic threshold correction and sharp multipole active filters give good copy under severe QRM, weak signal and selective fading.

There's an FM (limiting) mode for easy trouble-free tuning that's best for general use and an AM (non-limiting) mode that gives superior performance under weak signals and heavy QRM.

A handy Normal/Reverse switch eliminates re-tuning while checking for inverted RTTY.

An extra sharp 800 Hz CW filter really separates the signals for excellent copy.

12 1/2 x 12 1/2 x 6 inches. Uses floating 18 VDC or 110 VAC with MFJ-1312, \$9.95.

MFJ PORTABLE ANTENNA

MFJ's Portable Antenna lets you operate 40, 30, 20, 18, 15, 12, 10 meters from apartments, motels, camp sites, vacation spots, any electrically clear location where space for full size antenna is a problem.

A telescoping whip (extends 54 in.) is mounted on self-standing 5 1/2 x 6 3/4 x 2 1/4 inch Phenolic case. Built-in antenna tuner, field strength meter, 50 feet coax. Complete multi-band portable antenna system that you can use nearly anywhere. 300 watts PEP.

MFJ-162
\$79.95



MFJ ANTENNA BRIDGE MFJ-204B \$79.95

Now you can quickly optimize your antenna for peak performance with this portable, totally self-contained antenna bridge that you can take to your antenna site—no other equipment is needed.

You can determine if your antenna is too long or too short, measure its resonant frequency and antenna resistance to 500 ohms. It's the easiest and most convenient way to determine antenna performance available today to anyone. There's nothing else like it and only MFJ has it. Built-in resistance bridge, null meter and tunable oscillator-driver (1.8-30 MHz). Uses 9 V battery. 4 x 2 x 2 inches.

REMOTE ACTIVE ANTENNA

The authoritative "World Radio TV Handbook" rates the MFJ-1024 as "a first-rate easy-to-operate active antenna... Quiet, with excellent dynamic range and good gain... Very low noise factor... Broad frequency coverage... the MFJ-1024 is an excellent choice in an active antenna"

54 inch remote active antenna mounts outdoor away from electrical noise for maximum signal and minimum noise pickup. Often outperforms long-wire hundreds of feet long. Mount anywhere—atop houses, buildings, balconies, apartments, ships.

Use with any radio to receive strong clear signals from all over the world. 50 KHz to 30 MHz. High dynamic range eliminates intermodulation. Inside control unit has 20 dB attenuator, gain control.

Switch 2 receivers and auxiliary or active antenna. "On" LED. 6 x 2 x 5 in. 50 ft. coax. 12 VDC or 110 VAC with MFJ-1312, \$9.95.

MFJ-1024
\$129.95

200 WATT VERSA TUNER

MFJ-901B \$59.95

MFJ's smallest 200 watt

Versa Tuner matches coax, random wires and balanced lines from 1.8 thru 30 MHz. Works with all solid state and tube rigs. Very popular for use between transceiver and final amplifier. Efficient air-wound inductor gives more watts out. 4:1 balun, 5x2x6 in.



ROLLER INDUCTOR TUNER



MFJ-989 \$329.95

Meet the "Versa Tuner V", the compact roller inductor tuner that lets you run up to 3 KW PEP and match everything from 1.8 to 30 MHz.

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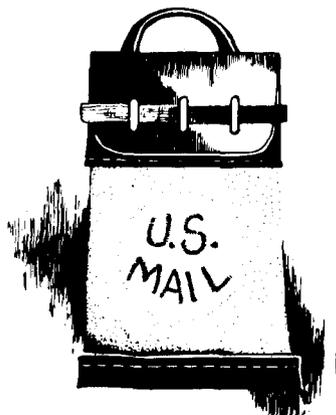
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comments

amplifier parasitics

Dear HR:

Richard Measures's article in the April, 1986, issue, "Grounded-Grid Amplifier Parasitics," was most interesting. It provided insight into several amplifier circuit designs that are indeed troublesome.

I, too, experienced parasitic oscillations in my first SB-220. While the plate tuning capacitor did arc over, no damage was done. A local Amateur who was well versed in VHF equipment construction pointed to the silver mica capacitor and RF choke tied from each tube socket grid pin to ground as suspect. At his suggestion, the component leads were reduced to the shortest possible length. The choke was also re-positioned so that its "cold" end was laid against the chassis. This appeared to reduce the choke Q and lessen the probability of parasitic oscillation. After these simple modifications, the amplifier remained stable. The tuning capacitor never arced again.

For the past eight years I've had first-hand production experience with several hundred HF linear amplifiers using the Eimac 8874 and 8877. To date I've not seen a single case of parasitic oscillation or instability of any kind with these tubes. In addition to careful circuit layout, the key to stable operation appears to be the use of Eimac's recommended tube sockets. It's no accident that a tube manufacturer specifies all relevant operating parameters — from airflow require-

ments, to element voltages, to such mundane items as heat-dissipating anode connectors and sockets. The E.F. Johnson socket specified for use with the 8874 can be mounted so that the grid pin terminal lugs are bent over and soldered directly to the socket saddle. The Eimac SK-2210 socket for the 8877 provides four short, direct, grid grounding spring clips. In both cases, the grid-to-ground connection has very low inductance and a large conductive area.

The possibility of interelectrode shorting demands the inclusion of a current limiting resistor in the plate supply. Without it, the tubes and HV rectifiers are in jeopardy. The resistance provides a voltage drop that's dependent upon the current drawn. The voltage drop can actuate a plate current relay that turns off the amplifier if the dreaded short occurs. This resistor, like the "feedback resistors" in AG6K's article, provides cheap insurance.

Reliable equipment operation isn't magical. Nor is it accidental. It should be the heart of the design.

Ray R. Heaton, NJ0G
Canon City, Colorado 81212

Dear HR:

Having had 36 — I repeat, *three dozen* — 572 tubes fail in a manner similar to that described by AG6K, in his April article (page 31), I found his conclusions very interesting and provocative.

The amplifier I was using was grid-driven, neutralized, and had parasitic suppressors in both plate and filament leads. The filament lead suppressors varied from several to as many as eight turns of No. 14 enameled wire wound on an 82-ohm 2-watt resistor. I had no arcing at the plate tuning capacitor to warn me because the capacitor is rated at 7000 volts. In every case, the big bang would result in one tube failing at a time. The tube would develop a grid-to-filament short and sometimes the filament would open.

I liked AG6K's explanation and cure, but several things keep sticking in my

mind. He says the cure is 90 percent, not 100 percent effective. In my case, on three or four occasions I definitely saw the grid meter give a reverse kick just before the big bang. The tubes were operated Class C with high bias voltage.

He is right about lots of power being involved, because the bang would blow the 30-Ampere fuses in the 234-volt line feeding the power supply.

The trouble seems to have started around 1981. Tubes purchased before that time gave years of trouble-free operation. I have an old HXL-1 in which the tubes must be 15 years old. I may be wrong, but I came to the conclusion that the troubles began when the manufacturer changed the amplification factor from 160 to 200. (I have a feeling AG6K is going to write more on this.)

John Labaj, W2YW
Elsmere, New York 12054

directive antenna

Dear HR:

W4MB's article, "A New Class of Directive Antenna," (April, 1986, page 107) — with its coverage of the Landstorfer antenna — was very interesting. I was impressed when this idea was recently demonstrated by Frank Rutter, K3AW, at the Tropical Ham-boree. Then I remembered that a little more gain can be developed with a straight shorter (5/4 wave) element Yagi which would be much simpler, mechanically, to reproduce. An example of this, the "extended double Zepp"-type Yagi beam antenna was described "The Extended Element Beam" in the December, 1983, issue of *QST*.

The Landstorfer antenna does make a nice exercise in wave theory. Maybe somebody will come up with a more compact structure that will provide increased gain and be useful for construction on the HF bands. A step in this direction is the log-Yagi as outlined by Leo D. Johnson, W3EB, in "Log Yagis Simplified" (*ham radio*, May, 1983). **Wayne W. Cooper, AG4R**
Miami Shores, Florida

a VHF noise bridge

Measure resistances and reactances to within 3 ohms at 146 MHz

Although there is no need to enumerate the many merits of the noise bridge, it is not used as often as one might expect. One of the reasons for its limited acceptance by the Amateur community may be that one needs some knowledge of the impedance-transforming properties of transmission lines as well as modest mathematical skills in order to take full advantage of its great measuring potential.

Several excellent articles about noise bridges operating in the frequency range of 3.5 to 30 MHz have been presented in this magazine.^{1,2} However, to date, nothing has been said about a VHF noise bridge.

The usefulness of a noise bridge depends mainly on its accuracy. Throughout the HF spectrum it is difficult to maintain a 1 percent accuracy over the relatively large frequency range of 3.5 to 30 MHz. In the VHF version bandwidth is small but the operating frequency is considerably higher, which poses the main difficulty. Conventional noise bridge construction with a variable resistor and a variable capacitor does not lead to success.

At VHF frequencies, a variable resistor of 200 ohms, for example, exhibits too much inductance. In addition, the sheer physical size of the variable capacitor in conjunction with the usually awkward position of its terminals make it practically impossible to provide interconnections without adding prohibitively large inductances, thus degrading performance severely.

This article describes the construction of a noise bridge for the 2-meter band (144 to 148 MHz) that has sufficient accuracy to permit credible and reproducible measurements on multi-element antennas or antenna systems consisting of antenna and transmission line. A practical example of determining the impedance of an antenna via its feedline from the shack is presented.

The four items that control noise bridge accuracy are the wideband transformer, the variable resistor, the variable capacitor, and the physical layout (wiring). Obviously, single-point grounding is mandatory. If we replace the variable resistor with a PIN diode and the variable capacitor with five parallel connected tuning diodes, it is possible to shrink the size of the noise bridge to a minimum and achieve almost perfect wiring. A certain weakness exists because of the rather poor RF properties of the SO-239 jack; because most Amateurs use the PL-259 plug, it was retained.

the wideband transformer

The transformer must have electrical symmetry and close magnetic coupling between primary and secondary windings. It consists of four tightly twisted No. 24 enameled copper wires with 0.5 mm diameter. Two opposite wires of the bundle are the primary and secondary windings. The bundle is threaded about 3.5 times through a toroidal core — for example, an Amidon T 50-10. The beginning and end of each winding must be marked with short pieces of sleeving material and then connected per fig. 1. It is important to have equal wire lengths between transformer terminals A and D and circuitry as well as between terminals B and C and point M. The toroidal transformer must be mechanically secured to the chassis with nylon hardware to prevent a change in calibration later on.

noise bridge diagram

The complete schematic of the noise bridge, shown in fig. 2 consists of a separate noise source and bridge.

The noise signal is fed to the bridge via two equally long, thin coaxial cables 26.8 inches (68 cm) in length, corresponding to a half-wavelength at 146 MHz. The noise source is a 6.2-volt Zener diode whose noise spectrum is amplified and fed to transformer T2, which is identical to the bridge transformer T1. The secondary center tap of T2 is connected only to the two shields of the coaxial cables and not to the ground system of the noise generator. This results in reduced chassis currents and guarantees a very sharp null indication by the bridge. The noise generator is housed in a shielded box away

By A.E. Popodi, OE2APM/AA3K, Moosstrasse 7, Salzburg 5020, Austria

from the bridge section. The adjustable noise level results in improved null indication in some receivers and helps in finding the null. The center tap of the secondary

winding of T1 is connected through a short piece of coax to the BNC connector (output to receiver). This BNC connector should be insulated from the chassis. The 22- μ H choke provides the ground return for the diode current and the tuning voltage. A gear train is recommended for the R and C dials.

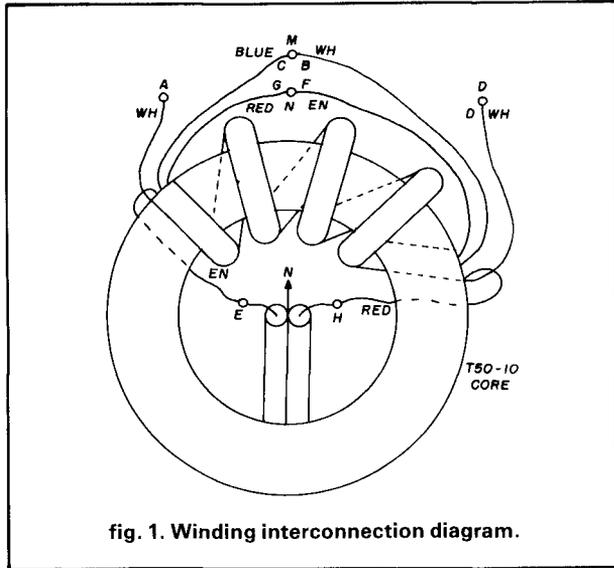


fig. 1. Winding interconnection diagram.

mechanical layout

Figure 3 shows the layout of the noise bridge components. A base plate of silver-plated brass serves as the common mounting surface for all bridge parts. Point A is a short, insulated standoff; points K and L are good high-frequency feedthrough capacitors. Additional bypass capacitors are provided in parallel with the feedthrough capacitors. All five diodes are mounted between two small metal plates that have five holes each. This diode package is then soldered between their respective points. Point M, the center tap of the secondary winding, is a plain feedthrough insulator. Point N is a heavy but short grounding standoff. It is also the grounding point for the two coaxial cables that carry the noise signal. The reference capacitor C_0 must be soldered directly, with short leads, to the SO-239 jack.

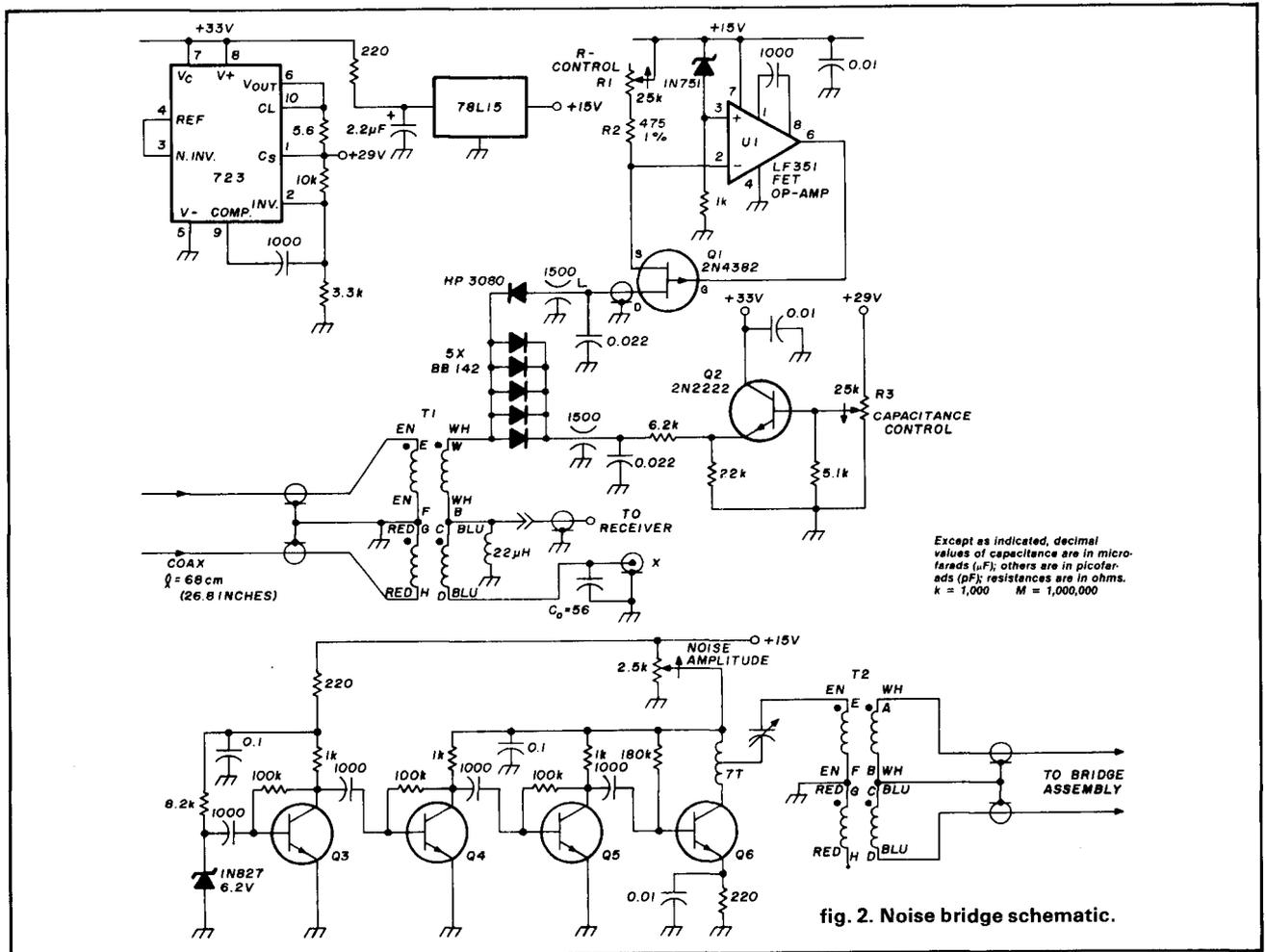


fig. 2. Noise bridge schematic.

control signals

The PIN diode requires a stable, constant current source. A P-channel FET, Q1, serving as constant current source, is controlled by the FET-input operational amplifier U1. At its input, a Zener reference voltage is compared with the voltage drop that the diode current generates across the variable resistor R1 and range-limiting resistor R2. The dial of resistor R1 is calibrated in ohms. Current range is about 0.2 to 10 mA, which corresponds to a diode resistance variation of 150 to 4 ohms. The connection to the diode should be made using shielded cable.

The five parallel connected tuning diodes require a variable DC voltage of 0.5 to 28 volts, controlled by potentiometer R3. The purpose of the 5.1-kilohm resistor is to linearize the (nonlinear) relationship between tuning voltage and capacitance. Transistor Q2 provides a low impedance and its base-emitter junction serves to compensate for the temperature coefficient of the tuning diodes. The 15- and 28-volt supplies must be regulated.

calibrating the resistance dial

The calibration of the R dial requires a little test jig to determine the relationship between diode AC resistance and DC current. This is shown in fig. 4. A signal generator supplies a 30-MHz signal to point A of an SPDT switch that may consist of a small metal bar that makes contact with either point B (non-inductive test resistor) or point C (PIN diode). The DC current can be delivered by the constant current supply described above or from an external DC source. A DVM is used to measure the current accurately. A second instrument is used to monitor the RF voltage at point A. The DC current must be adjusted until the voltages at B and C are equal. Three identical, non-inductive resistors of 50 ohms are required. The first measurement is made with 25 ohms (two resistors in parallel). The next readings are taken with 50, 100, and 150 ohms. This test jig must be built on a copper-clad board, with short leads to all critical points; a common grounding point is important. If the values of current are plotted on 3-by-3 decade logarithmic graph paper, the four points will lie on a straight line because of the logarithmic relationship between diode resistance and diode current. From this graph, the DC currents for all other resistance values can be read and the R dial can now be calibrated. (See fig. 5.)

calibrating the capacitance dial

This requires the measurement of the relationship between diode capacitance and DC voltage. The previously mentioned diode package can be measured with a capacitance bridge, but the applied voltage must not exceed the tuning voltage. Capacitance meters that use constant current charging cannot be used because of the 6.2-kilohm resistor.

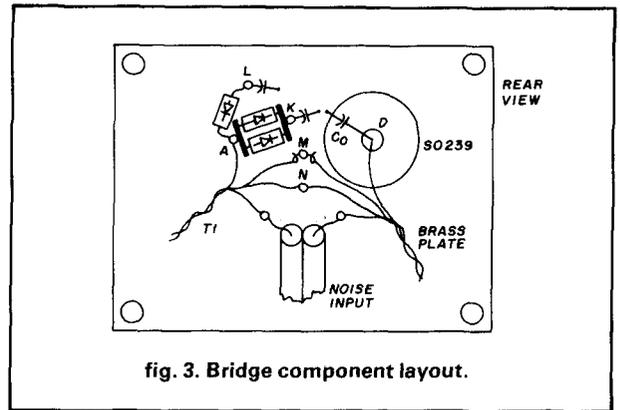


fig. 3. Bridge component layout.

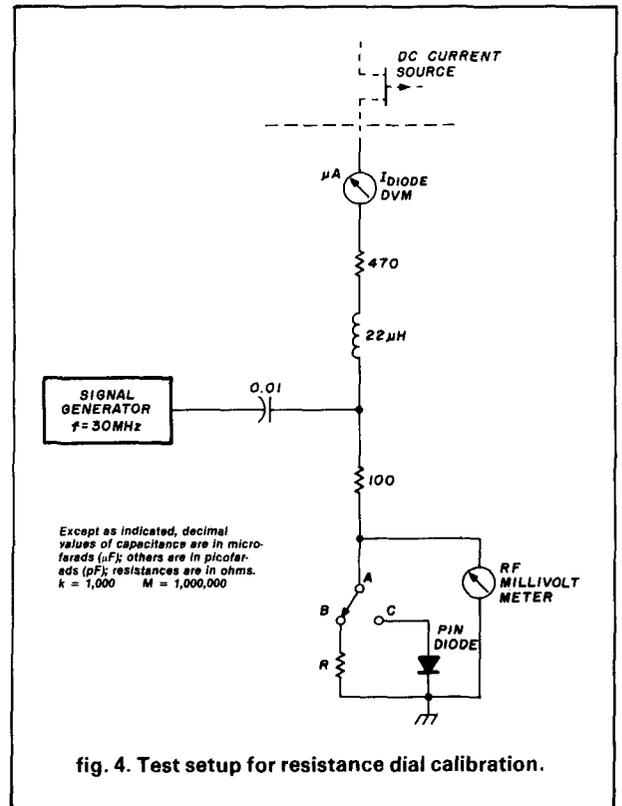


fig. 4. Test setup for resistance dial calibration.

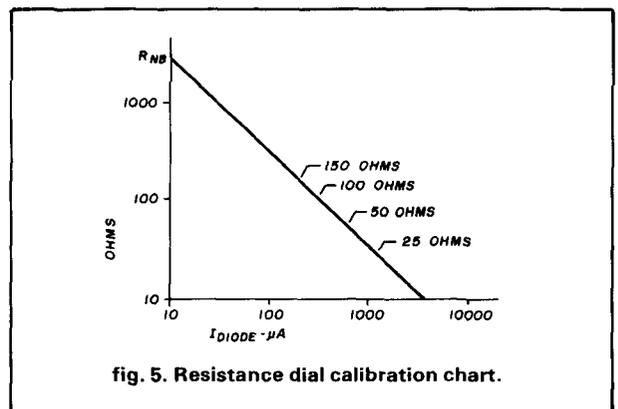
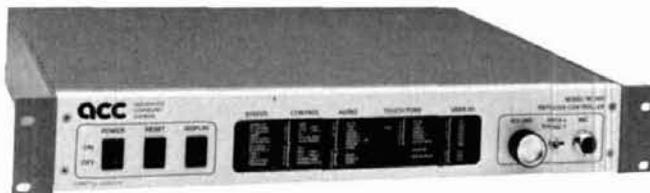


fig. 5. Resistance dial calibration chart.

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Another method of measuring the capacitance in the noise bridge is to connect an inductor in parallel with the tuning diodes via a large DC blocking capacitor. The DC voltage may be set to 3.5 volts. The anode terminals of the diodes must be isolated from the noise bridge circuitry and a 100-kilohm resistor connected from this point to the ground to provide a DC return for the tuning voltage. With the inductor connected, measure the resonant frequency first. Then add a known capacitance, 33 pF, in parallel with the diodes and measure the new resonant frequency, repeating this with 68 pF. The values of diode capacitance and inductance can now be calculated. After removing these additional capacitors, calibrate the C dial. For example, a capacitance of 70 pF is related to a specific frequency that is selected by adjusting the tuning voltage. A recommended inductance is 0.26 μ H, about 7 turns of diameter No. 18 AWG wire with 0.35-inch (9 mm) coil diameter.

calibrating the noise bridge

In order to understand the alignment procedure and interpret noise bridge readings properly, it is important to analyze the effect of parasitic inductances.

The equivalent circuit of a resistor that has self-inductance (as a result of excessive lead inductance) is shown in **fig. 6**. If we convert the series R-L circuit into its equivalent parallel R-L circuit, resistor R1 is always larger than R and L1 is larger than L. Since L1 is in parallel with the reference capacitor C_o , it reduces its apparent value and the noise bridge variable capacitor must be set to a smaller value than C_o in order to balance the bridge. Therefore, if we measure a resistor with self-inductance, the noise bridge indication is a higher R value and a capacitance value smaller than C_o . As an example, at 145 MHz, the noise bridge will measure a 50-ohm resistor at 51.34 ohms and with 3.5 pF less capacitance than C_o , if the series inductance is 9 nH. This happens to be the inductance of a 1-centimeter length of No. 28 wire.

Figure 7 shows the actual electrical circuit of the noise bridge X terminal area. L is the inductance between the center pin of the SO-239 connector and transformer, including leakage inductance. The reference capacitor C is assumed to be non-inductive. R is the load resistor. **Figure 8** shows the calculated resistive and capacitive components of the impedance measured between points A and B as a function of R, under the assumption that $L=2.5$ nH and $C=58$ pF. It is interesting to note that for resistance larger than 23 ohms the apparent capacitance is larger than C. This capacitance enhancement is caused by the inductance L, which is in series with C, creating a series L-C tuned circuit that operates below its resonant frequency. We also see that a 50-ohm resistor appears to be only 38.8 ohms. If we reduce R from 50 to 25

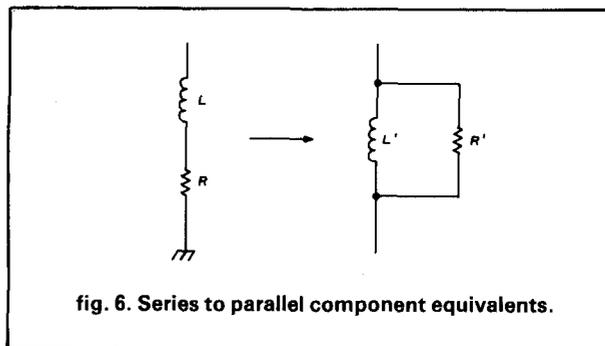


fig. 6. Series to parallel component equivalents.

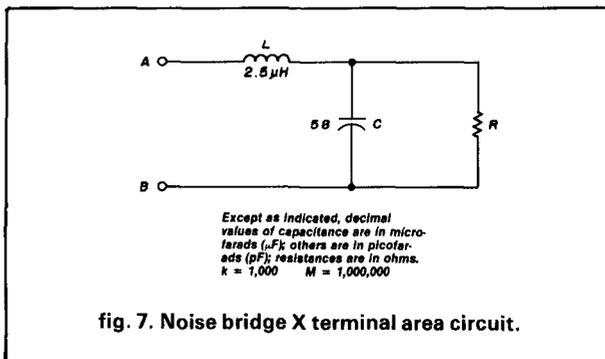


fig. 7. Noise bridge X terminal area circuit.

ohms, the resistance decreases fairly linearly, but the capacitance decreases non-linearly from 64.5 to 60.1 pF. In other words, the resistance variation results in a resistance and capacitance change.

From the above it may appear that building an accurate noise bridge is very difficult, if not impossible. However, if we provide the same inductance of 2.5 nH in the other branch of the noise bridge, the same capacitance enhancement occurs, but in the opposite direction and the above 38.8-ohm resistor becomes 50 ohms again. Therefore, the criteria for correct noise bridge operation are as follows:

1. A resistance change at the X terminal must not affect the capacitance reading.
2. A capacitance change at the X terminal must not affect the R reading.
3. A capacitance variation at the X terminal must be equal to the change of the variable capacitor. If we add, for example, a 33-pF capacitor in parallel with the reference capacitor and if the variable capacitor is increased by only 25 pF to obtain bridge null, then the capacitance enhancement at the X terminal side is too small. We must therefore add inductance to the X terminal side.

How well these criteria are met depends on transformer construction and alignment. Despite the low impedance level of the bridge circuitry, parasitic capacitances also affect noise bridge accuracy. PIN- and tuning diodes may also introduce self-inductance.

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$$Z_{IN} = R_{IN} + jX_{IN} = Z_o \frac{(R_L + jX_L) \cosh(a + jb) + Z_o \sinh(a + jb)}{(R_L + jX_L) \sinh(a + jb) + Z_o \cosh(a + jb)} \quad (2)$$

$$R_L = Z_o \frac{a - \text{Nepers} \quad b - \text{Radians}}{Z_o R_{IN} (1 + A^2 + B^2) - A (Z_o^2 + R_{IN}^2 + X_{IN}^2)} \quad (3a)$$

$$X_L = Z_o \frac{Z_o X_{IN} (1 - A^2 - B^2) + B (R_{IN}^2 + X_{IN}^2 - Z_o^2)}{Z_o^2 + (A^2 + B^2) (R_{IN}^2 + X_{IN}^2) + 2Z_o (BX_{IN} - AR_{IN})} \quad (3b)$$

$$R_{IN} = Z_o \frac{(R_L + Z_o A) (Z_o + AR_L - BX_L) + (R_L + AZ_o) (AX_L + BR_L)}{(Z_o + AR_L - BX_L)^2 + (AX_L + BR_L)^2} \quad (4a)$$

$$X_{IN} = Z_o \frac{(X_L + BZ_o) (Z_o + AR_L - BX_L) - (R_L + AZ_o) (AX_L + BR_L)}{(Z_o + AR_L - BX_L)^2 + (AX_L + BR_L)^2} \quad (4b)$$

$$D = 1 + e^{4a} + 2e^{2a} \cos(2b) \quad A = \frac{e^{4a} - 1}{D} \quad B = \frac{2e^{2a} \sin(2b)}{D}$$

$$a - \text{Nepers} \quad b - \text{Degrees} \quad e = 2.71828$$

Parallel to series conversion:

$$R_S = R_P \frac{X_P^2}{R_P^2 + X_P^2} \quad X_S = X_P \frac{R_P^2}{R_P^2 + X_P^2} \quad (5)$$

Series to parallel conversion:

$$R_P = \frac{R_S^2 + X_S^2}{R_S} \quad X_P = \frac{R_S^2 + X_S^2}{X_S}$$

Table 1. Conversion formulas.

recommended calibration procedure

All parts must be added directly in parallel to the reference capacitor C_o , using the shortest possible leads.

1. Connect a non-inductive, 1/4-watt resistor in parallel to C_o .
2. Set the resistance dial to 50 ohms and the capacitance dial to a value equal to the sum of C_o and the SO-239 socket capacitance (in our case, 59.5 pF). If there is no noise null, slight bending or reshaping of the transformer leads will help. A small piece of ferrite held close to one of the wires indicates where to correct.
3. Add a 33 pF capacitor to C_o . If the capacitance dial must be increased by less than 33 pF to obtain bridge null, additional inductance must be added at the X ter-

minal side (this inductance may consist of a simple 0.157 inch, wire loop). If necessary, the taps on the center balancing inductors shown in **fig. 3**, may be changed. This balancing inductor consists of three turns of bare wire, its center point soldered to the feedthrough insulator. If equality cannot be achieved, the ratio of the two capacitance values (which is larger than unity) can be used as an instrument correction factor so that any reading on the capacitance dial is multiplied by that factor. This improves bridge accuracy.

4. Add another 50-ohm resistor in parallel to the first one. The R dial should indicate 25 ohms, and the C dial setting should not change.
5. Adding a 33-pF capacitor to the first 50-ohm resistor should not affect the R dial indication.

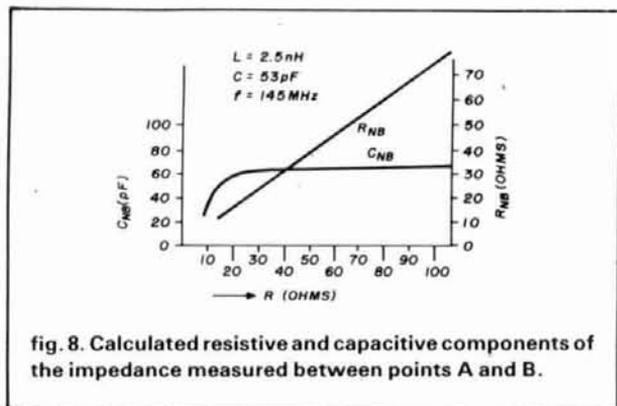


fig. 8. Calculated resistive and capacitive components of the impedance measured between points A and B.

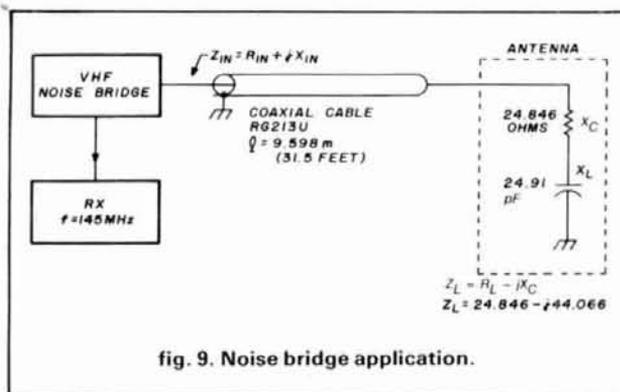


fig. 9. Noise bridge application.

measuring admittances with the noise bridge

The ideal location for admittance measurements is on the C_o side of the SO-239 connector, but this is not convenient. Measurements on the other side of the connector are easier to make. However, the additional inductance of the 0.748-inch center pin reduces accuracy, especially if adapters must be used. For example, the difference in R and C readings is about 1.5 ohms and 2 pF if a 50-ohm BNC termination resistor is measured, using a PL to BNC adapter. However, the error is small.

measuring antenna impedance: example

The block diagram of the test setup is shown in fig. 9. It is assumed that the antenna may be represented by the series connection of a 24.846-ohm resistor and a 24.91-pF capacitor. The noise bridge is connected to the cable input with the 2-meter receiver serving as bridge null indicator.

At this point we must digress and remember that we can calculate the load impedance Z_L of a transmission line from the (measured) input impedance Z_{IN} if the cable parameters — attenuation, length, and characteristic impedance — are known. Likewise, we can determine Z_{IN} if Z_L is known. These conversions can be made with

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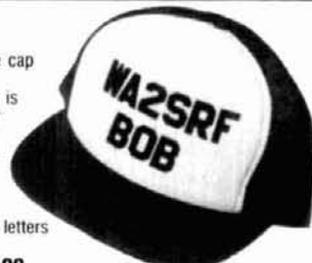
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Smith charts, but formulas are more accurate and convenient, especially if a programmable calculator or computer is available. **Table 1** is a listing of the required formulas. Formulas 1 and 2 can be used if you have a programmable calculator with complex operating mode (for example, an HP-15C). Formulas 3 and 4 lead to the same result, but are more cumbersome to use.

Since the noise bridge readings are in parallel resistance values and the formulas assume series configuration, we must convert parallel-into-series circuits and vice-versa. These formulas are also listed in **table 1**.

The most important cable parameter is length, represented by the term b in the formulas; it must be known fairly accurately. One method of determining the cable length, besides actually measuring it with a scale, is to disconnect the antenna from the coax and connect instead a suitable known resistor. You can then calculate with formulas 2 or 4 the cable input impedance Z_{IN} and compare it to the input impedance that was measured with the noise bridge. If there is a difference, try other values for b until agreement is reached.

In our example, assume the cable length is not precisely known and estimate a length of 31.3 feet (9.55 meters). (**Figure 9** shows the exact length as 31.49 feet, or 9.598 meters.) The cable length corresponding to one wavelength at 145 MHz is

$$\frac{3 \cdot 10^8}{145 \cdot 10^6} \cdot 0.66 = 1.3655 \text{ m or } 4.48 \text{ feet} \quad (1)$$

where the factor 0.66 is the velocity constant of the cable. Since we have assumed a length of 31.3 feet (9.55 meters), the value of b in formulas 1 and 2 becomes

$$b = 360^\circ \cdot \frac{9.55}{1.3655} \cdot \frac{1}{57.296} = 43.943 \text{ radians} \quad (2)$$

The factor 57.296 converts degrees into radians. If we use formulas 3 and 4, b must be expressed in degrees.

The value of a , the attenuation of the 31.3-foot (9.55-meter) cable, can be found from a handbook. Assuming 3 dB per 100 feet (30.48 meters), we obtain:

$$a = \frac{3 \cdot 9.55}{30.48} \cdot 0.115 = 0.1081 \text{ Nepers} \quad (3)$$

The factor 0.115 converts dB into Nepers. The characteristic impedance Z_0 is assumed to be 50 ohms.

Now terminate the coax with a known resistor. Select a value that renders readings well within the range of the noise bridge. Obviously, values too close to 50 ohms must be avoided. The resistor must be accurately measured with a DVM. Solder the non-inductive (preferably 1/4-watt) resistor, keeping leads as short as possible, between the center pin and flange of an SO-239 socket and then plug it into the coax. The load impedance in our example is:

$$Z_L = 101.3 + j0$$

(all values are expressed in ohms). Using formulas 2 or 4, the input impedance Z_{IN} is calculated to be with $a = 0.1081$ and $b = 43.943$ to:

$$Z_{IN} = 87.299 + j 4.046$$

This is the input impedance measurement that should be indicated by the noise bridge.

The noise bridge readings (taken at 145 MHz) are: $R_{NB} = 77.5 \text{ ohms}$ and $C_{NB} = 65 \text{ pF}$. Since the capacitance setting for a pure resistor is 59.5 pF, the capacitance difference is 5.5 pF. This represents, at 145 MHz, a capacitive reactance of $-j 199.57 \text{ ohms}$. The noise bridge readings are therefore 77.5 ohms in parallel with $-j 199.57 \text{ ohms}$. Converting into its series equivalent, using formula 5, we have $Z_{IN} = 67.34 - j 26.15$. Comparing this with the above calculated value for Z_{IN} from Z_L for another set of parameters, a and b , we find, after a few trials, we that $a = 0.109$ and $b = 44.3406$ render the best agreement between measured and calculated Z_{IN} . This value is

$$Z_{IN} = 69.67 - j 27$$

This compares favorably with the noise bridge measured input impedance of $Z_{IN} = 67.34 - j 26.15$.

Having found the correct cable parameters, reconnect the antenna (in our example, the test load) and measure the input impedance Z_{IN} with the noise bridge. The readings are: $B_{NB} = 40 \text{ ohms}$, $C_{NB} = 83.5 \text{ pF}$. The actual capacitance is $83.5 - 59.5 = 24 \text{ pF}$. Capacitive reactance is $-j 45.73$. Converting into its series equivalent with formula 5, we obtain: $Z_{IN} = 22.66 - j 19.82$. This is the measured cable input impedance with the antenna connected. This value must be inserted in formulas 1 or 3 to calculate the antenna impedance Z_L , using $a = 0.109$ and $b = 44.3406$. The result is: $Z_L = 27.195 - j 43.97$. This is the measured antenna impedance.

As shown in **fig. 9**, the actual load impedance is $Z_L = 24.846 - j 44.066$.

This is a remarkably good result, considering the high operating frequency and the fact that the assumed values for cable attenuation and characteristic impedance may not be correct. However, errors in a and Z_0 are much less significant than errors in b .

In this example, the actual load consists of a 103-ohm resistor in parallel with an 18.9-pF capacitor, which is the parallel equivalent. This permits a more inductance-free connection, thereby reducing the instrumentation error.

summary

The construction of a VHF noise bridge that is accurate enough to permit credible and reproducible measurements on antenna systems is possible if a PIN diode serves as variable resistor and tuning diodes replace the variable capacitor. The component layout must be such that no wiring interconnections are necessary. Undesirable ground currents that degrade the null indication are

avoided using single point grounding, a brass mounting surface, balanced noise injection, and proper transformer construction.

For antenna measurements via the feedline, we must know its exact length. If the length is not known, it can be found from measurements of the cable input impedance with the noise bridge and by comparing this value with the calculated input impedance, using a known termination resistor. One advantage of this method is in the fact that the calculated value of b represents the actual cable condition and includes its velocity constant, which does not have to be known. All necessary formulas to calculate load impedance from input impedance, and vice-versa, are presented as are network conversion formulas.

If the above method cannot be used because we cannot connect the test load, or if the cable length is not known accurately enough, the noise bridge readings are still the exact load impedance that the transceiver "sees." This load is the antenna impedance, which may be transformed by the transmission line into a completely different value, depending on cable length.

If you want to measure impedances directly at the X terminal, be careful to avoid undesirable inductances and capacitances. Series connection of several adapters will degrade accuracy. Generally, a resistor with series inductance (or self-inductance) measures higher; the capacitance reading is below the reference value.

To circumvent the deficiencies of the SO-239 connector, measure the unknown impedance using a coaxial cable half a wavelength long at the frequency of interest, with properly integrated PL-259 plugs on both ends. Thus, the SO-239 connector becomes part of the coax geometry and does not affect accuracy. Components must be connected with the shortest possible leads, preferably using an SO-239 jack that is then connected to the cable.

Possible sources of error are the instrument tolerance in the noise bridge and discrepancies in the assumed values for cable attenuation and characteristic impedance. The validity of the formulas may also be questioned. But according to numerous tests — and bearing in mind the statistical distribution of errors — the RMS error of this VHF noise bridge is less than 3 ohms in both the resistive and reactive components.

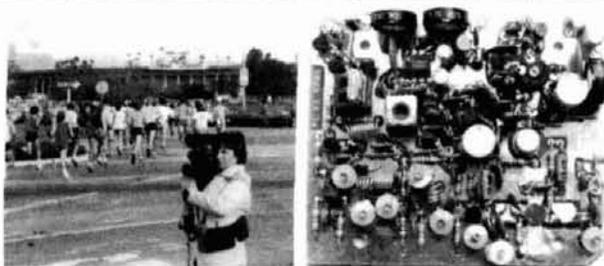
There is still room for improvement of the presented design, possibly in transformer construction, bridge alignment, and in establishing electrical symmetry between the X terminal and reference branch of the noise bridge.

references

1. R. A. Hubbs, W6BXI, and A. F. Doting, W6NKU, "Improvements to The RX Noise Bridge," *ham radio*, February, 1977, page 10.
2. Forrest Gehrke, K2BT, "A Precision Noise Bridge," *ham radio*, March, 1983, page 50.

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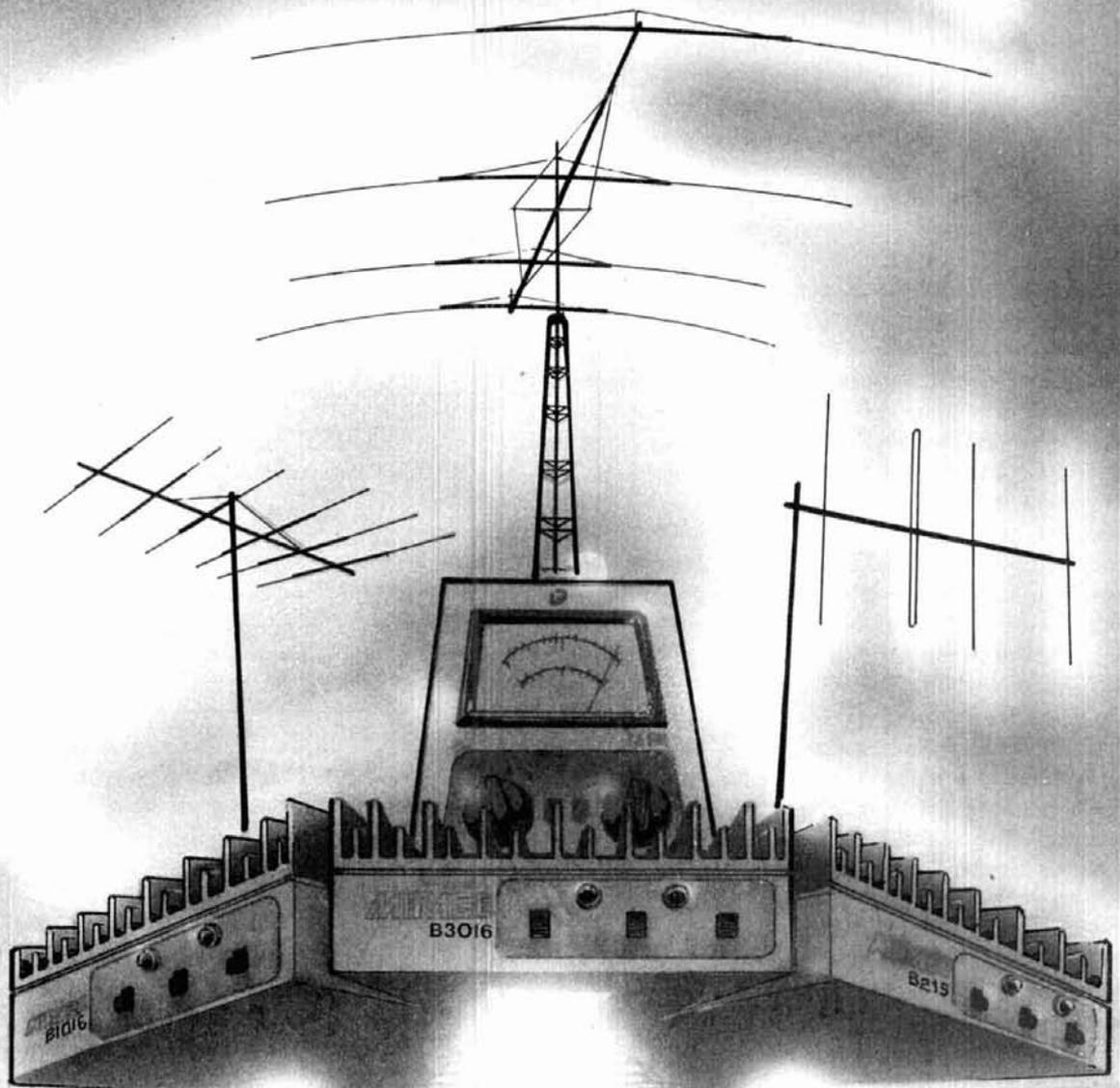


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artificial transmission lines

Construction of striplines and hybrid couplers using hand tools

Impedances can be matched in a variety of ways; some examples are the well known 1/4-wave stub and its lesser known cousin, the series-section matching line. For OSCAR work, where circular polarization is required, the branch line hybrid is ideal.

In most matching methods, transmission lines of non-standard impedances are required. The easy way out is to parallel two or more coax cables to come close to the required impedance; the harder way is to fabricate transmission line from copper pipe and brass tubing. Series-section matching uses two or more lengths of different, but standard value impedance coax. The problem with these, however, is splicing them together.

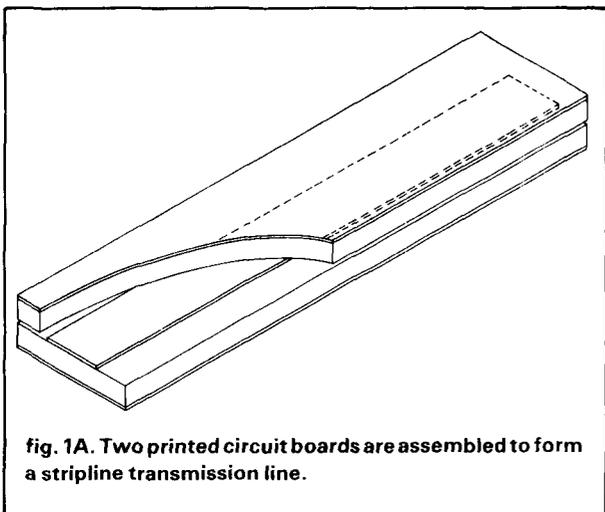


fig. 1A. Two printed circuit boards are assembled to form a stripline transmission line.

stripline

One form of transmission line used at UHF is called stripline. It is basically two printed circuit board strips. One PC board has a ground plane on one side and the transmission line center conductor etched on the other side. The other PC strip has a ground plane only. The two are assembled as in fig. 1A. To complete the self-shielding feature, such as in coaxial cable, a conductive foil covers the exposed edges of the dielectric. The impedance of a stripline transmission line impedance is directly proportional to the width, W , of the line and inversely proportional to the ground-plane spacing, b . The W/b ratio and the dielectric constant, ϵ , of the laminate determine the impedance of line (see fig. 1B).

But there's a problem with stripline. Printed circuit boards are fairly thin, and the center conductor width is small for the more popular line impedances. Thin traces are suitable for printed-circuit manufacturing but are rather awkward for the average ham to manufacture. The way to circumvent this problem is to widen the ground-plane spacing with Plexiglass®. The center line thus becomes proportionally larger for the same impedance (see fig. 2).

A quarter-wave artificial line was made with a printed circuit board exterior, two Plexiglas spacers and 0.002 inch (0.05 mm) brass shim stock for the center wire (fig. 3). Measurements were made with a General Radio admittance meter type 1602-A (fig. 4) at 150 MHz. The result for 0.25 inch, 0.125 inch and 0.062 inch Plexiglass is shown in fig. 5. Some advantages are obvious; for a line impedance of 50 ohms and using 0.25 inch (6.5 mm) spacers the center conductor width is 0.4 inch (10 mm), a dimension easily cut with average tools. But consider, too, the surface area. Most readers know about skin depth at radio frequencies. RF travels on the skin of a conductor. At

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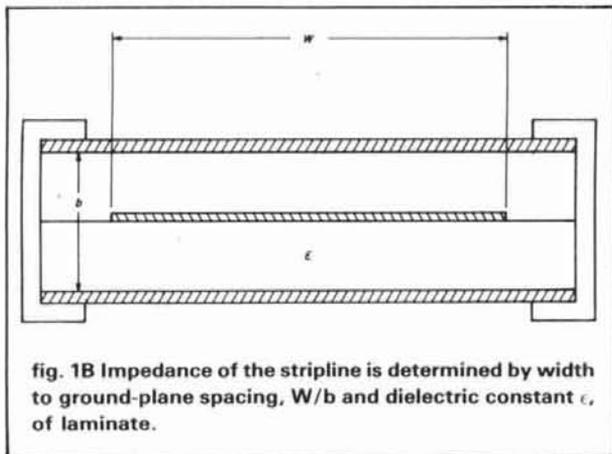


fig. 1B Impedance of the stripline is determined by width to ground-plane spacing, W/b and dielectric constant ϵ , of laminate.

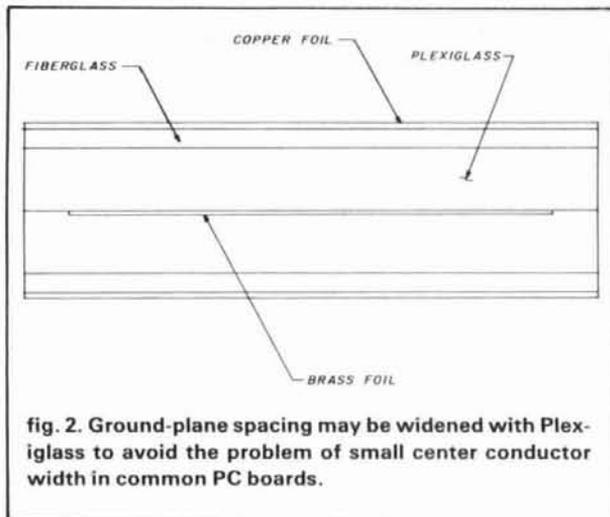


fig. 2. Ground-plane spacing may be widened with Plexiglass to avoid the problem of small center conductor width in common PC boards.

a depth, δ , ("skin depth") the current decreases to 37 percent of its surface value. For a copper conductor,

$$\delta = 2.6 \sqrt{1/f}$$

where

δ = skin depth (inches)

f = frequency (Hertz).

As an example, at 150 MHz skin depth would be 0.00021 inch (0.005 mm). Thus, 0.002 inch (0.05 mm) shim stock is adequate for UHF. A width of 0.4 inch (10 mm) is equivalent to a round center conductor of approximately 0.25 inch (6.4 mm) diameter.

The resonant length depends on the dielectric of the Plexiglass:

$$V = 1/\sqrt{\epsilon}$$

where

V = velocity of propagation

ϵ = dielectric constant

and

$$L = \frac{3 \cdot 10^{10} \cdot V}{f}$$

where

L = electrical wavelength (cm)

f = frequency (Hertz)

V = velocity factor

The measured velocity factor was 0.60 or a dielectric constant of 2.78, close to the listed constant of 2.8 for Plexiglass. The Fiberglass part of the PC board is part of the line dielectric ($\epsilon = 4$) and affects the total dielectric constant as the Plexiglass gets thinner. I used a velocity factor of 0.6 for the length calculation of quarter-wave stubs. The SWR, being the important factor, is flat over a wide frequency range. The hybrid

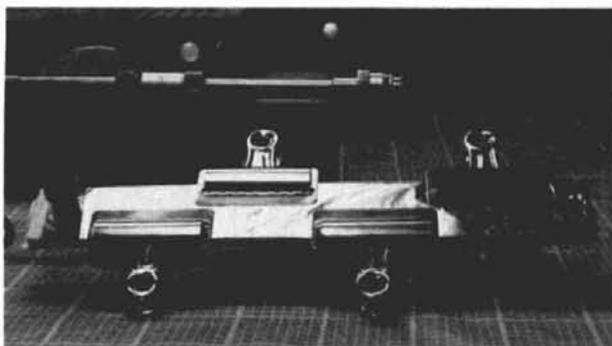


fig. 3. 1/4-wave stub fitted with a GR connector on the left and a 50-ohm termination made up of four film resistors on the right. Aluminum foil wrap stub are held together with paper clips.

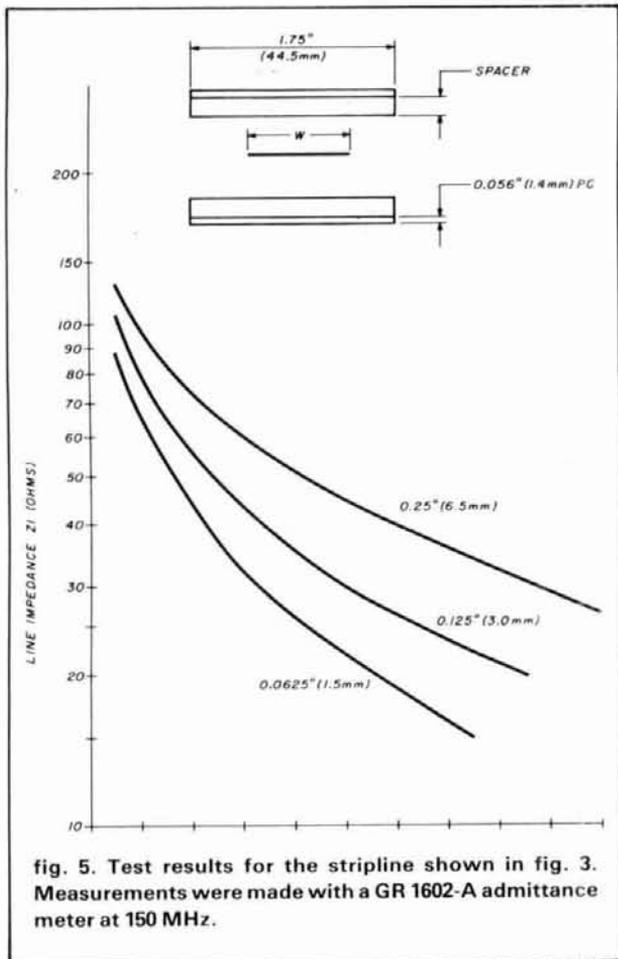


fig. 4. Test setup using the GR 1602-A bridge.

coupler, however, has a sharp isolation bandwidth and several factors affecting resonant length, which are discussed later.

construction of stripline

The center conductor is 0.002 inch (0.05 mm) brass. This is available as brass shim stock in sheets or rolls



from machine tool supply firms. **Figure 6** shows the fixture used for accurately slicing the shim stock. The base is a thick slab of Plexiglass. Formica or bakelite would also work, but the material must be hard enough so an Xacto® blade won't cut into it. I bought two steel rulers and mounted one firmly to the Plexiglass. I attached the second ruler with two DeStaco hold-down clamps, also available from tool supply firms.

To cut an accurate strip, the shim stock edge is placed against the fixed ruler. The second ruler, with the shim underneath, is spaced to the required width with vernier calipers. The clamps are secured and an Xacto knife is used to slice the brass shim stock. It takes a little practice, but the results are much better than you'd get with scissors.

The plastic spacers are Plexiglass brand Lucite.® I used this well-known brand because of its widespread availability and the possibility of variations in the dielectric constant of other brands. Check the thickness of the Plexiglass; it does have some rather wide tolerances. The printed circuit board is standard 0.0625 inch (1.5 mm) G-10 glass epoxy. A table saw with a

fine-tooth blade was used to cut the Plexiglass and the PC board.

To mount the RF connector, a hole is first drilled through one of the PC boards and both Plexiglass spacers. The bottom PC board is left undrilled. The diameter of the hole is the width of the mounting flange of the RF connector. I used BNC connectors because most of my test equipment uses BNCs. BNC connectors, however, are prone to be intermittent. Use UHF connectors for 2-meter work and N connectors for 70 cm and above. The TNC connector is excellent for low-power work at UHF. Not well known to Amateurs, the TNC is small and has low SWR characteristics.*

A small hole was drilled into the brass strip for soldering to the connector. This presented quite a problem since the spinning drill grabbed the thin brass, but the problem was solved by squeezing the brass strip between two pieces of scrap Plexiglass (**fig. 7**). The top piece has a hole predrilled to the right diameter. The brass strip is positioned accurately underneath, then the assembly is held firmly by hand and the hole is drilled through. The result is a nice clean hole in the right place.

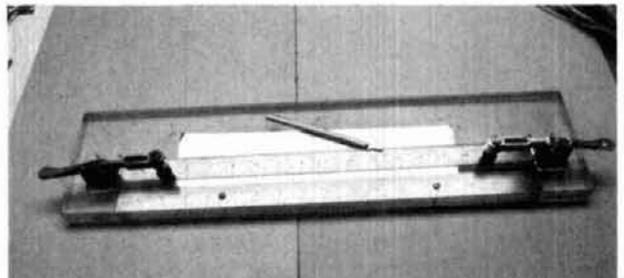


fig. 6. Tools for cutting brass shim stock.

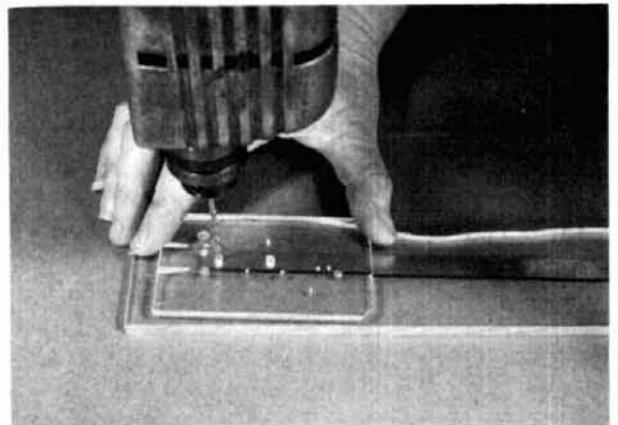
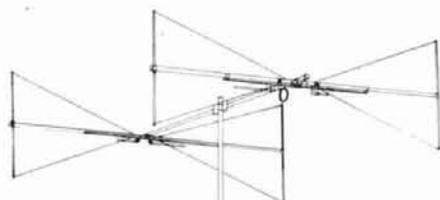


fig. 7. Drilling a hole in the brass shim stock. Two pieces of Plexiglass are used to guide the drill.

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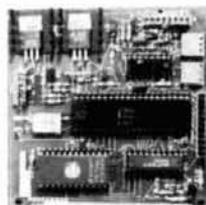
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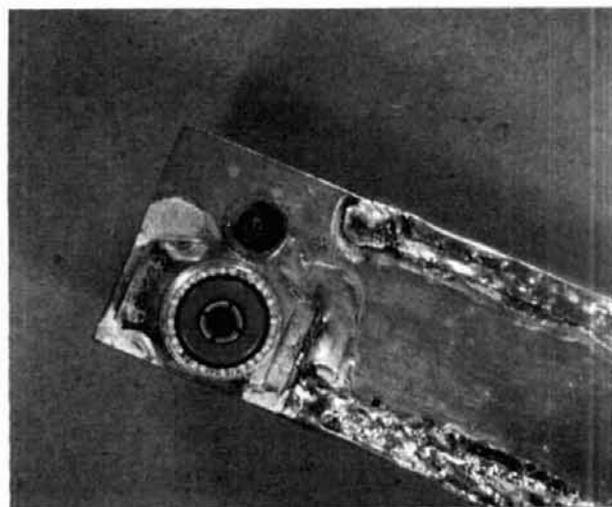
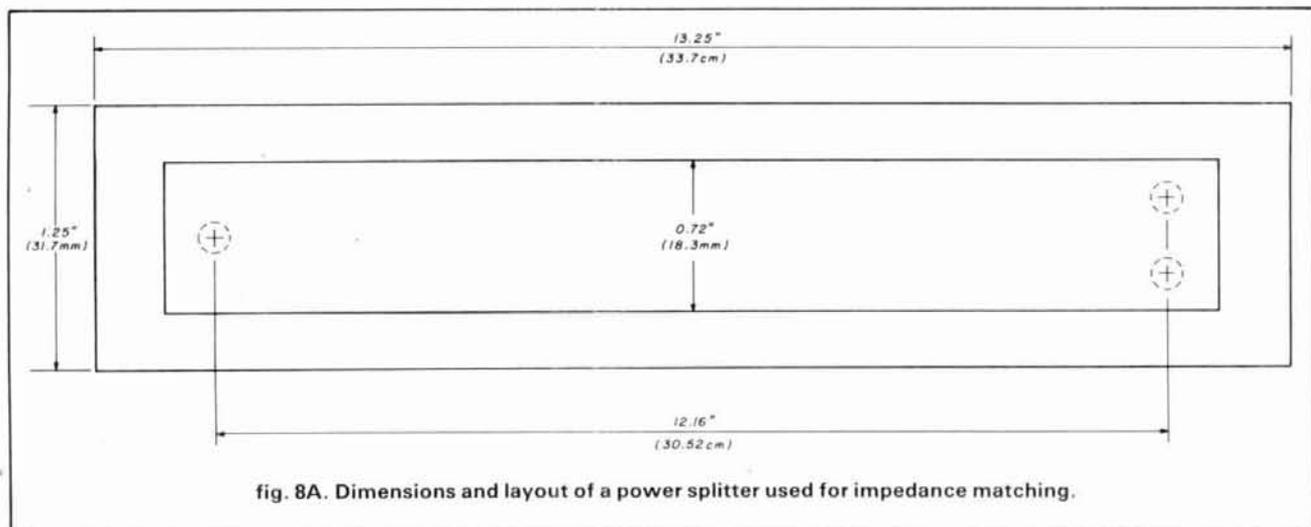


fig. 8B. UHF connector has been filed down to fit. Note solder access hole for the connector on the back side.

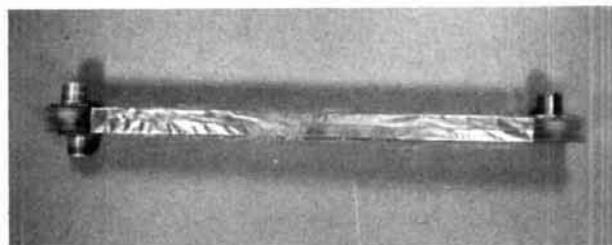


fig. 8C. A quarter-wave 2-meter power splitter.

The transmission line is ready for final assembly after the center conductor has been soldered to the RF connectors. I could have drilled a number of holes and held the transmission line together with nuts and bolts, but I found it easier to glue the whole assembly. I sim-

ply held everything together with C-clamps and wicked plastic glue along the edges with a hypodermic needle. The glue is methylene chloride.**

Avoid using plastic glue with acetic acid as an ingredient (vinegar odor); it is conductive. A variety of glues are available from commercial firms selling plastics. The outer conductor is completed by soldering 0.001 inch (0.03 mm) brass shim stock between both PC boards.

How wide should the line be made? Or in other words, how far away should the center conductor edge be from the outer shield? If the transmission line is too wide, it tends to be inductive; if it's too narrow, the line impedance is affected by the outer shield being

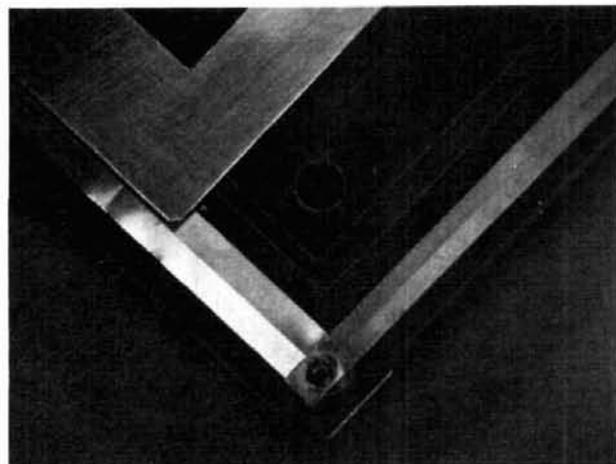


fig. 9. The pieces making up a hybrid coupler. When the strip was cut, a line was drawn with a needle to mark the center of the strip. This line was used for drilling the solder hole.

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too close to the center conductor. I found the best distance between center strip and outer shield to be equal to the thickness of the spacers. Thus if 0.125 inch plastic spacers are used, the total width of the stripline is 0.375 inch (including the 0.0625 inch PC boards) larger than the width of the center conductor.

matching lines

A quarter-wavelength matching line is used to demonstrate the first practical use of these striplines. The impedance transforming properties of quarter-wave transmission lines are well known. Most Amateurs use them to couple antennas with an impedance different from that of the feed coax. Basically

the input impedance, Z_a , of a quarter-wave line terminated in a resistive impedance, Z_b , is

$$Z_a = Z_1^2 / Z_b$$

where Z_1 = impedance of quarter-wave line, rearranging

$$Z_1 = \sqrt{Z_a Z_b}$$

This means that the matching line, commonly called

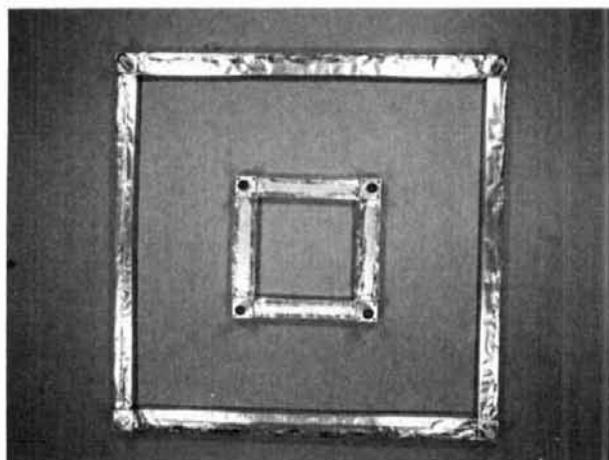


fig. 10. Completed hybrid couplers for 2 meters and 70 cm.

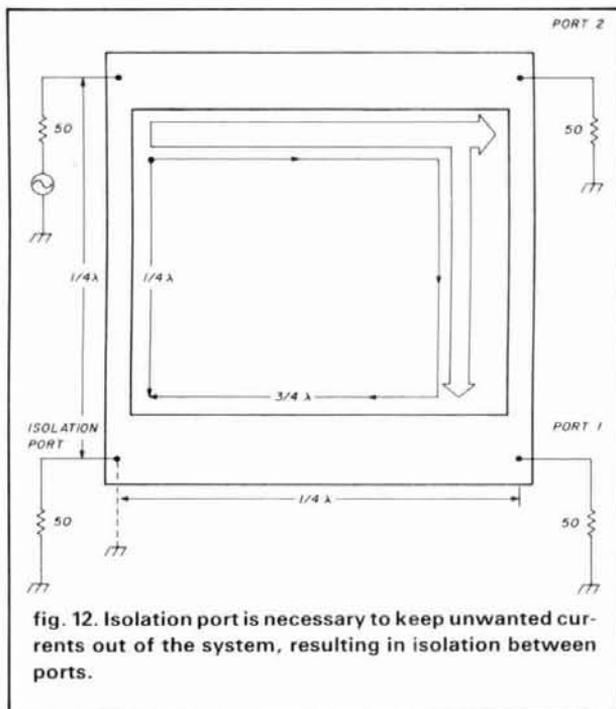


fig. 12. Isolation port is necessary to keep unwanted currents out of the system, resulting in isolation between ports.

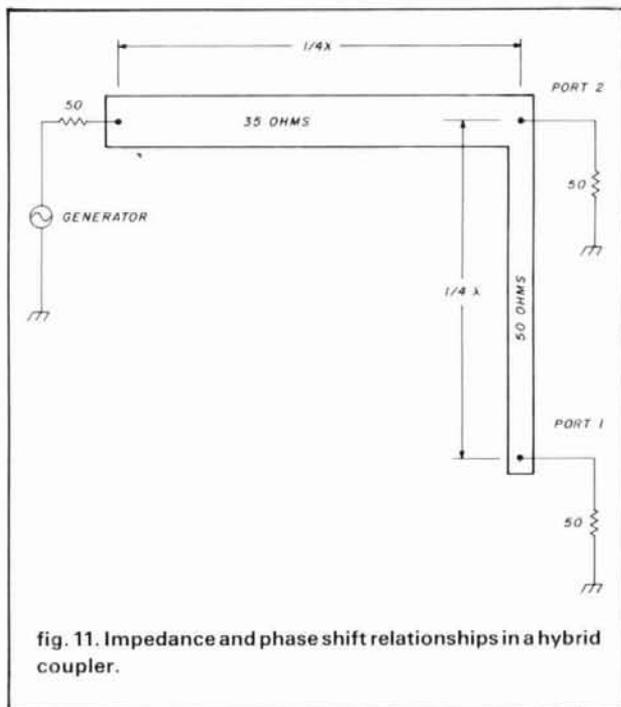


fig. 11. Impedance and phase shift relationships in a hybrid coupler.

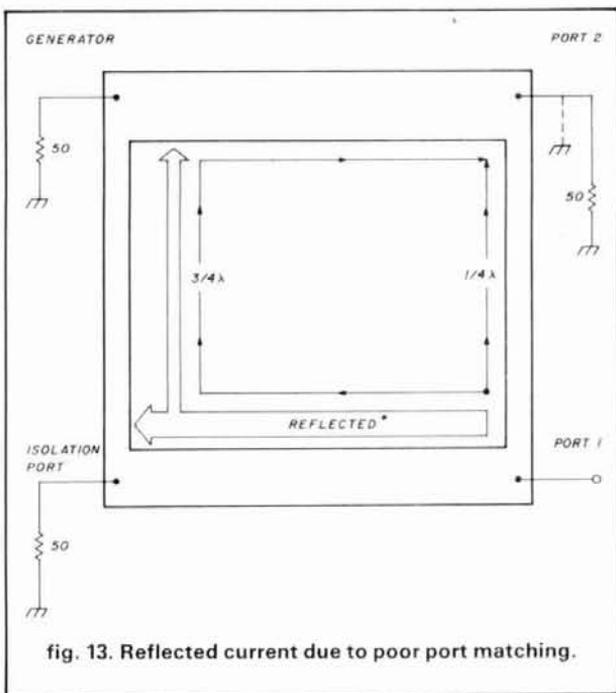


fig. 13. Reflected current due to poor port matching.

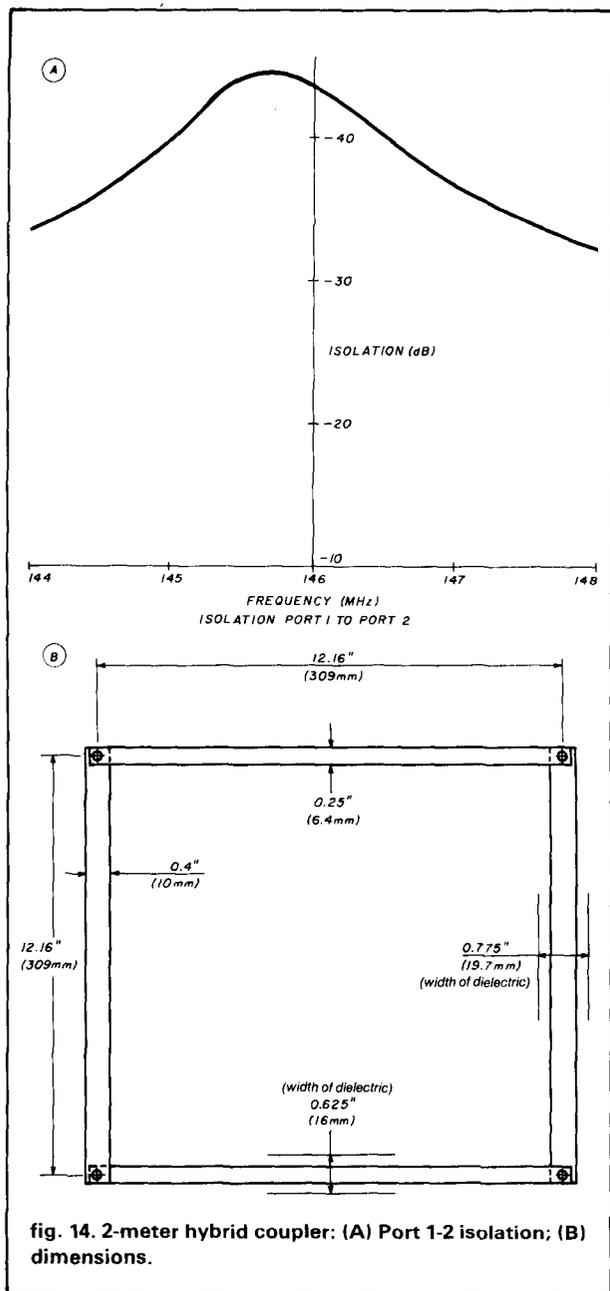


fig. 14. 2-meter hybrid coupler: (A) Port 1-2 isolation; (B) dimensions.

a Q section, must have an impedance, $Z1$ to match an antenna Z_a to coax Z_b . If two antennas of 50 ohms are paralleled, the impedance is 25 ohms, and a Q section of 35 ohms is required to match this combination to 50-ohm coax.

The dimensions and layout for such a power splitter are shown in fig. 8A. With 0.25 inch (6.4 mm) spacers, the SWR was less than 1.1:1 from 144-148 MHz. A UHF connector was soldered to each side of the line to make it possible to solder them side by side. Even so, their mounting base had to be filed down to make them fit fig. 8B. The mounting hole for the UHF connector was drilled through both PC and Plexiglass strips so the center conductor could be soldered to

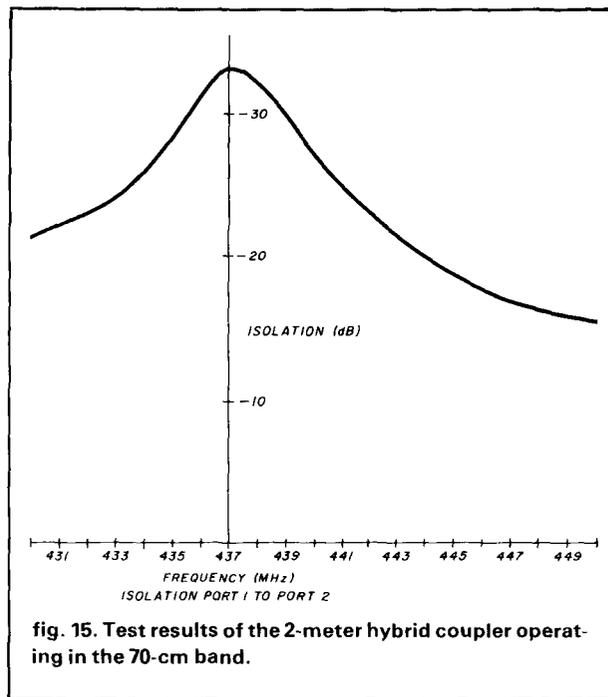


fig. 15. Test results of the 2-meter hybrid coupler operating in the 70-cm band.

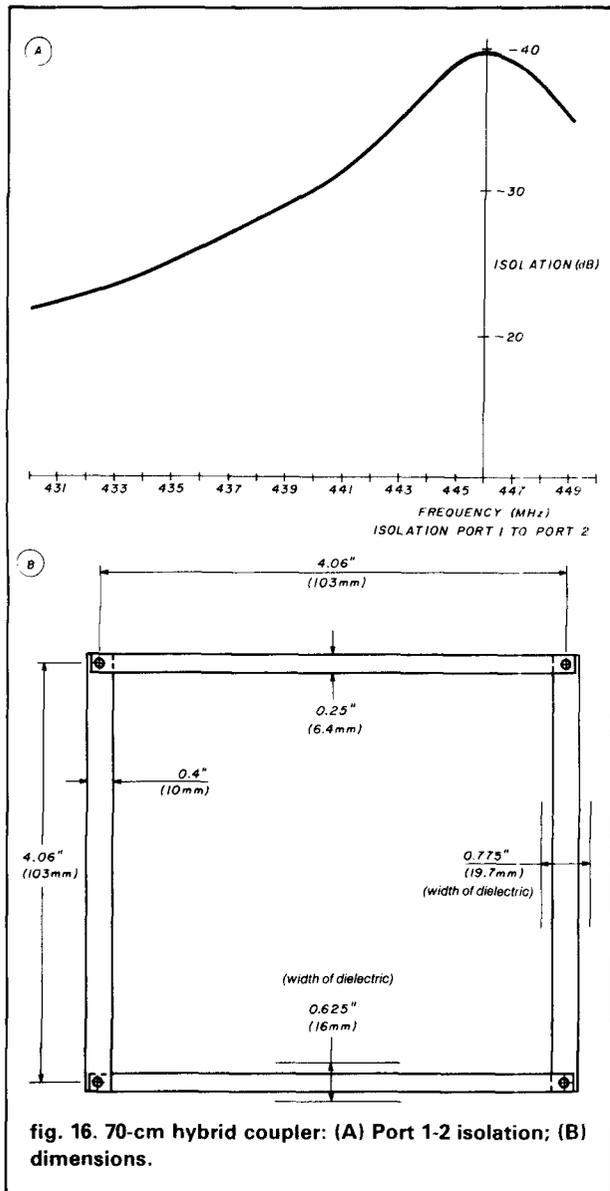
each connector from the back. A completed power splitter is shown in fig. 8C. Various types of power dividers are covered in reference 1.

hybrid couplers

Made up of interconnected transmission lines, the branch-arm hybrid coupler provides a 3-dB power split and a 90-degree phase shift between both outputs (fig. 9). Complete units for 2 meters and 70 cm are shown in fig. 10. This is ideal for OSCAR 10 communications, in which two Yagis are mounted at right angles to each other and fed out of phase by 90 degrees. Depending on which antenna is fed first, we can get right-hand or left-hand circular polarization. The hybrid coupler can be used in reverse to combine the signal returning from the satellite. Ernie Franke, WA2EWT, wrote an excellent article on this device.²

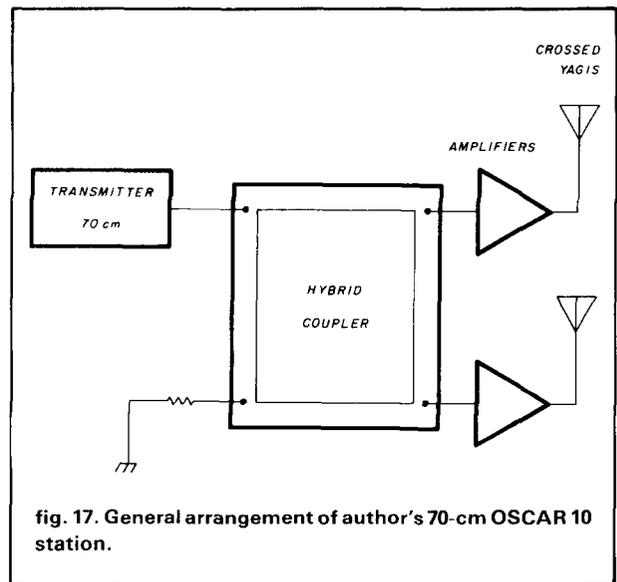
I constructed a hybrid-coupler from coax for the receiving end of my OSCAR 10 station. Three coax cables, including the outer shields, had to be soldered to each RF connector. Because the physical result didn't exactly excite me, I tried to come up with a better way of making these couplers; this led to the work presented here. (Although the basic idea behind these couplers is covered in this article, I would also recommend that anyone interested read parts 1 and 2 of reference 2.)

The quarter wavelength 50-ohm line parallels port 1 and port 2 with a total resistance of 25 ohms at port 2 (fig. 11). Note that port 1 has a 90-degree phase shift from port 2. The 35-ohm line is used to convert the



25 ohms back to 50 ohms. Adding a second leg (fig. 12) sets up the following conditions. The current from the generator divides itself between port 2 and port 1 as before. A much smaller current also flows towards the isolation port from the generator following two paths. The long way around is one-half wavelength longer, or 180 degrees out of phase. These signals arrive in opposite polarity and cancel. This virtual short at the isolation port sets up two shorted quarter-wave stubs, one toward the generator and one toward port 1. Their high impedance prevents current from flowing into the isolation port.

Now what happens when reflected current flows back into port 1 because of poor port matching? The reflected current is absorbed by the isolation port and the generator. Again a small current flowing toward port 2 by way of two paths creates a virtual short at



port 2. The resulting shorted quarter wave stubs prevent current flow from port 1 to port 2. The result is isolation between ports (fig. 13).

The first hybrid coupler constructed was for 2 meters. With care in fabrication, excellent isolation can be achieved between ports (fig. 14A). Inside and outside cuts on the Plexiglass and PC frame were made with a table saw. Make sure the result is square. The distance between the RF connectors was marked accurately before a pilot hole was drilled. Good isolation depends on equal distances between ports. Even if the frame isn't perfectly square, make sure these distances are equal. Note the width of the frame legs, 0.625 inch (16 mm) and 0.775 inch (19.7 mm). One might think that a fractional value would be hard to duplicate; buy a pair of inexpensive plastic vernier calipers and practice on a piece of scrap before making the final cut. All the hybrid couplers used 0.125 inch (3 mm) Plexiglass. The completed assembly was held together with eight small C-clamps. Methylene Chloride was wicked between the pieces with a hypodermic needle (a small brush or Q-tip® would also work).

After approximately an hour's drying time, the shield is completed by soldering on the 0.001 inch (0.03 mm) brass shim stock.

Width of the stripline also affects the frequency resonance of the coupler. The line becomes inductive with increasing width. Since 0.125 inch (3 mm) Plexiglass is used, the line width is 0.375 inch (9.5 mm) wider (including the 0.0625 inch [1.5 mm] PC boards) than the brass center conductor. All these factors are much more apparent in the hybrid coupler than in the simpler power splitter because the hybrid coupler tunes more sharply.

I also ran some tests with the 2-meter hybrid coupler at the third harmonic in the 70 cm band. Each leg

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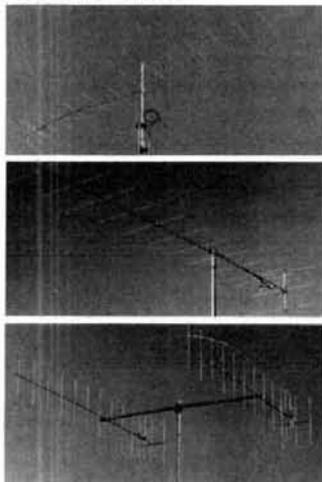
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then becomes 1 and 1/2 wavelengths. The frequency tripled almost perfectly (fig. 15) and again with good isolation.

The second coupler was made for the 70 cm band. Dimensions are shown in fig. 16. As the coupler becomes smaller, care in construction becomes even more important. The center of the frame had to be cut with a sabre saw because the unit is too small for a table saw blade. A file was used to finish the dimensions. This unit will be used for the transmitting end of OSCAR 10.

Presently the rig has one low-power amplifier and the output drives two crossed Yagis with a matching arrangement. I can now double the output by adding an amplifier. Impedances are 50 ohms, and the advantage here is that I can tune antennas for minimum SWR with a standard 50-ohm SWR bridge.

conclusions

The aim of this article has been to present a simple method of constructing matching devices of high quality, in which connector problems commonly encoun-

Appendix A (See fig. 5.)

The information below is provided for the benefit of readers who wish to make their own graph for the data shown in fig. 5.

	Zt termination (ohms)	W spacers inch (mm)	1/Zc conductance (μmhos)	susceptance (μmhos)	Z1 impedance (ohms)	
0.25 inch (6.5 mm)	50.2	0.047(1.19)	3.4	0	121.5	
	50.0	0.097 (2.46)	5.1	0.4	99.0	
	50.3	0.150 (03.8)	7.2	0.15	83.6	
	50.1	0.203 (5.16)	9.5	0.3	72.6	
	50.1	0.245 (6.22)	11.4	0.3	66.3	
	50.1	0.297 (7.54)	13.9	0.5	60.0	
	50.2	0.348 (8.84)	16.35	0.9	55.4	
	50.2	0.403 (10.2)	19.2	1.4	51.1	
	50.1	0.445 (11.3)	22.2	1.4	47.6	
	50.2	0.498 (12.6)	25.2	2	44.6	
	50.2	0.550 (13.9)	14	1.3	41.9	
	50.2	0.600 (15.2)	12.55	1.5	39.7	
	50.2	0.650 (16.5)	11.15	1.3	37.4	
	50.2	0.750 (19.0)	9.25	1.3	34.1	
	50.2	0.850 (21.6)	7.55	1.3	30.8	
	50.2	1.000 (25.4)	6.00	1.3	27.4	
0.125 inch (3.0 mm)	50.3	0.047 (1.19)	4.6	0.5	104.6	
	50.2	0.097 (2.46)	7.8	0.6	80.2	
	50.2	0.150 (3.81)	11.55	0.8	65.9	
	50.2	0.203 (5.16)	16.1	0.6	55.8	
	50.3	0.245 (6.22)	20.3	1.0	49.8	
	50.1	0.297 (7.54)	15.1	0.7	43.5	
	50.1	0.348 (8.84)	12.4	0.6	39.4	
	50.1	0.403 (10.2)	10.2	0.9	35.7	
	50.2	0.445 (11.3)	8.8	0.9	33.2	
	50.2	0.498 (12.6)	7.6	1.0	30.9	
	50.2	0.550 (13.9)	6.55	1.0	28.7	
	50.2	0.650 (16.5)	5	1.0	25	
	50.2	0.750 (19.0)	4	1.2	22.4	
	50.2	0.850 (21.6)	3.25	1.4	20.2	
	0.0625 inch (1.5 mm)	50.1	0.047 (1.19)	6.4	0	88.5
		50.1	0.097 (2.46)	11.85	0.2	65.1
50.1		0.150 (3.81)	19.15	0.2	51.1	
50.1		0.203 (5.16)	15.0	0	43.4	
50.1		0.245 (6.22)	11.7	0.1	38.3	
50.1		0.297 (7.54)	8.9	0.4	33.4	
50.1		0.403 (10.2)	5.5	0.5	26.2	
50.1		0.498 (12.6)	4.0	0.6	22.4	
50.1		0.600 (15.2)	2.9	0.9	19.4	
50.1		0.750 (19.0)	1.9	0.9	15.4	

1/4-wave measuring above 50 ohms

1/2-wave measuring below 50 ohms

$$Z1 = \sqrt{ZtZc}$$

$$Z1 = \sqrt{2.5 Zt/Zc}$$

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Appendix B. Data for figs. 14, 15, and 16. 2-meter hybrid coupler Port 1-2 isolation.

143.95 MHz	-34 dB
144.39	-36
144.86	-39
145.13	-41
145.88	-44
146.37	-41
146.8	-38
147.34	-35
148.04	-32

2-meter hybrid coupler (operated in 70-cm band) Port 1-2 isolation.

430.065	-20 dB
431.695	-23
433.475	-25
434.42	-27
435.55	-30
437.5	-33
438.95	-38
440	-27
440.97	-25
442.64	-23
444.035	-20
447.035	-18
449.82	-15

70-cm hybrid coupler Port 1-2 isolation.

449 MHz	-35 dB
448	-37
447	-39
446	-40
445	-39
444	-37
443	-35
442	-33
441	-31.5
440	-30
439	-29
438	-28.5
437	27.5
436	26.5
435	25.5
434	25.5
433	24
432	23.5
431	23
430	22.5

tered in making matching systems are eliminated. Moving up to the GHz ranges could be accomplished by using styrofoam rather than Plexiglass in a ring hybrid; the size problem could be avoided by operating on an odd harmonic such as shown above.

references

1. George Chaney, W5JTL, "Extended/Expanded Power Dividers," *ham radio*, October, 1984, page 73.
2. Ernie Franke, WA2EWT, "The Branch-Line Hybrid," *ham radio*, Parts 1 and 2, April (page 107) and May (page 93), 1984.

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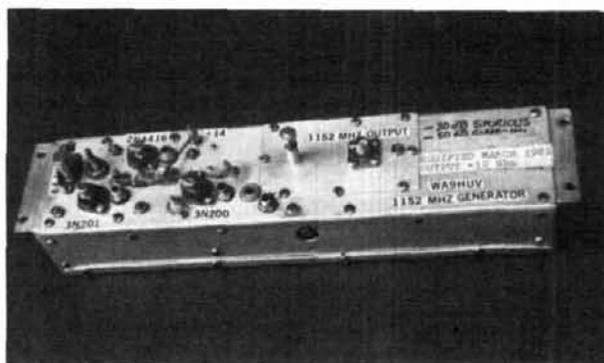


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low-noise phase-locked UHF VCO

part 1: the noise problem

Much has been written about voltage-controlled oscillators. In a recent *ham radio* article Hans Roensch, W0DTV, described a free-running UHF VCO, correctly acknowledging that such an oscillator cannot be used effectively in narrowband systems where low phase noise is required.¹ W0DTV's article referenced an earlier article of mine, which included a description of a way to phase lock oscillators to reduce noise.²

One of the major disadvantages of the phase-locked loop I described in reference 2 is the lack of AFC, requiring that the VCO be set on frequency manually to effect phase lock. Under adverse conditions, drift of the oscillator's tuned circuit may exceed the hold-in capability of the loop, causing the VCO to unlock or jump to another phase-lock point. In this scheme the oscillator's frequency is divided by a factor of 40 to make it compatible with the phase detector. This, as we shall see, is another disadvantage, which adds 32 dB of excess noise to the VCO.

To make this a more practical system, two additional features are needed: automatic frequency control (AFC) and UHF phase detection to avoid the need for prescaling.

background

A free-running VCO intended for use as a receiver's local oscillator (LO) in the 1215-1300 MHz band will generally exhibit a very broadband phase noise charac-

teristic. Without the benefit of crystal control, its spectrum may be so wide that the carrier is not readily identifiable on a spectrum analyzer because the deviation factor is so large. While the degree of phase modulation is relatively minor on the HF and VHF bands, as frequency is increased the modulation angle becomes proportionally larger. Self-excited TV oscillators, for example, often sound like buzz saws on a UHF receiver as they wander around. Something better than this is obviously needed for use as a local oscillator in a narrowband receiver intended for reception of NBFM, SSB, or CW in the 1215-1300 MHz band.

The 1296-MHz transceiver I put together fifteen or twenty years ago was built around a 1152-MHz crystal-controlled signal source. I added a 144-MHz SSB signal to the 1152-MHz generator in an upconverter to develop the 1296-MHz SSB exciter signal. Conversely, I used the 1152-MHz generator as the LO in a downconverter and a 2-meter receiver as the IF. This is a scheme in general use by many UHFers. Note that twice the 1152-MHz oscillator frequency is 2304 MHz, a fact of considerable interest to those operating both bands.

The original 1296-MHz exciter employed a crystal-oscillator-multiplier chain driving a step-recovery di-

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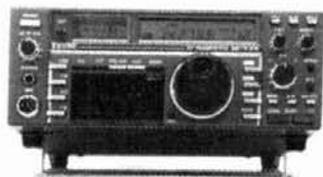
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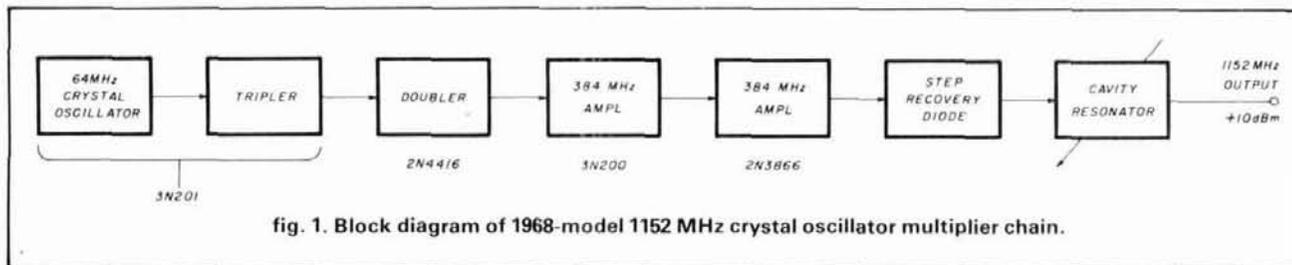
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ode (SRD) multiplier associated with a cavity resonator to develop the 1152-MHz local-oscillator signal. A 64-MHz crystal oscillator was followed by a tripler, a doubler, and two stages of 384-MHz amplification. The second amplifier, a 2N3866, was used to drive the SRD. The power output from the cavity resonator was +10 dBm. Most of the circuitry was relatively straightforward, but the SRD and cavity resonator circuits were quite complicated mechanically. Many contacts were made on 1296 MHz using this signal source for the exciter and downconverter, even before the 1296-MHz band was as well populated as it is today. **Figure 1** is a block diagram showing the crystal-oscillator multiplier system.

instrumentation

Since that time I have acquired an HP-8551/851B spectrum analyzer, which gives me the opportunity to look more closely at the oscillator's noise and spurious performance. The frequency spectrum showed spurious signals about 30 dB below the carrier and amplitude and phase noise at or below the noise floor of the spectrum analyzer. An oscillogram of its spectrum is shown in **fig. 2**, with a photo of the unit.

The 8551 can measure 70 dB below the carrier in a 1-kHz bandwidth. Phase and amplitude noise of an oscillator can be observed on this spectrum analyzer if the noise is great enough; however, for phase noise measurements of a clean and highly stable source, the spectrum analyzer leaves much to be desired. Nevertheless, it does represent a benchmark against which the noise and spurious signal characteristics of other oscillators can be compared.

Why be concerned with oscillator spectral purity? Because sideband amplitude and phase noise can convert directly into the receiver's passband and limit overall sensitivity under multiple signal conditions.^{3,4} For example, when a weak signal is being detected in the presence of a stronger signal, oscillator phase noise — beating with the strong signal — appears at the mixer's output and enters the IF even though the strong signal may not. If the phase noise of the local oscillator is great enough, the desired signal may be completely buried in noise. Therefore, it is important that the phase noise of the local oscillator be made as small as possible. Low phase noise is one of the most important characteristics of an oscillator.

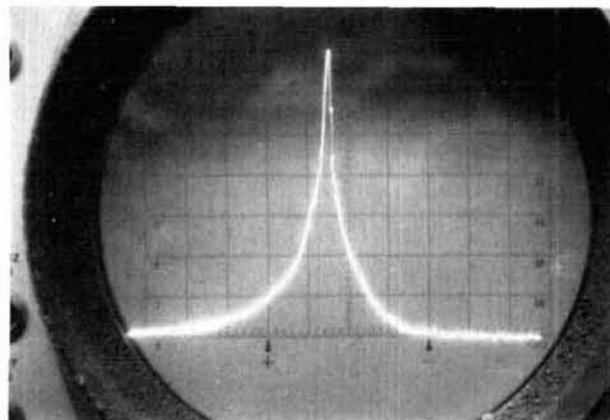


fig. 2. Oscillogram of spectrum of crystal oscillator multiplier chain. BW = 1 kHz. Horizontal scale 30 kHz/cm; Vertical scale 10 dB/cm.

specifications

The VCO described here was intended to replace the 1152-MHz crystal-controlled oscillator-multiplier chain discussed above. The ground rules I set were to achieve performance as close to that of the original unit as possible and to accomplish this in a simple manner. The oscillator would be operated directly at 1152 MHz without the need for frequency multipliers or cavity resonators and would be phase locked to a crystal reference signal in a relatively simple phase-lock loop. AFC would be included to avoid the possibility of any frequency ambiguity.

phase-locked loops

The theoretical aspects of phase-locked loops have been well covered in the references listed at the end of this article. It might be a good idea to do some reviewing before proceeding further. In particular I suggest reading (or re-reading) the two articles by Craig Corsetto, WA6OAA.^{5,6} For the most part, I will use Corsetto's notation to make this article easy to follow.

phase noise at VHF

It is less difficult to design a PLL around a digital phase detector than an analog one, especially when the VCO operates in the HF or VHF bands. But going beyond VHF into the UHF region introduces problems

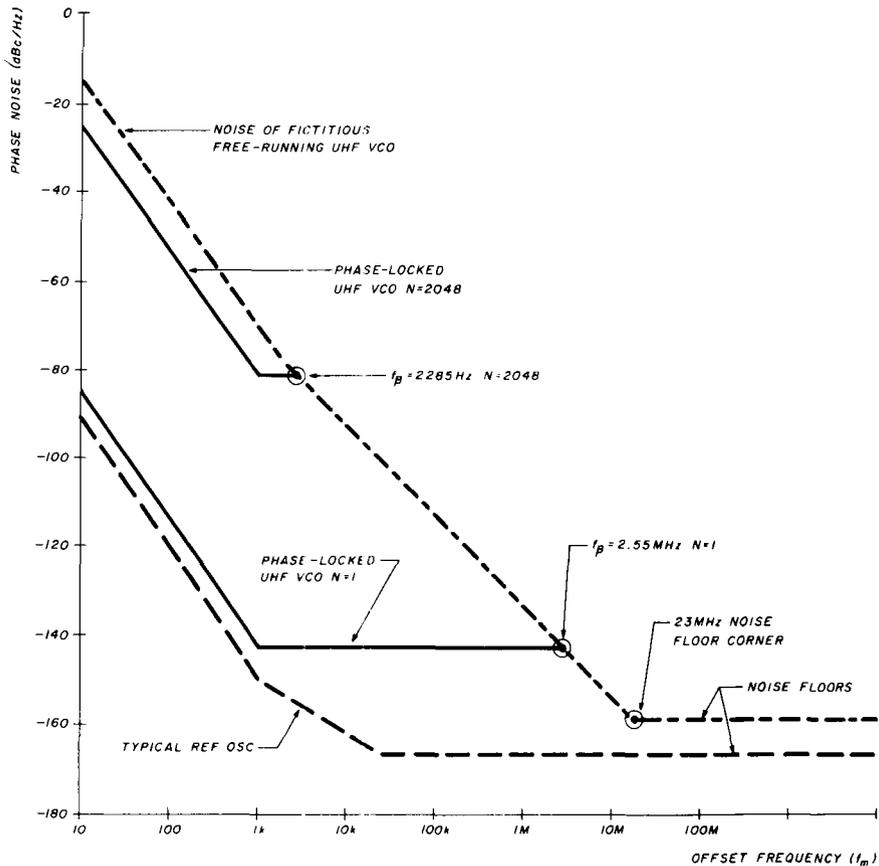


fig. 3. Possible phase noise characteristics of a UHF VCO.

that call for a considerable amount of ingenuity to keep phase noise low. The alternative would be to use multiple loops, but this increases the circuit complexity considerably.

To start out, I used a CD4046 phase/frequency detector; this required that the frequency of the VCO be prescaled (divided) by a large number so it would be compatible with the CD4046's upper frequency limit. I used an RCA CA3179 prescaler followed by a 74LS191 divider. The prescaler operated in the divide-by-256 (UHF) mode, and the 74LS191 was programmed to divide by eight. Total division was 2048, providing 562.5 kHz to the phase detector. By itself, this circuit was effective in providing AFC and phase detection, but, as we shall see, the noise introduced due to the division factor would be unacceptably high.

loop bandwidth

The loop bandwidth, f_β , is a key factor in terms of phase noise because frequencies less than f_β are under the control of the PLL while those greater than f_β are not. f_β is the frequency corresponding to unity open-loop gain:

$$f_\beta = \frac{K_\phi K_{vfo}}{2\pi N}$$

K_ϕ = phase detector sensitivity in volts/radian.

K_{vfo} = 42 MHz/volt, voltage tuning sensitivity.

N = 2048, oscillator division factor.*

For the CD4046, $K_\theta = 0.7$. Plugging in these values yields $f_\beta = 2285$. The significance of this number will now be discussed.

It is possible to calculate to a fairly good approximation the phase noise of a free-running oscillator as a function of sideband frequency, using the following relationships:^{7,8,9}

$$\mathcal{L}(f_m) = 10 \log \left\{ \frac{FKT}{2P_{av}} \left[1 + \left(\frac{f_o}{2f_m Q_L} \right)^2 \right] \right\} \text{dBc/Hz}$$

This equation is not as formidable as it may seem. The first term is Johnson noise divided by the oscillator's power output, which is 1/SNR (1/signal-to-noise ratio). F is the noise factor of the active device, K is Boltzman's constant, and T is the absolute temperature, °K.

The second term represents the manner in which noise is distributed on each side of the carrier frequen-

*I have departed from Corsetto's notion by defining N in the usual manner as the divisor, a number equal to or greater than 1. This should help avoid confusion.

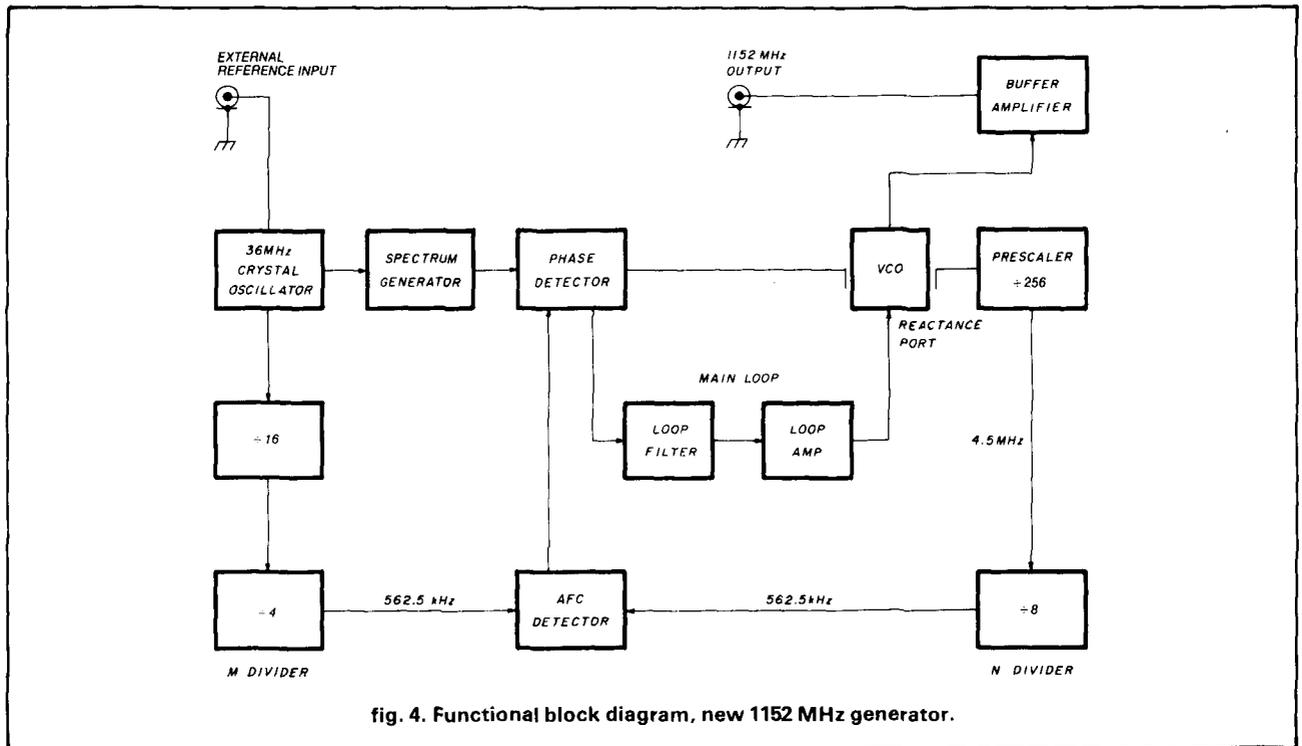


fig. 4. Functional block diagram, new 1152 MHz generator.

cy. The term f_m is the distance away from the carrier that a measure of phase noise might be made. Note that when f_m is very large, the second term approaches unity, and

$$\mathcal{L}(f_m) \text{ approaches } 10 \log \left[\frac{1}{2 \text{ SNR}} \right]$$

This is generally referred to as the single-sideband noise floor.

Going away from the carrier, VCO noise decreases until it intersects the noise floor at $f_m = f_o/2Q_L$. At a VCO frequency $f_o = 1152$ MHz and loaded Q , $Q_L = 25$, the noise floor corner is 23 MHz. (As a rule of thumb, $Q_L = 0.2 Q_U$, where Q_U is the unloaded Q .)

closing the loop

Using the various values of f_m , the dotted curve of fig. 3 was drawn, including the noise floor, noise corner, and unity gain band edge, f_β . When the loop is closed, the noise departs from the 20-dB/octave slope and tends to become constant from f_β to the carrier. The solid curve of fig. 3 represents the noise response of a fictitious VCO phase locked to a reference oscillator. Because N is so large, VCO noise near the carrier is relatively high.

The importance of f_β cannot be overemphasized. As the loop bandwidth is widened, more and more phase noise comes under the influence of the loop, making for a quieter VCO.

One way to widen the loop bandwidth is to reduce N . Unfortunately, the upper frequency limit of the CD4046 is about 2.5 MHz, based on a propagation

time of 200 ns between terminals 15 and 13. The lower limit on N is therefore about 450, giving

$$f_\beta \cong 10 \text{ kHz}$$

This reduces in-band phase noise by about 15 dB, which is better, but still not good enough.

phase noise characteristics

The phase-noise floor of a well designed crystal oscillator is about 165 dB below the carrier at offsets beyond 20 kHz but increases rapidly at lower frequencies as shown in fig. 3.¹⁰ This curve was extrapolated from various manufacturer's specifications and includes low-frequency flicker noise. Since the noise of a VCO locked to this reference is increased by $20 \log N$ above the noise of the reference, the best that can be expected of the VCO under these conditions is about -80 dBm/Hz at offsets below f_β . Notice that the phase-locked noise level is only 10 to 15 dB lower than for the free-running mode, because N is so large and f_β so low. The curve of the free-running VCO was calculated and has been verified only indirectly. While the curve is referred to as "fictitious," it may in fact be quite representative of the VCO's actual performance. Use of such a VCO as the LO in a communications receiver would surely degrade overall performance, especially in a multi-signal environment. An alternative would have to be found.

phase/frequency detector — part of the solution

The CD4046 is an interesting device because it is a

combination phase and frequency detector. In this dual role, it first steers the VCO toward the desired frequency (i.e., provides AFC) and then phase locks it to the reference. While the 4046 is not the only means to this end, it is far simpler than most other schemes. However, because it requires the use of a prescaler, phase noise is relatively high at UHF. What would happen if *somehow* N could be made equal to unity? $f\beta$ would then become 2.55 MHz, providing a theoretical reduction in phase noise of over 60 dB! This would put the VCO noise in the vicinity of -150 dBc/Hz and allow the noise specification of the UHF oscillator to be met.

In an earlier *ham radio* article I wrote about a programmable HF receiver that uses direct synthesis ($N=1$).¹¹ For AFC I added a counter, digital comparator, and a DAC (digital-to-analog converter). This receiver is still the workhorse of my station. It occurred to me recently that I might be able to use a similar direct phase detection scheme to provide phase locking and low noise at UHF, together with a CD4046 for AFC purposes. The question was, could these two circuits be made to work together? If so, this would finally solve the noise problem.

the final scheme

The UHF PLL that finally evolved is illustrated in functional block form in **fig. 4**. The main loop includes a phase detector operating directly at 1152 MHz. The auxiliary loop includes the CD4046, which provides AFC. A "picket fence" of reference signals¹² 36 MHz apart in the vicinity of 1152 MHz, is fed from the spectrum generator to one port of the phase detector. Another port receives a sample of output RF from the oscillator. The third port receives a frequency-steering signal from the CD4046. The output of the phase detector feeds a loop filter and amplifier driving the reactance port of the VCO.

With this configuration, the noise of the VCO is basically the same as that of the reference oscillator. Assuming that the noise curve of the reference shown in **fig. 3** is accurate, then the VCO phase noise should be -90 dBc/Hz near the carrier, dropping down to -150 dBc/Hz 10 kHz from the carrier and beyond. These are very respectable numbers indeed.

frequency programming

Using the numbers associated with **fig. 4** establishes 1152 MHz as the UHF oscillator's only operating frequency. However, a number of other options have been made available:

- Provisions have been made to enable selection of $N = 7, 8,$ or 9 , corresponding to VCO frequencies of 1008, 1152, or 1296 respectively ($f_{VCO} = 144N$).
- A VXO can be used instead of the fixed-frequency

crystal oscillator to vary the UHF oscillator's frequency by a small amount, typically ± 1.0 MHz.

- Other output frequencies may be selected by changing the crystal frequency. Given a desired UHF output frequency, the corresponding crystal frequency will be as follows:

$$f_x = \frac{64 f_{VCO}}{2048} \quad \text{for } N = 8$$

$$\text{or } f_x = 0.03125 f_{VCO}$$

For example, if the VCO frequency is to be 1116 MHz, $f_x = 0.03125 \cdot 1116 = 34.875$ MHz.

As another example, suppose the UHF oscillator is to be used as the LO for an OSCAR 10 upconverter. If the SSB generator is at 28 MHz, $f_{VCO} = 463$ MHz and $f_x = 14.46875$ MHz. Of course, in this situation both the crystal oscillator and UHF oscillator inductances would have to be increased appropriately.

If you are planning operation on the new 902-928 MHz band, and if you use 29 MHz as the IF, a high-side VCO will operate at 933 MHz and $f_x = 29.15625$ MHz, or a low-side VCO will operate at 875 MHz with $f_x = 27.34375$ MHz.

The circuits described here are by no means all-inclusive. The basic circuitry can easily be applied to other frequencies and other schemes, including fully-synthesized systems. For example, a frequency synthesizer could be substituted for the reference oscillator; however, this is beyond the scope of this article. The objective here is based on the concept that most Amateur UHF applications can be satisfied by providing a dedicated output frequency per individual circuit board.

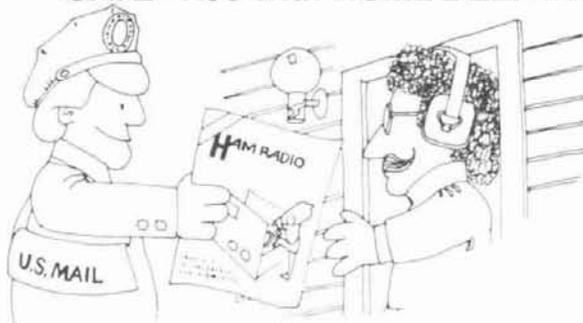
Next month: construction, testing, and performance.

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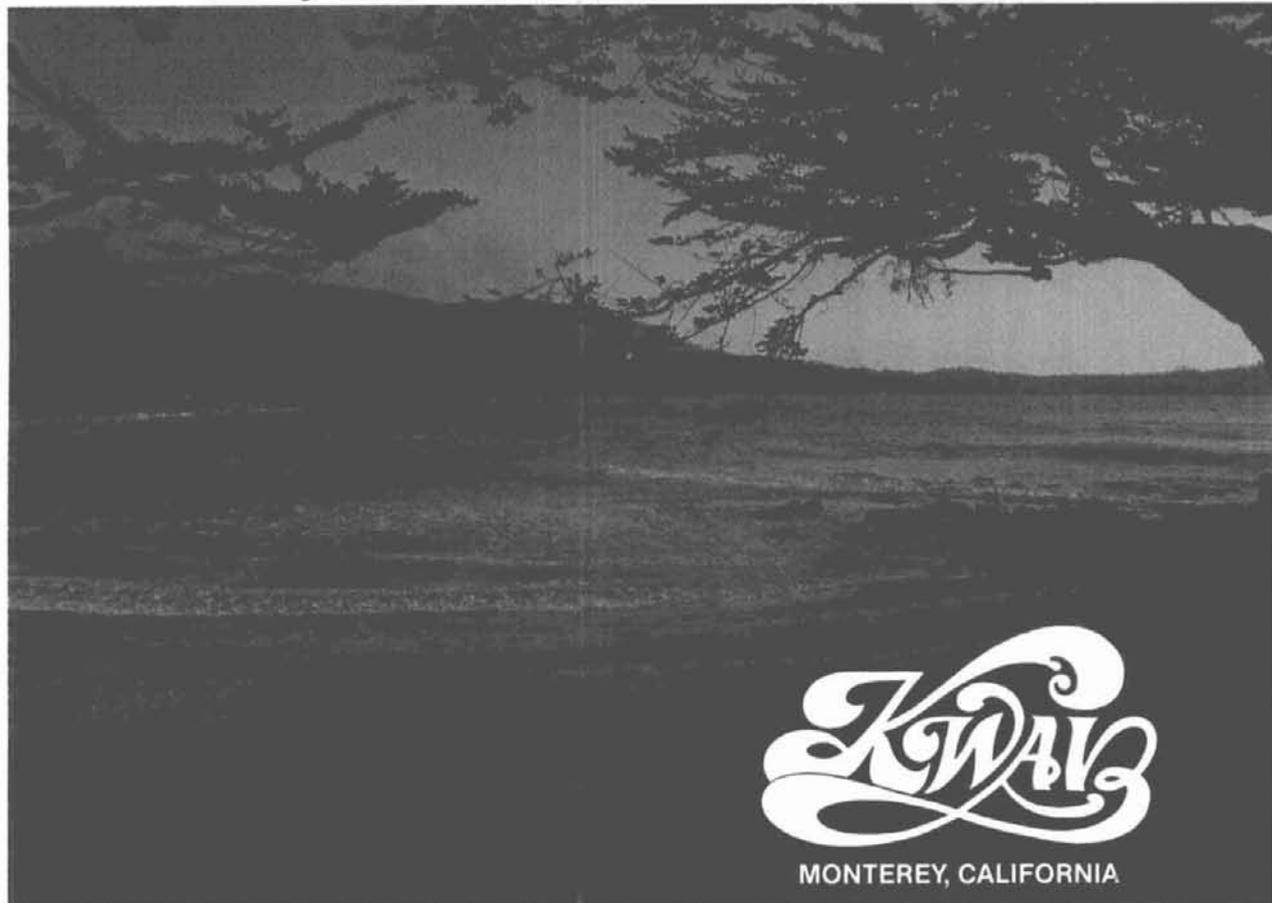
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using the multimeter

In last month's column we discussed various forms of multimeters. Amateur Radio and other electronic hobbyists use in making electronic measurements. This month we'll discuss how these instruments are used in practical applications. The proper use of volt, current and ohmmeters — as well as how to make high voltage and RF voltmeter probes — will also be discussed.

how to connect meters

It's essential that you learn the correct way to connect meters into a circuit, because using these instruments incorrectly can lead to catastrophe. Figure 1 shows the correct methods for connecting the various forms of a basic meter. Note well that voltage, current, and resistance aren't measured in the same ways; this fact leads to a high potential for damage to multimeters because the different functions are switch-selected. It's all too easy to "misconnect" a multimeter by switching ranges without first changing the position of the probes. The connections for voltmeters and current meters are shown in fig. 1A.

There are two simple rules to memorize:

1. Voltmeters are connected in parallel with the load.
2. Current meters are connected in series with the load.

Don't ever violate these rules! The second rule — always connect the ammeter in series and never in parallel — is especially important. If an ammeter is connected across the load, its low internal resistance will draw large current from the power supply of the circuit under test, and that current is

usually much larger than the full-scale range of the meter. On an analog meter (a "pointer type" rather than digital) the pointer will often bend around the peg and a puff of smoke will waft from the edge of the case. The problem may be reduced in some digital multimeters (DMM), but is still present. Fortunately, most manufacturers now place fuses in series with their multimeter probes.

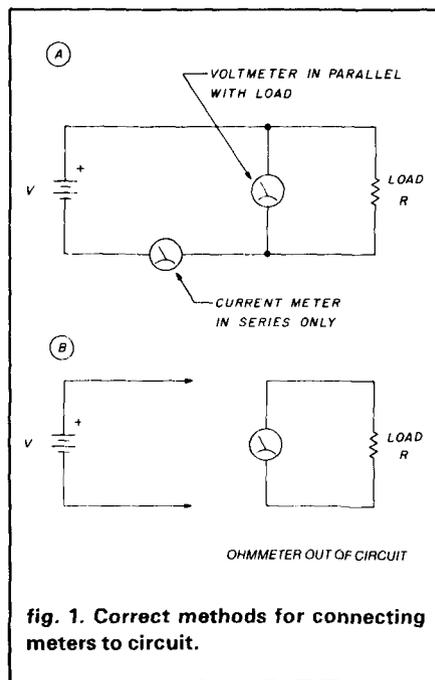


fig. 1. Correct methods for connecting meters to circuit.

The rule for ohmmeters is to disconnect the resistance being tested from the circuit even though the power is turned off. There are two reasons for this procedure: first, there may be parallel alternate paths for current to follow, and these will cause an erroneous lower reading; second, there may be current stored in capacitors in the

circuit, and that current can be large enough to destroy the meters.

Power supply filter capacitors are particularly dangerous to meters. Although even professional electronics workers may ignore this rule, it's a good habit to follow even if disconnecting components is a bit of a nuisance.

voltmeter "errors"

I can recall an incident in a laboratory class in which an electrical engineering instructor couldn't tell a certain student why the voltages read in an experiment were considerably lower than called for in the lab manual — and lower than the results of other students. The reason for the error turned out to be loading of the circuit by the voltmeter.

A voltmeter has an input impedance. For a volt-ohm-milliammeter (VOM) type of instrument, the input impedance can be determined by the sensitivity rating in ohms per volt. Most good meters have a sensitivity of 20,000 ohms per volt, and some especially fine meters are rated at 100,000 ohms per volt. Many inexpensive imported meters, on the other hand, have a 1000 ohms/volt sensitivity, which is very bad. Incidentally, the sensitivity reflects the full-scale "natural" range of the meter movement used in the VOM. The 20,000 ohms/volt instrument uses a 50 μ A movement, while the 1000 ohms/volt meter uses a 1 mA meter movement.

Figure 2 shows a sample circuit to illustrate the problem of loading. The circuit consists of a 10-volt source, V , and two series resistors, R_1 and R_2 . What we need to know is the voltage across resistor R_2 — that is, voltage V_2 . The correct voltage will be:

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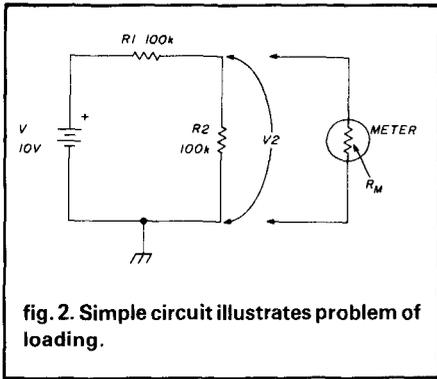
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$$V_2 = \frac{V \cdot R_2}{R_1 + R_2} = \frac{10 \text{ volts} \times 10K}{(100K + 10K)}$$

$$V_2 = 0.909 \text{ volts}$$

Now, consider what happens when we connect the voltmeter across resistor R2. The total resistance of this branch of the circuit is now the parallel combination of R2 and the meter's input resistance. Consider a 1.5 volt full-scale setting for the meter. At this setting, the 20,000 ohm/volt model has an input impedance of 30,000 ohms, and the 1000 ohms/volt has an input impedance of 1500 ohms. When connected in parallel with R2 to measure the voltage drop across the resistance, the combination of R2 and the input impedance forces new values of "R2" of 7500 and 1300 ohms, respectively. These heavily loaded resistances reduce the measured voltages from 0.909 to 0.697 and 0.128 volts, respectively. These errors, which are substantial, clearly illustrate the reason for using a voltmeter with a high internal impedance.

high voltage probes

Most high voltage meters are really ordinary voltmeters with a multiplier resistor or voltage divider network added. **Figures 3 and 4** show two alternate methods for adding high voltage ranges to the standard multimeter. The HV probe of **fig. 3** is used on those meters that have a specified input impedance of 10 Megohms (for example, VTVMs). When the series resistance inside the probe is 990 Megohms, the voltmeter will read 1/100 the actual voltage. Thus, a 30,000 volt potential will read 300 volts on the meter. This

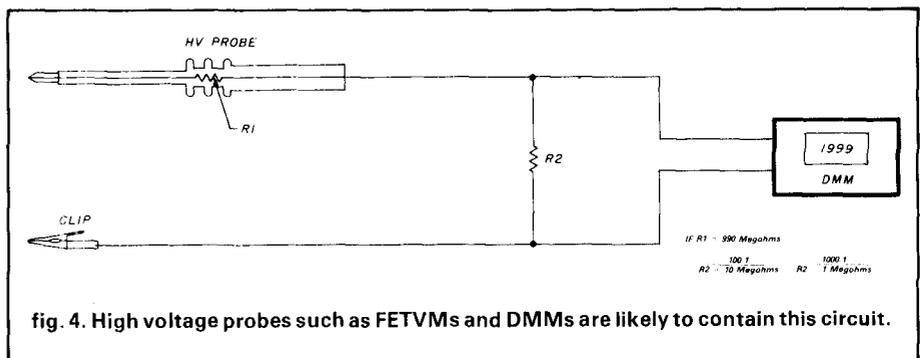
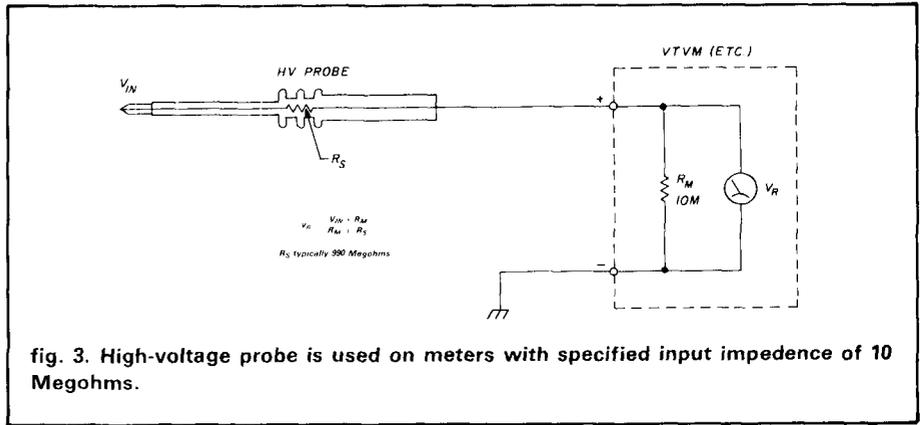
type of probe is widely available from electronic supply houses, especially those that cater to television service technicians, who often use such probes in conjunction with regular voltmeters for measuring anode potentials on color TV sets.

The basis for the probe shown in **fig. 3** is the resistor voltage divider circuit, in which one element is the series resistance and the other is the voltmeter input impedance. These probes require an input impedance of 10 Megohms. However, modern electronic voltmeters, including FETVMs and DMMs, have input impedances much higher than 10 Megohms. For these cases we use a circuit such as the one shown in **fig. 4**. Again, when you buy an HV probe for your instrument it's likely to have this circuit inside; in fact, some of the "universal" probes on the market are little more than circuits such as the one shown in **fig. 4** with 100:1 or 1000:1 reduction ratios.

You can, if you prefer, make such a probe yourself. I once made one for a hospital electronics lab that was

based on the old-fashioned model shown in **fig. 3**. We had the old probe, which mated with a traditional VTVM, but it didn't work on the new DMM with its advertised 1000-Megohm input impedance. Since the meter had a pair of banana jacks spaced 0.75-inch apart (a standard value), I mounted resistor R2 on a dual banana plug and soldered the combination to the ends of the old HV probe. The value of R2 was 1 Megohm, so with the 990 Megohms of the probe resistor I had a new probe with a 1000:1 reduction. We needed the probe for measuring the 12-15 KV anode potential of some elderly Sanborn scopes. In that case, a reading of 1.2 to 1.5 volts indicated the correct value. In other applications, one could use the same 10 Megohms for R2 as was common for VTVM input impedances to make a 100:1 reduction HV probe.

A high voltage probe should be equipped with a good alligator clip for this connection. If you use an ordinary alligator probe, or a poor quality alligator clip for the common lead, then all bets are off — you could easily zap



the meter. Damage to the meter is especially likely when it and the circuit under test are both grounded. If the common lead comes loose, the current from the high voltage circuit will try to find ground through the instrument.

meters in RF circuits

Very few multimeters are designed

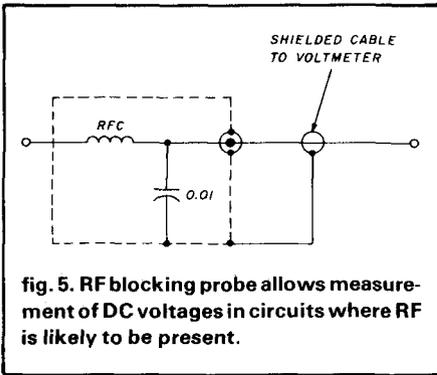


fig. 5. RF blocking probe allows measurement of DC voltages in circuits where RF is likely to be present.

to operate in RF circuits. There are two problems: first, we sometimes need to measure DC voltages in the presence of large RF voltages; second, we might want at least a relative indication of the value of the RF voltage present in the circuits. Fortunately, we can build our own probes that serve both functions.

The RF blocking probe shown in fig. 5 is designed to allow measurement of DC voltages in circuits where RF is likely to be present, such as in a radio transmitter. The circuit inside the probe is a low-pass filter consisting of a 2.5 mH RF choke and a 0.01 μ F capacitor. This circuit will block enough RF in most cases to permit a reading of the DC component. If there's still a problem, try two or three sections of the RFC/capacitor circuit to provide additional attenuation.

There are problems to be aware of

when using the RF blocking probe shown in fig. 5, however. The most obvious is that the RFC and the capacitor might interact with LC elements in the circuit and could thus distort the readings. It's also possible to damage certain circuits by detuning them — as in detuning a plate tank circuit while the circuit is live, for example.

Another problem is that RF chokes have a resonant frequency. This frequency is a result of the inductance and interwinding capacitance of the choke. When using the probe at the choke's natural resonant frequency, it will act like any other resonant circuit and perhaps destroy itself.

RF voltmeter probe circuits are shown in fig. 6. Both of these are sometimes called "demodulator probes" because they'll demodulate AM signals. A service instrument called a signal tracer is little more than an audio amplifier with a low capacitance probe up-front to pick up audio signals. If we replace the low capacitance probe with one of the circuits shown in fig. 6, we'll be able to troubleshoot AM receiver RF and IF circuits. With the diodes shown, we can measure RF potentials up to about 50 or 60 volts peak. For greater potentials, use two or more diodes in series. The diodes, by the way, are old-fashioned germanium diodes. Although largely supplanted in the market by silicon diodes, there are still many 1N60 diodes used as video detectors in TV receivers. You can still buy 1N60 diodes under the ECG-109 and certain other "universal" replacement part numbers.

The probe shown in fig. 6A was used in a number of low-cost demodulator probes associated with signal tracers a few years ago. The circuit shown in fig. 6B, on the other hand, has been popular among Radio Amateurs for decades because a similar circuit was published in the ARRL's *Handbook*. Finally, there's another circuit, shown in (fig. 6C) that's also very popular, and can be calibrated in terms of RMS voltage.

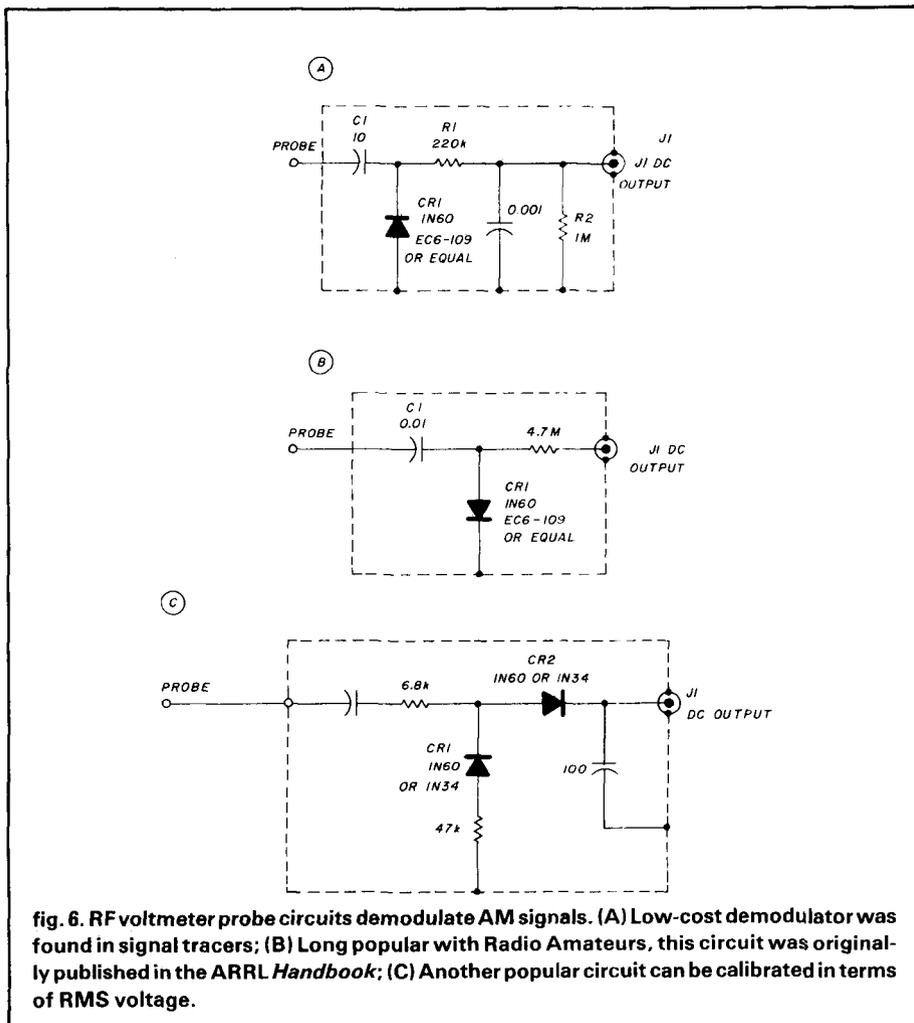


fig. 6. RF voltmeter probe circuits demodulate AM signals. (A) Low-cost demodulator was found in signal tracers; (B) Long popular with Radio Amateurs, this circuit was originally published in the ARRL *Handbook*; (C) Another popular circuit can be calibrated in terms of RMS voltage.

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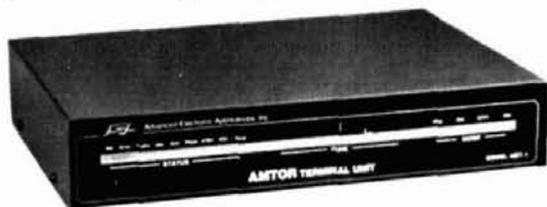
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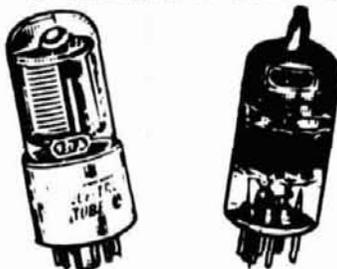
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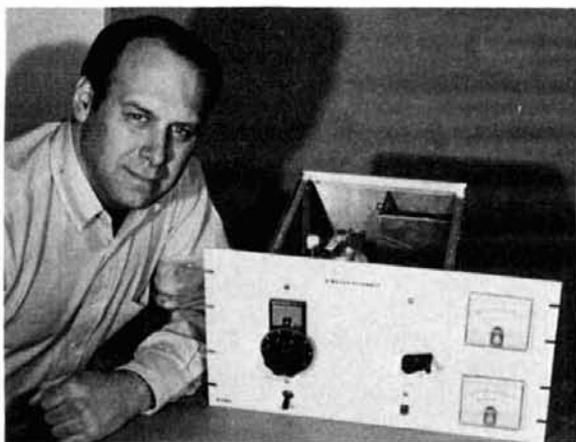
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Several years ago I became interested in VHF contesting and soon realized that contests require the ultimate in VHF operating skill, knowledge of propagation, and the best equipment an operator can muster.

Six meters, located in the "gray zone" between HF and VHF, but exhibiting characteristics of both, has made or broken many a VHF contest effort. If it's open, working 6 meters requires topnotch skills to maintain rate and sift through pileups on or near 50.110. If 6 is dead, then high power, good antennas, and scatter techniques are the name of the game.

It was the urge to work the 6-meter scatter circuits — and the rigors of contesting — that made me consider obtaining a full legal-limit kilowatt for the band. The amplifier had to be able to deliver full power output without strain for hours. It had to be a trouble-free design; after all, who likes to doctor an amp during a band opening? Because of second harmonic problems in the FM broadcast band and proximity to channel 2, it would also have to have a very clean signal. Quite an order!

There simply weren't any commercial 6-meter amps that met my requirements. Ten-year old marginal commercial amps built before the "amplifier ban" days and 150-watt bricks were the sum total of selections available. Because most of the older units used a pi output circuit that just wouldn't provide enough harmonic rejection, they weren't clean and had second harmonics only 40 dB down. By today's standards, amps built for use above 50 MHz must exhibit second harmonic attenuation of at least 60 dB below the fundamental signal.

So I began to look for a design that would fit these parameters. After some research, it became clear that

the pi-L output circuit, which provided a clean signal and sufficient harmonic suppression, would be the right way to go.

A 1000-watt dissipation tube was necessary. This meant that I'd have to use a pair of tubes such as those of the 8874 series or a single tube in the 8877 class. I ruled out glass envelope tubes because of high internal capacitances.

I chose the Eimac 3CX1000A7, a 1000-watt plate dissipation triode that's very similar to the 8877 except for a different socket. Parts are available from most parts supply houses. I used my junk box, RadioKit, Amp Supply, and a local parts supply house to obtain the necessary items.*

The amplifier is built on a 10 x 12 x 3-inch Bud chassis. (fig. 1). Aluminum panels (0.040 inch thick) are used for the chassis bottom cover, sides, and top plate. Aluminum "L" stock, available from most hardware stores, is used to hold the sides and top plate securely. All metalwork was done in my workshop using standard hand tools.

circuit description

The amplifier uses a grounded grid circuit with either the Eimac 3CX1000A7 or 8877, ceramic/metal triodes intended for linear service in the HF and VHF ranges. The amp provides the legal power output of 1500 watts PEP and CW service with no effort and requires a driver delivering between 50 and 80 watts at 50 MHz. This is well within the limits of multi-mode rigs.

With a plate voltage of 3000 volts at 0.8 amps the

**By Lauren Libby, KX00, 6166 Del Paz Drive,
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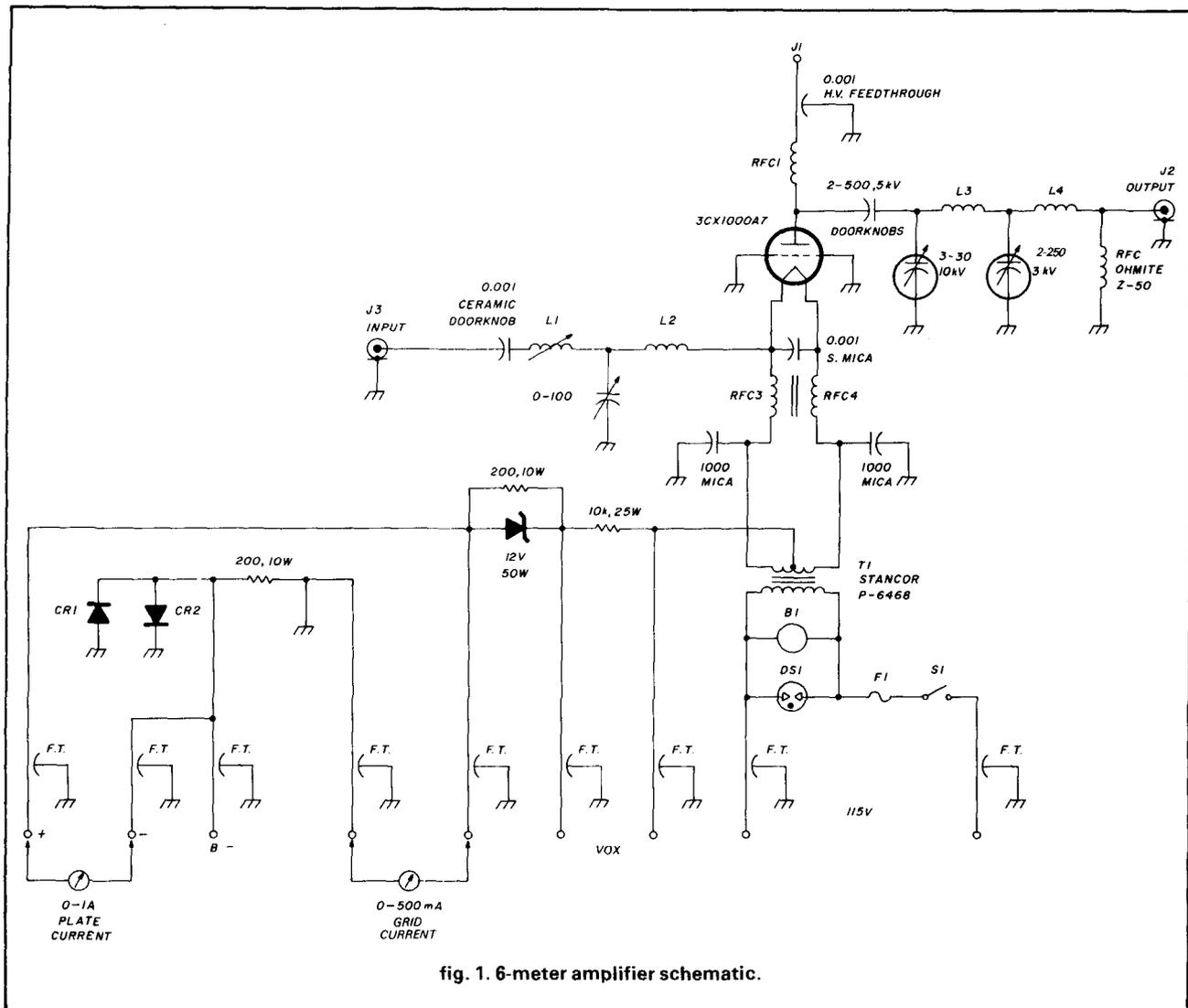


fig. 1. 6-meter amplifier schematic.

amplifier performs at 60 percent efficiency. The grid is grounded by means of the grid ring of the 3CX1000A7 socket providing a low-inductance path to ground. The amplifier is completely stable.

One notable feature of the amplifier is the use of a vacuum variable capacitor for tuning and loading controls in the plate circuit. The plate tuning capacitor is a 3-30 pF and the loading capacitor is a 0-250 pF. I used these units because they were available. The tuning capacitor should be a vacuum-variable because of the high voltages and currents present. An air-variable with large spacing could be used — just be sure not to exceed the voltage rating of the capacitor. The loading capacitor can be an air-variable that is of good RF transmitting design and rated for at least 2000 volts.

The pi-L circuit provides good harmonic suppression and broad frequency coverage. Most designs for

*RadioKit, Box 411H, Greenville, NH 03048; AmpSupply, 201 Snow Avenue, Raleigh, NC 27602

parts list

- B1 blower (Dayton IC180)
- CR1,2 1000-volt, 1-Amp diodes (Radio Shack)
- DS1 110-volt lamp and holder
- FT 0.001 500-volt feedthroughs
- J1 Millen high-voltage connector
- J2 "N"-type chassis connector
- J3 BNC chassis connector
- L1 6 turns, No. 18 on slug coil form available from Radio Kit, CTC 1538-4.3 or equivalent, spaced 7/8 inch
- L2 6 turns No. 18, 1/2 inch diameter, 5/8 inch long, self-supporting
- L3 3-1/4 turns, 1/4-inch copper tubing, 2-inch diameter 4 inches long
- L4 8 turns, 3/16-inch copper tubing, 2-1/4 inches long, 3/4 inch diameter
- RFC1 43 turns, No. 16 enameled, spacewound about 4-1/8 inches long on 3/4 inch diameter x 6-1/2 inch long teflon rod threaded to fit wire windings
- RFC2 Ohmite Z-50
- RFC3,4 30-Amp filament choke (available from Amp Supply) bifilar wound on ferrite choke
- T1 5-volt, 30-Amp filament transformer (Stancor) No. P-6468

the 6-meter band cover only the first couple of Mega-hertz of the band because of exotic designs using "floating turns" and expandable coil arrangements.

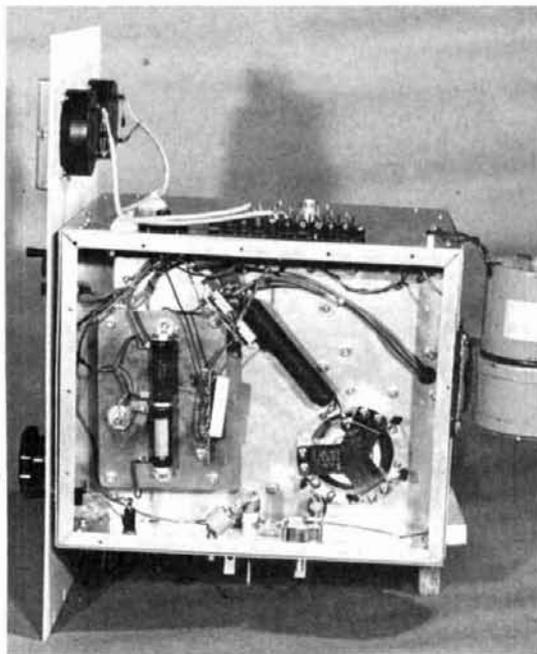


fig. 2. Grid compartment, bias supply, and input circuits. All connectors outside the compartment are made through feed-through capacitors. The input components are pictured in the lower center of the grid compartment.

These designs have been attempts to deal with high internal capacitances present in transmitting tubes. Only about 30 pF of capacitance are needed to resonate most circuits at 50 MHz, and many tubes have almost that much capacitance. So, in essence, the tube is a fixed tuning capacitor resulting in no tuning range for a variable capacitor.

This amplifier circuit provides for this condition by raising the Q of the circuit to allow for more capacitance tuning range. By increasing the Q , harmonic suppression is improved.

A 12-volt 50-watt zener diode is placed in series with the cathode return line to set the desired plate idling current and bias. The plate and grid circuits are metered in the cathode return lead.

the input circuit

The input circuit is a "T" design consisting of two coils and a shunt capacitor. One coil and capacitor are variable. With these two adjustments it's possible to cover a broad range of input impedances.

The controls are brought out the side of the unit for easy tuneup. Since the input circuit is a fairly broadband circuit, no tuning is needed once it's set for the first Megahertz of the band.

The input matching circuit can be seen in the lower center of the under-chassis photograph (fig. 2). The filament choke, a commercial unit obtained from Amp Supply, is capable of handling 30 amps of current at 5 volts.

A 1000-pF ceramic doorknob capacitor is used between the BNC input connector and the variable inductor in the input circuit. A transmitting mica would have worked just as well, as long as it was capable of handling 100 watts of drive power. Silver mica capacitors are used to isolate the filament line.

bias circuit

The bias circuit is built on a subassembly consisting of a brass plate and components. The subassembly is mounted on 1-inch spacers above the bottom of the chassis. The large resistors shown near the zener diode are suspended on a teflon rod hung from mounting supports.

plate circuit

Figure 3 shows the layout of the pi-L circuit. The plate choke is 43 turns of No. 16 gauge wire wound on a 3/4-inch diameter teflon rod measuring 6-1/2 inches long. I threaded the rod using an NC (National Course thread) die and then spacewound the coil in the threaded grooves. Half-inch copper strap is used to connect the plate circuit components. (This again is to accommodate the rigorous operating conditions.) Since the plate circuit has a high Q , large circulating currents are present. The vacuum variables are mounted with 0.060-inch aluminum "L" brackets that were fashioned with metal shears and bent to shape. The plate inductor L3 is wound from 1/4-inch copper tubing. The "L" portion of the circuit is mounted away from the loading capacitor at a 90-degree angle and is connected to a Z-50 (Ohmite) RF choke and antenna connector.

The layout is clean and easy to reproduce. Notice that an aluminum shield protects the filament transformer from stray RF.

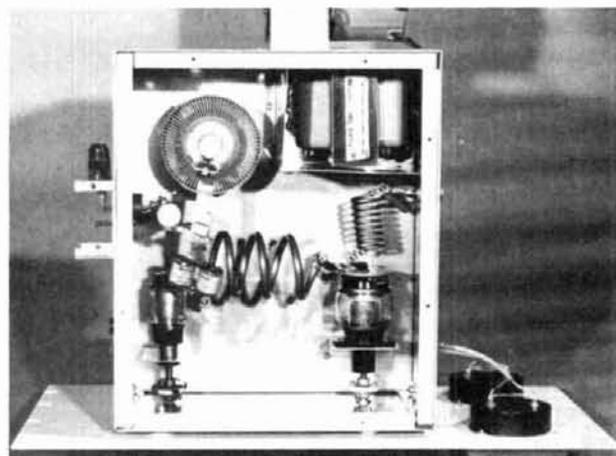


fig. 3. View of plate compartment. Note the location of the high voltage capacitor, plate choke, and plate circuit. This is an uncluttered layout and easy to reproduce.

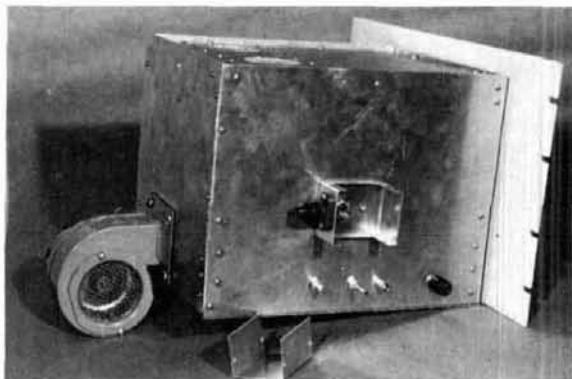


fig. 4. Rear view of completed unit. High-voltage connector and input tuning controls are pictured. The blower is positioned to pressurize the lower portion of the chassis.

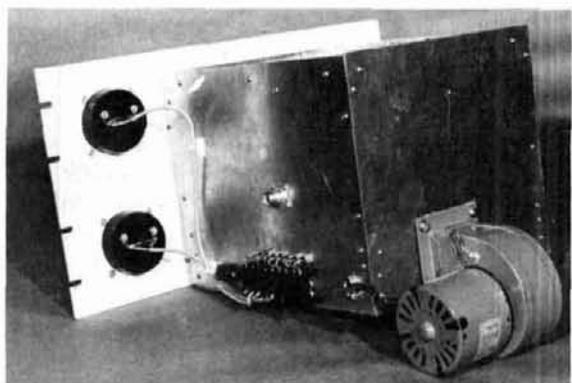


fig. 5. Completed rear view showing the feedthrough capacitors, output connector, meter mountings, and blower location.

The high-voltage connector is encased in an aluminum mini-box and connected to the high-voltage feedthrough capacitor. Safety is paramount when dealing with lethal voltages such as those used in this design (see fig. 4).

The tube chimney used with the 3CX1000A7 is a piece of teflon sheet (0.030 inch) cut to fit around the anode of the tube and fastened with teflon tape. Air-flow is directed from below the chassis and through the socket, and is then exhausted through the tube and out the top of the amplifier (see fig. 5).

tube performance data

Either a 3CX1000A7 or an 8877 can be used in the circuit. The 3CX1000A7 uses either the Eimac SK-860 or SK-870 air system socket, a breechlock type. The 8877 uses a plug-in Johnson 122-247-202 socket.

Both tubes use 5 volts for the filament voltage. The primary difference is that the 3CX1000A7 requires 30 amps of current, since it has a directly heated filament, and the 8877 requires 10 amps.

Many operating parameters were tried with this

piece of equipment. The most suitable ones for Amateur use are listed for the 3CX1000A7 below:

Plate Voltage	3000 Volts
Plate Current (Single Tone)	0.800 A
Plate Current (Idling)	0.125 A
Grid Voltage (Bias)	- 12 Volts
Grid Current (Full Drive)	0.200 A
Filament Voltage	5 Volts
Filament Current	30 Amperes
Power Input	2400 Watts
Power Output	1450 Watts
Drive Power	75 Watts

adjustment and tuneup

The completed amplifier is shown in fig. 6. Before applying any operating voltages, grid dip the input and output circuits to 50 MHz with the tube in the socket. This can be accomplished by putting a 50-ohm load on both the input and output connectors. Tune the variable inductor and capacitor in the input circuit to resonate at 50 MHz. Note that this will have to be tuned again after the amplifier is operating; this will put it in the ballpark, however.

Grid dip the plate tuning circuit to 50 MHz without applying any voltages. You may have to expand or compress L3 to resonate the circuit. L4 should not require any adjustment and is not as critical as L3. However, it should resonate near 50 MHz.

Turn on the blower and apply filament voltage. Let the tube warm up, check the filament connections at the tube to ensure that a full 5 volts is present. Sometimes a voltage drop can occur across the filament choke. The tube should be within 0.25 volt either side of 5 volts.

Place a wattmeter in the input and output line of the amplifier. The input meter should be capable of handling at least 100 watts and the output meter should be capable of measuring 1500 watts output. I used a 2500-watt slug in my Bird meter. Tuneup was executed into a 1500-watt dummy load.

After the tube has warmed up, apply reduced plate voltage (about 2000 volts) and look for any evidence of arcing or other abnormal conditions. If everything appears to be operating normally, apply a small amount of drive and adjust the input circuit for minimum SWR. Do this quickly and with no more than 10 watts of drive.

Apply more drive gradually and adjust the plate tuning and loading controls for maximum output power. Look for any abnormal conditions. If none are observed, increase the drive and retune. If everything looks good, increase the plate voltage to 3000 volts and quickly tune the amplifier with about 50 watts of drive applied. Read the output power, compute the input power by multiplying plate voltage by the plate

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fig. 6. Front view of the "Colorado Kilowatt."

current and compare it with the output power measured. This will give you an idea of the plate circuit efficiency. If everything appears normal, increase the drive to 80 watts, set the parameters suggested in this article, and you'll have a commanding signal on the 6-meter band.

final comments

Several lessons were learned in designing and building this amplifier. One was not to hook the connection of the high-voltage strap going to the tube to a bolt running through the teflon rod of the RF plate choke. During tuneup I had flaming teflon rod as a result of all the circulating currents running through a 6-32 screw. Make sure the connection of the tube strap is on the same side as the one to which the choke winding is attached.

Before you begin construction of this amplifier, I'd suggest you do some reading: Bob Sutherland, W6PO's "Two-Kilowatt Amplifier for Six Meters," which appeared in *ham radio* in February, 1971, and Bill Orr's *Radio Handbook*, regarding the design parameters of the pi-L circuit, are "must" reading.

Although you don't have to be an electrical engineer to build this amplifier (I'm an economist), it's not a project for the first-time builder. But if you have some experience, you may want to build it and enjoy the operating possibilities it affords. As you build, it may help to keep in mind something I've found to be true over several years of building amplifiers: for cleaner signals and years of trouble-free operation, it's best to over-build.

Because many good high-voltage circuits have already been published, I haven't included a power supply circuit with this article. Just be sure to make your power supply husky; if you have trouble lifting it, it's big enough.

acknowledgments

Many thanks to Ray Uberecken, AA0L, and Hal Bergeson, W0MXV, for their encouragement and help. Special thanks to Reed Brandon of Eimac for hours of help in the initial design of the circuit.

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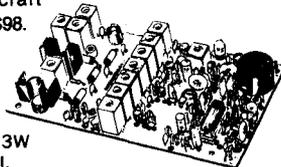
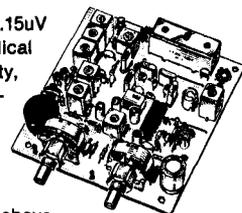


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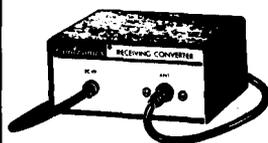
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144-146	50-52
144-146	28-30

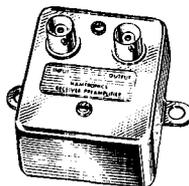
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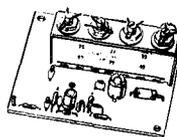
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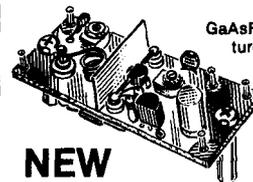
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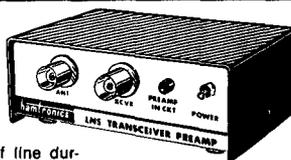
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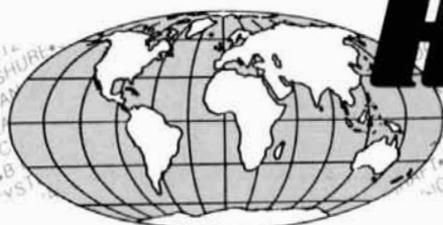
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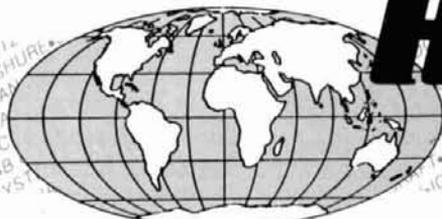
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The **step attenuator** is an important RF building block. On the workbench it can be used for testing the performance of amplifiers, mixers, or entire receiver systems; they're particularly useful for intermodulation tests. In test equipment they're useful for level references in spectrum analyzers and other instruments requiring wide dynamic range RF level measurements.

It's unfortunate, however, that step attenuators aren't often used in Amateur Radio receiver front ends. Anyone who's ever operated contests with a low dynamic range receiver knows the disastrous consequences of receiver overload and intermodulation interference; it's usually the third-order intermod products that cause problems in receivers.^{1,2}

The equations that define the third-order product levels indicate that if you reduce the input signal levels by 1 dB, the third-order products will decrease by 3 dB. Thus if you "switch in" 5 dB of attenuation at the front end, the intermod products will go down 15 dB. With multiple strong signals coming through the receiver bandpass, the step attenuator can indeed be a useful feature; under contest conditions, for example, there's no need for an expensive receiver to become less useful than it might be when the addition of a few resistors and switches could have been used to eliminate the problem (**fig. 1**).

Another problem arises during low signal level conditions, particularly at higher frequencies. Since the signal-to-noise ratio and "noise figure" of the receiver are largely determined by the front end, using a low-noise amplifier will improve ultimate sensitivity. The typical HF receiver front end consists of a tuned amplifier complemented with some type of gain-control circuitry. This gain control can be automatic (AGC) or manual (RF). Front-end design is complicated by the tuned circuits necessary for image rejection if a low IF is chosen (<20 MHz). However, the trend in

modern Amateur Radio receiver design is to first "up-convert" to a relatively high IF (typically 45 MHz). This technique places the image well up into the VHF spectrum and eases the front-end filtering requirements.

broadband constant gain and impedance

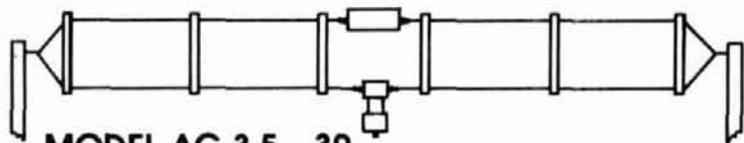
Some type of bandpass and impedance matching circuit is still required as an interface between the antenna and the usual discrete amplifier device. Unfortunately the input and output impedances of the familiar bipolar and FET devices do not match the universal 50-ohm standards.

The front-end amplifier problem can be greatly reduced by designing with a new broadband amplifier, the Signetics NE5025 (**fig. 2**). Priced at about \$1.50, the 5205 is a 20-dB gain block using a multiple feedback scheme that normalizes the input impedance over a very wide range. Both gain and impedance show only slight variation from DC to 650 MHz! The input impedance of the amplifier is simply "imaged" by the output termination; that is, if you terminate the output in 50 ohms, the input impedance will also be 50 ohms. This particular characteristic, in monolithic form, should be of interest to RF experimenters.

The 5025 also works in systems of 75 ohms and higher impedance. JFET double-balanced mixers (for example, the Siliconix U350) and the new ultra-high performance DMOS quad rings (such as the Siliconix Si8901) have a relatively low but constant input impedance, typically 12 ohms. Thus the 5205 can feed an 8901 through a 4:1 broadband balun for broadband front-end operation up to a few hundred MHz. This example completes a high-performance radio front-end concept free of resonant tuned circuits.

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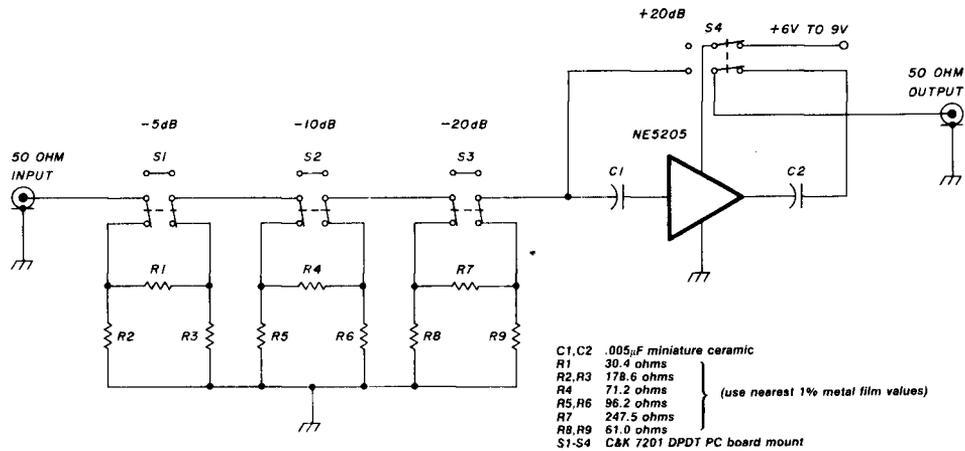


fig. 1. 35-dB step attenuator and gain stage improve intermod performance.

Table 1. Pi-network resistive attenuator (50 ohms).

dB Atten	R1 (ohms)	R2 (ohms)
1	870.0	5.8
2	436.0	11.6
3	292.0	17.6
4	221.0	23.8
5	178.6	30.4
6	150.5	37.3
7	130.7	44.8
8	116.0	52.8
9	105.0	61.6
10	96.2	71.2
11	89.2	81.6
12	83.5	93.2
13	78.8	106.0
14	74.9	120.3
15	71.6	136.1
16	68.8	153.8
17	66.4	173.4
18	64.4	195.4
19	62.6	220.0
20	61.0	247.5
21	59.7	278.2
22	58.6	312.7
23	57.6	351.9
24	56.7	394.6
25	56.0	443.1
30	53.2	789.7
35	51.8	1405.4
40	51.0	2500.0
45	50.5	4446.0
50	50.3	7905.6
55	50.2	14,058.0
60	50.1	25,000.0

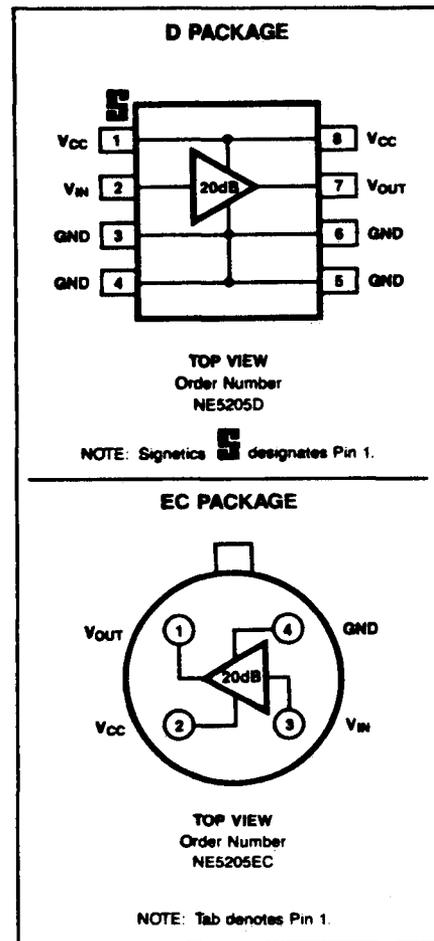
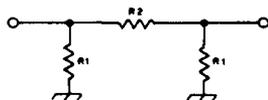


fig. 2. Pin configuration of Signetics NE5205.

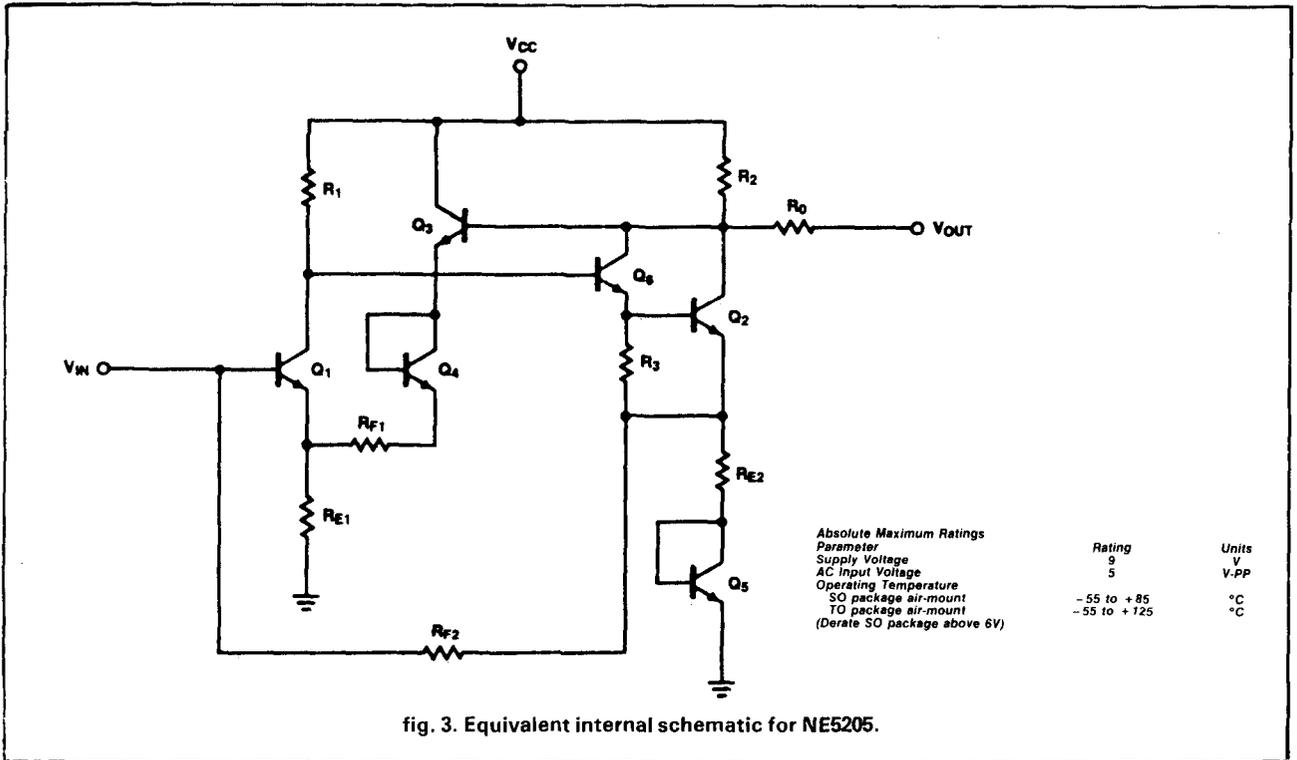


fig. 3. Equivalent internal schematic for NE5205.

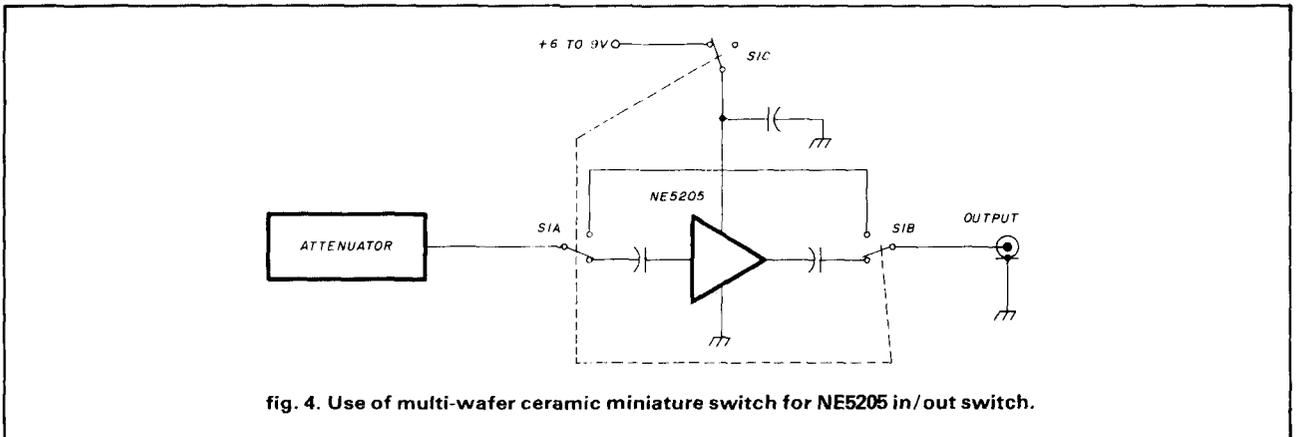


fig. 4. Use of multi-wafer ceramic miniature switch for NE5205 in/out switch.

Some filtering is still required, however. The use of upconversion techniques allows installation of a simple multi-pole 35- or 40-MHz low-pass filter ahead of the attenuator for image rejection. Inclusion of a broadcast band high-pass filter is also desirable for strong AM signal rejection.

overcoming circuit constraints

The circuit shown in fig. 1 allows both attenuation and amplification. Although using mini-toggle switches limits the frequency response to about 350 MHz, they are easy to mount, inexpensive, and rugged. This circuit is practical for the 160- through 2-meter bands.

A few precautions are necessary when using the 5205. It's usually easy to use if good RF techniques (i.e., providing adequate grounding and keeping the leads as short as possible) are employed. Care must be taken, however, when switching both the input and output circuits with a common switch assembly. The switch forms a capacitor between the input and output, while the switch leads and circuit board etching form a strip inductance. The resulting series LC circuit in the feedback loop will cause the amplifier to oscillate at a VHF or UHF frequency. The circuit shown oscillates at about 600 MHz, but the level is well below saturation, and the spectrum is very clean below 400 MHz. All oscillations can be eliminated by

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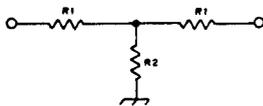
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Table 2. T-network resistive attenuator (50 ohms).

dB Atten	R1 (ohms)	R2 (ohms)
1	2.9	433.3
2	5.7	215.2
3	8.5	141.9
4	11.3	104.8
5	14.0	82.2
6	16.6	66.9
7	19.0	55.8
8	21.5	47.3
9	23.8	40.6
10	26.0	35.0
11	28.0	30.6
12	30.0	26.8
13	31.7	23.5
14	33.3	20.8
15	35.0	18.4
16	36.3	16.2
17	37.6	14.4
18	38.8	12.8
19	40.0	11.4
20	41.0	10.0
21	41.8	9.0
22	42.6	8.0
23	43.4	7.1
24	44.0	6.3
25	44.7	5.6
30	47.0	3.2
35	48.2	1.8
40	49.0	1.0
45	49.4	0.56
50	49.7	0.32
55	49.8	0.18
60	49.9	0.10



using a miniature ceramic rotary switch configured as **fig. 4**. The goal is to raise the feedback resonant frequency above the gain cut-off point of the 5205. This is accomplished by reducing switch capacitance and lead inductances. The 5205 can also be left "on" at all times, thus eliminating the oscillation problem.

construction techniques

The test unit was built on a 1 x 3-inch PC board with double-sided ground planes. The PC board can be mounted in a die-cast minibox that also holds the input and output sockets (BNC, N, or UHF) and the mini-toggle switches. The 5205 is available in standard N, surface mount, and TO-46 packages. If the TO-46 is used, the package should be mounted in a snug hole and the case soldered to the ground plane. Miniature ceramic input and output capacitors should be soldered directly to the 5205 leads. Good UHF design techniques must be employed even if the unit is used only at HF.

good intermod performance

Attenuation in 5-dB steps was chosen. This is somewhat arbitrary; other steps can be selected. **Tables 1 and 2** are included for convenience.³ This circuit, shown in **fig. 1**, allows gains of -35 to +20 dB in 5-dB steps, which should be adequate for any HF receiver requirements. The attenuators should precede the amplifier to maximize amplifier linearity.

The noise figure of the 5205 is less than 6 dB at 100 MHz for 50-ohm systems, dropping to 4.8 dB at 75 ohms. The third-order output intercept point is +17 dBm. This indicates that it will take two signals 33 dB above S9 to produce a third-order product at an S1 level.⁴ With only 5 dB of attenuation inserted, two signals must be 48 dB above S9 to produce an S1 level third-order intermod. This is indeed a strong front end!

summary

This simple project can greatly enhance the utility of a step attenuator on the test bench. In a receiver front end the NE5205 can eliminate bandpass filters while exceeding the intermodulation characteristics of many common mixers. Finally, when combined with a very strong mixer (such as the Si8901) an entire broadband, high-performance receiver system becomes possible.

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3. 1986 *ARRL Handbook*, American Radio Relay League, 1986, Chapter 25.
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W6SAI

a summer miscellany

Summer's here! Even though the sunspot cycle doesn't promise much DX, these *are* the months for antenna work. Here are some interesting designs you may want to try.

7-MHz sloping antenna

Many Amateurs have had success with the delta loop on the lower frequency bands. I've had queries about the effect of mounting the loop at an angle in order to conserve pole height. Does tilting the plane of the loop impede its fine DX record? I didn't know the answer to this question, but Kjell, SM6CTO, decided to try out the sloping loop shown in fig. 1. He found out that it worked very well; while he couldn't make a direct comparison with a vertical loop, he found it to be "a useful DX performer." (The antenna was described in the September, 1985, issue of *Radio Communication*, a publication of the Radio Society of Great Britain.)*

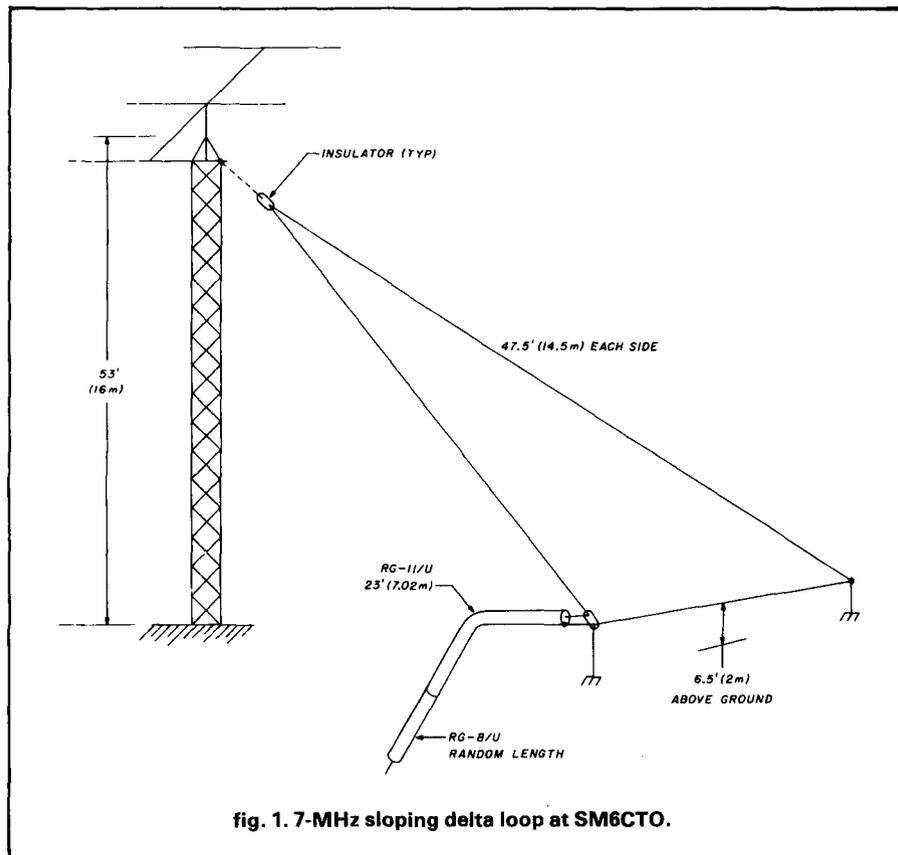


fig. 1. 7-MHz sloping delta loop at SM6CTO.

broadband 80-meter dipole

There's been a lot of sound and fury about the so-called broadband dipole for the 80-meter band (3.5 to 4.0 MHz). Many designs have been published and some of them work. One design that does work was recently described by Malcolm Johnson, VK6LC, in the November, 1985, issue of *Amateur Radio*, published by the Wireless Institute of Australia.* The layout is shown in fig. 2.

In brief, it's a cage dipole about 102 feet long, fed by a matching transformer and a 1-to-1 balun. The SWR on a 50-ohm transmission line across the 3.5- to 3.8- MHz range is less than

1.8-to-1, with a minimum SWR of 1.3-to-1 at the design frequency of 3.65 MHz. It's ideally suited for use with a solid-state transmitter. Less than half a wavelength long, the five-wire cage exhibits a capacitive reactance at the feedpoint that's transformed by the parallel line transformer to become slightly inductive. A shunt capacitor at the feedpoint parallel-resonates with the inductive reactance to aid in improving antenna bandwidth response.

The dipole is erected in inverted-V fashion, with the center apex at 36 feet above ground.

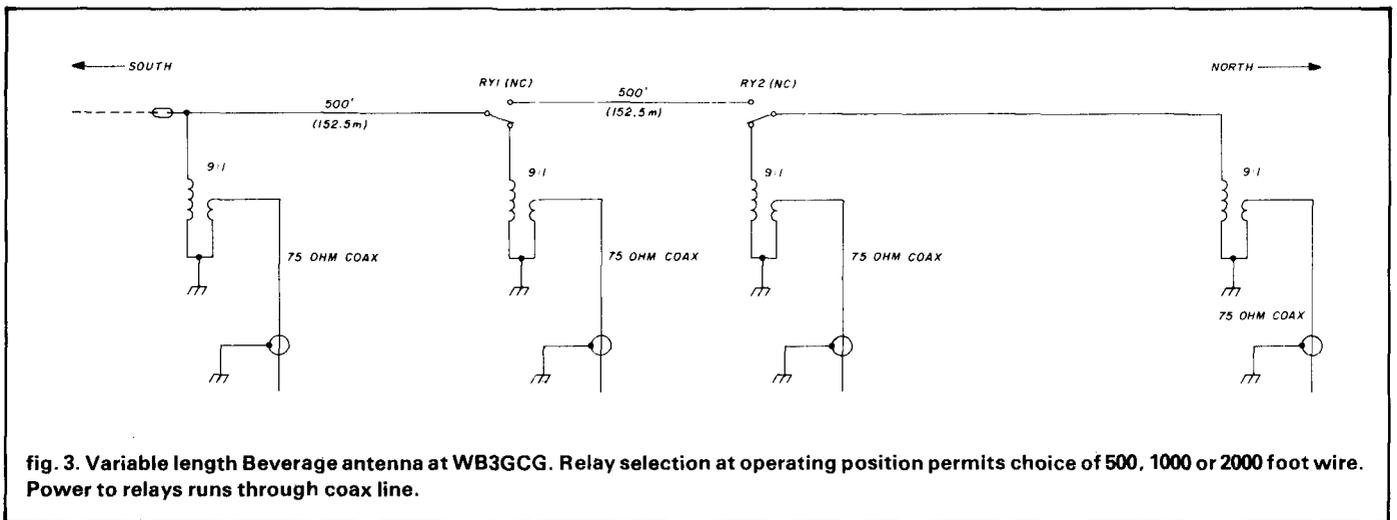
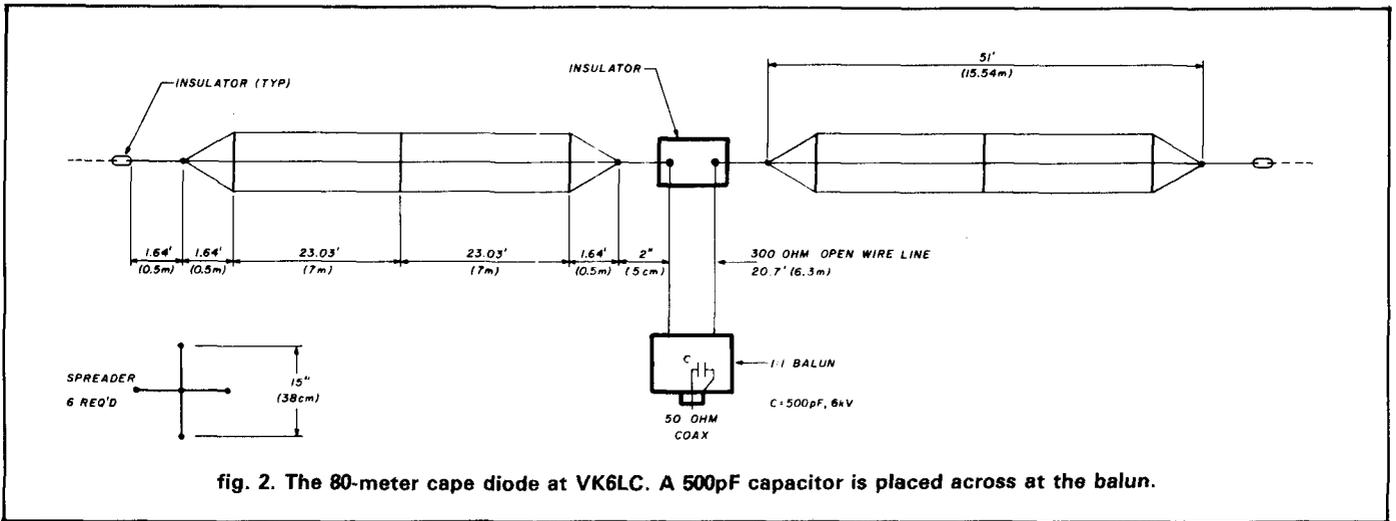
Malcolm used a four-way splice connector called a "Queblock" to make

his insulated spreaders. In any event, it seems that a little ingenuity will produce a spreader that will do the job. Six spreaders are required.

The two-wire transformer is about 0.08 wavelength long (20.7 feet) and has an impedance of 300 ohms. VK6LC used a home-made line, but I think that 300-ohm ribbon line could be used for low-power operation, provided the velocity factor of the line is taken into account. The shunt capacitor can be a high-voltage disc unit or mica capacitor of 1 kV or better, for powers up to several hundred watts.

In order to obtain an accurate SWR profile of the antenna, VK6LC used a half-wave long transmission line.

*Walter Schulz, K3OQF, "Designing A Vertical Antenna," *QST*, September, 1978, page 19.



The center resonant frequency of the antenna can be easily changed by adding or subtracting 5 inches of the 300-ohm line for each 20 kHz of desired frequency change.

Results? Plenty of DX worked, including such juicy examples as A71AD, ON5YA, YU4EBL, H44IA, WA6SLO, HA5XW and others — all with 100 watts! That's not bad for any antenna on the QRM-filled 80-meter band!

all you need is . . .

. . . a bunch of 200-foot towers! I just received a letter from Willy, WB3GCG, who has changed occupations and moved to a new QTH. He's had some big 160-meter antennas in the past and is looking forward to great

DX days ahead. On 20 acres of land, he's erecting three 200-foot high steel towers arranged in a triangle, approximately 500 feet apart. The towers will support the ends of several Beverage antennas, each 2000 feet long. Relays will be placed along the Beverage wires so the wire can be either 500, 1000, or 2000 feet long. When he's finished, Willy will have eight Beverage antennas. The feed system for the antennas is as shown in fig. 3. Each wire section is terminated in a 9-to-1 transformer. Coax lines run to the operating position; the wire lengths and terminating resistors are selected through a control box.

But that isn't all. Willy uses separate antennas for transmitting and receiving. For transmitting, he favors a

large vertically polarized loop (fig. 4). Similar loops are used as directors and reflectors. He can switch to horizontal polarization by means of a vacuum relay located at the apex of the loop.

A large number of loops are strung on catenary cables between the towers. Willy aims to have three separate 160-meter delta loop beams, each consisting of back-to-back four-element parasitic arrays with a common driven element (see fig. 5), strung between the towers! With the use of multiple feedlines and vacuum relays, each delta beam can be quickly reversed in direction. It takes a total of seven loops and 3500 feet of No.14 four-strand, vinyl-covered wire for one beam!

In closing, Willy remarks that the

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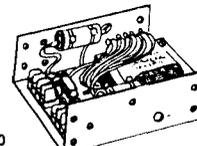


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delta loop beam really works. All of this reminds me of the song, "Will everyone here/kindly step to the rear/and let a winner lead the way!" Good luck, WB3GCG, and may the wintry winds be kind to your antennas.

the "rinky-dink" antenna at K6FD

Yes, that's what Ray, K6FD, calls his tuned 40-meter V-doublet (fig. 6). He uses it on the 30, 40, 80, and 160-meter bands. The antenna is "tuned" from the operating position with a T-network. The included angle between the legs is about 75 degrees, and the wires slope down slightly towards the ground. The antenna is decoupled from the feedline with a simple 14-turn coil, 3 inches in diameter, of small RG-141/U coax. The remainder of the feedline is RG-58/U.

The simple network allows unity SWR to be achieved on all bands. The coax feedline is about 100 feet long. Ray says that with appropriate coils in the network, the system will tune through the broadcast band.

Ray recommends this antenna to those operators who would like to try 80- and 160-meter operation but haven't done so because they haven't room for large antennas.

a cheap, top-loaded antenna for 160 meters

Arne, K0AS, is lucky in that he has a number of tall trees on his property. He wanted to work the low end of 160 meters and found design information for a top-loaded vertical antenna in an article in an old copy of *QST*. Following that design, he used a 50-foot high wire with plenty of top loading. The top loading disk, a rectangle in this case covering 480 square feet, is made of No. 10 copperweld wire. An L-network is placed at the base of the antenna to match it to a 50-ohm coax line. Beneath the antenna are 50 radials, each 125 feet long. A sketch of the antenna and the matching network is given in fig. 7. The feedpoint resistance of the antenna is about 18 ohms.

The resonant frequency of the an-

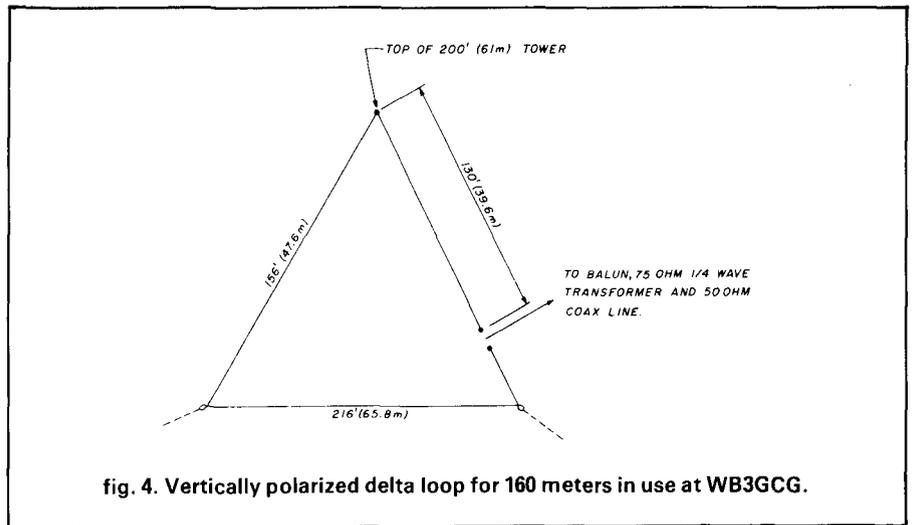


fig. 4. Vertically polarized delta loop for 160 meters in use at WB3GCG.

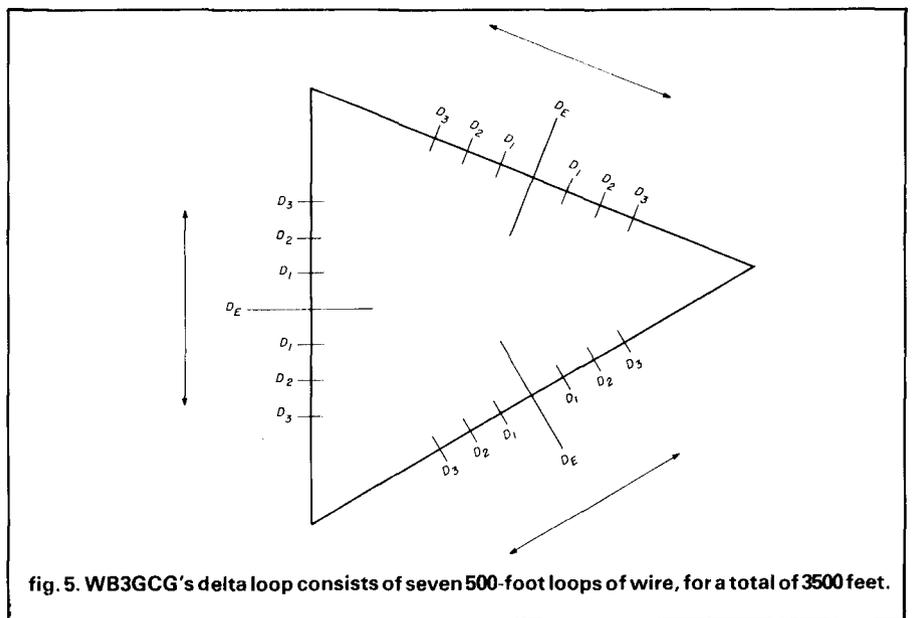


fig. 5. WB3GCG's delta loop consists of seven 500-foot loops of wire, for a total of 3500 feet.

tenna can be raised to about 1850 kHz by manipulating the switches in the base network. At this frequency, the operating bandwidth between the 2-to-1 SWR points on the feedline is about 60 kHz.

Arne says the antenna is "quite inexpensive and the results are most gratifying." You couldn't ask for much more than that.

another nifty low-band antenna

Bob, K9EVI, wanted an antenna that would cover 160, 80, 40, and 30 meters and fit in his back lot. What to do? He had a tower that supported a

tribander for 20, 15, and 10 meters — now he needed an antenna for the low bands.

His solution was to use a center-fed dipole, 45 feet on a leg. The antenna is slung, in inverted-V fashion, from the top of his 45-foot tower. The ends are about 15 feet above ground level. Bob uses a 600-ohm, open wire feedline about 45 feet long that runs down to his station and into a simple matching network (fig. 8) for 80- and 160-meter operation. For the other bands, he uses an old Johnson "Matchbox" tuner. On 80 and 160 meters, the antenna feeders are tied together and the system works as a

top-loaded vertical antenna, with the feeders doing the major portion of radiation.

the first radio handbook

The Wireless Experimenter

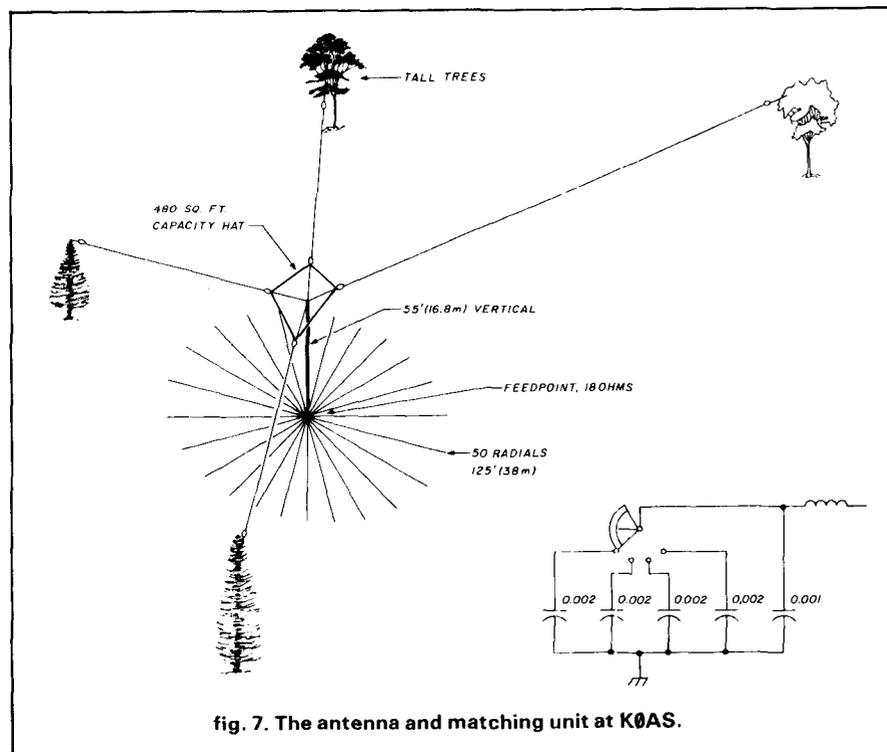
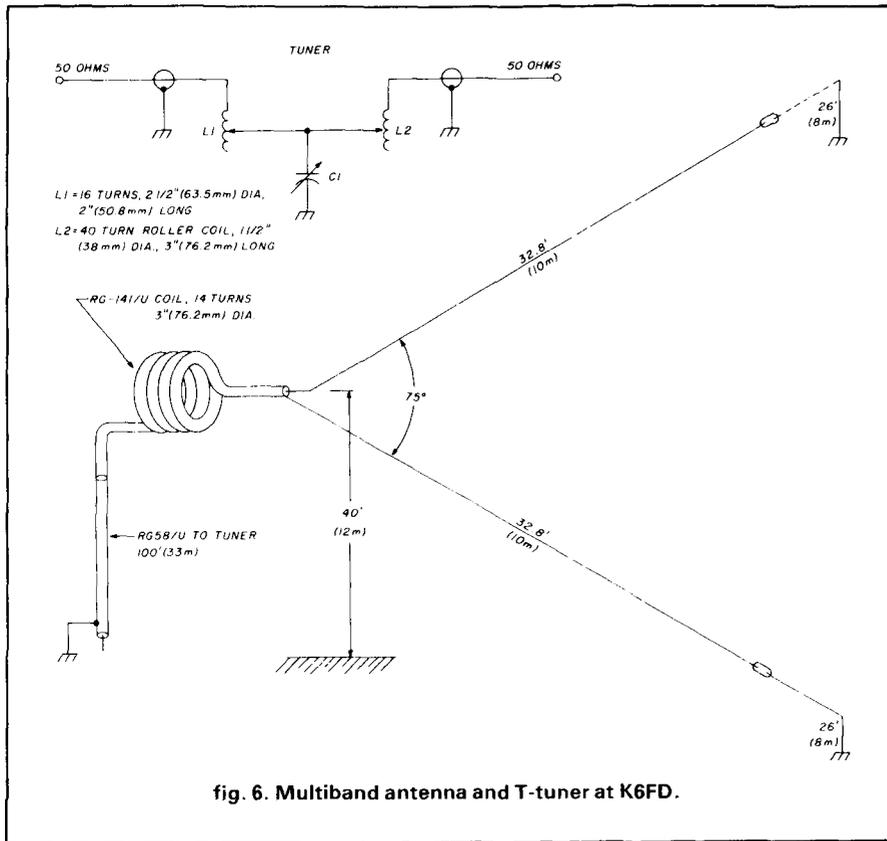
proclaimed it "the publishing event of the year." Experimenters in the United States and Canada bought out the first edition even before it was on the presses. And the General Electric Company bought 500 copies sight-unseen.

Starting with Marconi's famous experiments at the turn of the century, the advance of wireless (i.e., radio) rushed ahead in Europe. Following in the footsteps of Marconi, experimenters and engineers in Germany quickly advanced the radio art. But very little of this advanced knowledge crossed the Atlantic to the United States. Hearsay, letters, and month-old magazines were the only sources of information available to experimenters and Radio Amateurs in the United States.

There were, however, rumors of a wonderful handbook, written in German, entitled *Lehrbuch für Drahtlose Telegraphie (Textbook for Wireless Telegraphy)*. A few copies could be found in college libraries, but the information was obviously accessible only to those who had a good command of technical German.

The 1912 version of the book — written in 1905, published in Braunschweig in 1908, and revised in 1912 — was translated by A.E. Seelig of Wellsville, New York, and published by McGraw-Hill in the fall of 1915. And what a wonderful book it was! Written by Professor Jonathan Zenneck of the Technical High School of Danzig, the 440-page hardbound book clearly defined and explained the wonderful world of wireless. The book bristled with photographs of arc and spark transmitters and various types of crystal, carborundum, magnetic, and diode receivers. Much attention was given to antenna design and installation. Long-range propagation via the ionosphere was discussed along with gray-line propagation at sunrise and sunset.

Interestingly, comprehensive data was provided on voice transmission using an arc transmitter, a technique seemingly known to only a handful of experimenters.



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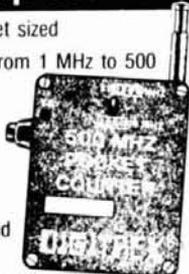
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This beautifully illustrated book, printed on cream-colored heavy paper, made Professor Zenneck an instant celebrity in the United States.

the doctor is interned

Shortly before World War 1, Dr. Zenneck came to the United States. Welcomed with a dinner at the Institute of Radio Engineers in New York, he visited many radio laboratories, as

well as the German-owned radio station at Sayville, New York.

On July 6, 1917 the wireless world was stunned by a headline in the New York Times: ARREST GERMAN RADIO EXPERT AND TAKE HIM TO ELLIS ISLAND. The Department of Justice had determined that Dr. Zenneck was "one of the most dangerous German subjects in this country," and claimed that he had participated in "the memorable German drive through

Belgium" and had later "falsified his passports" to gain admission to the United States (fig. 9).

Were these accusations true? No matter. Dr. Zenneck was interned at Ellis Island for the duration of the war. Released at the end of the war, he reportedly enjoyed a reunion dinner with his colleagues at the Institute of Radio Engineers, but thereafter disappeared from history.

By that time the glamour of "Zenneck" had faded. Great strides in radio communication had been made during the war period and the vacuum tube was supplanting the spark, the arc, and the crystal detector. DeForest's audion, which originally rated a half-page in "Zenneck," was now supreme and large portions of the first Radio Handbook were swept into the dustbin of history.

"Zenneck" today

Looking at yesterday through the eyes of today is an instructive experience. Zenneck had a firm grasp of the basic principles of wireless. Much of his book is fundamentally correct and the work stands as a monument to the author and the many prominent scientists who assisted him. Copies of the first edition of *Wireless Telegraphy* (1915) are very rare and hard to locate. (I found mine in a second-hand bookstore.) It is prudent for connoisseurs of the radio art to be alert for a copy of this work because it represents the very foundation of radio handbooks today.

A belated — and much-deserved — congratulations to Professor Jonathan Zenneck for a job well done!

2-meter EME directory

The 16-page directory of active 2-meter "moonbounce" stations worldwide, listing each station's name, QTH, and equipment used, has been reprinted. For a copy, write to me at EIMAC, 301 Industrial Way, San Carlos, California 94070. Enclose five first-class stamps (or five IRCs) for postage.

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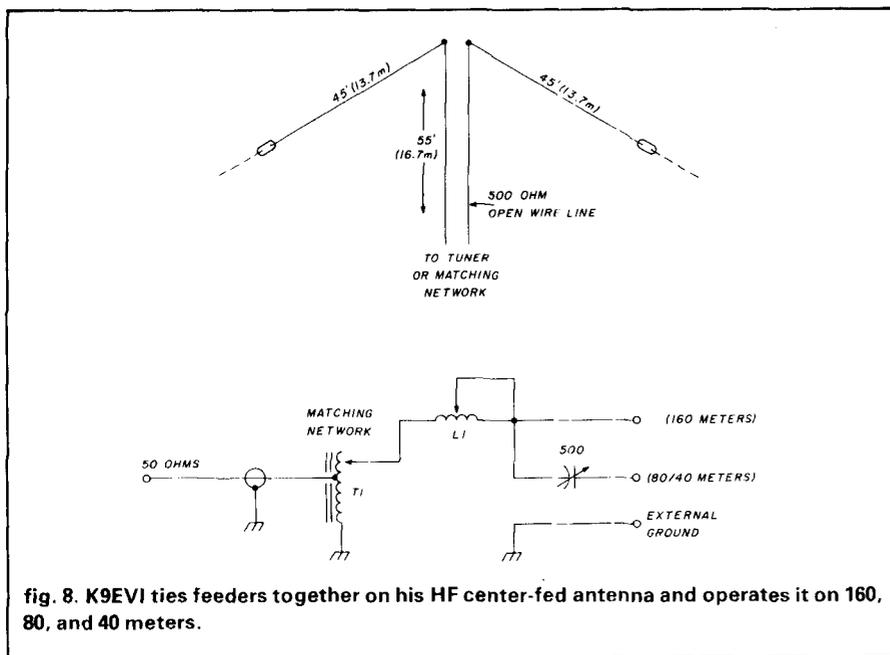


fig. 8. K9EVI ties feeders together on his HF center-fed antenna and operates it on 160, 80, and 40 meters.

ARREST GERMAN RADIO EXPERT AND TAKE HIM TO ELLIS ISLAND

Professor Zenneck Is to Be Interned During War By Order From Washington.

By the United Press.

Trenton, N. J., July 6.—Acting under special orders from the Department of Justice at Washington, United State Deputy Marshal Linford Denny, of this city, late last night placed Prof. Jonathan Zenneck, German radio expert, under arrest and took him to Ellis Island, where he will be interned for the duration of the war.

The Department of Justice is said to look upon Professor Zenneck as one of the most dangerous German subjects in this country. Germany looks upon him as one of her most skilled wireless telegraph experts, and he came to this country especially to direct German wireless activities. For a long time he was in charge of the German radio station at Sayville. Of late he has been living at Boonton, at which point he was arrested by Deputy Denny.

Before coming to America Professor Zenneck served in the German Army in an official capacity. He participated in the memorable German drive through Belgium and later by falsifying his passports gained admission to the United States.

4

fig. 9. The New York Times reported arrest and detention of Professor Zenneck.

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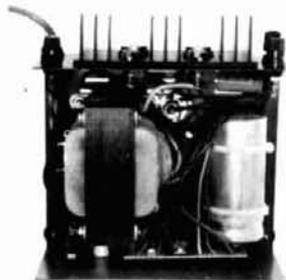
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RS-10A	7.5	10	4 x 7 1/2 x 10 3/4	11
RS-12A	9	12	4 1/2 x 8 x 9	13
RS-20A	16	20	5 x 9 x 10 1/2	18
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VS-35M	25 15 7	35	5 x 11 x 11	29
VS-50M	37 22 10	50	6 x 13 3/4 x 11	46

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RS-10S	7.5	10	4 x 7 1/2 x 10 3/4	12
RS-10L(For LTR)	7.5	10	4 x 9 x 13	13
RS-12S	9	12	4 1/2 x 8 x 9	13
RS-20S	16	20	5 x 9 x 10 1/2	18



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extending receive coverage for the IC-02 and IC-04

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The ICOM IC-02 (2 meters) and IC-04 (70 cm) handhelds are a natural step up from the earlier IC-2 and IC-4. Microprocessor controlled, these newer models feature a liquid crystal display, an S-meter, a built-in CTCSS (continuous tone-coded squelch system), and scanning capability, all in a water-resistant package that accepts accessories designed for the IC-2 series.

The United States version of the IC-02 transceives from 140 to 149.995 MHz; the IC-04 will transceive on the upper 10 MHz of the 70-cm band from 440 to 449.995 MHz. With the simple modifications described in this article, the IC-02 can be adapted to receive from 140 to approximately 163 MHz; the IC-04 can be modified to receive up to about 465 MHz. Transmit capability is unaffected, and any frequency entered will be properly stored in memory. Because this isn't a permanent modification, each rig can easily be returned to its original state.

Extending the receive capability of either unit will let you listen to the public service frequencies (police, fire, and radiotelephone, for example) located just above the 2-meter and 70-cm bands. Modifying the IC-02 also permits reception of National Weather Service broadcasts at 162.40, 162.475, or 162.55 MHz in most metropolitan areas. Receive sensitivity for frequencies this far removed from the 2-meter band is reduced, but should be adequate for most applications.

the microprocessor

The IC-02 and the IC-04 are each controlled by a Hitachi HD44795 80-pin microprocessor which operates the display, keyboard, and frequency synthesizer. The processor operating environment is determined by an initialization matrix (figs. 1 and 2) consisting of four output and four input lines connected to each other in a specific pattern with isolating diodes. This pattern determines processor reset frequency, upper and lower band limits, step size, method of frequency entry from the keyboard, and other functions. The modification procedure described here changes the initialization matrix to remove the receive frequency limits as determined by the microprocessor. Receiver coverage, however, is still limited by the tuning range of the synthesizer VCO and by receiver sensitivity.

disassembling the units

Before you start, make sure you have a soldering iron with a very fine tip; you'll be working with extremely small components. [If you've never worked with such small components, in such tightly confined space, you may want to practice first. — Ed.]

Begin by disassembling the battery pack and antenna from the transceiver. Then remove the battery mounting plate and locking lever assembly. Unfasten the five screws holding the metal back cover to the rig and take off the cover, using care not to damage the "O" rings that seal the back cover to the rest of the case. (On the IC-04 only: remove the large metal shield covering the PLL circuitry.) Now separate the chassis and top section and place them next to the front case; note the ribbon cable connecting the chassis to the front section. Undo the two screws on the DTMF/CTCSS board and set the board off to the other side of the front case (02AT/04AT only). The unit is now ready for modification.

By Robert K. Morrow, Jr., WB6GTM, RR 1,
Box 6F, Flora, Indiana 46929

initialization matrix

The microprocessor board is identical in the IC-02 and IC-04 except for the diodes attached to the initialization matrix area located at the top left corner of the board (fig. 3). We'll be working with the portion of the matrix connecting microprocessor lines R10-R13 to R20 and R21.

ICOM uses very small three-pin chip diodes — type A3, D3, or E3 (indicated on the diode itself) — to pro-



Fig. 3. Initialization diodes can be located at positions D1-D4, which are found at the top left corner of the microprocessor circuit board. The factory diodes are surface mounted on the triangular pads at D2 and D3 for the IC-02, and at D1 and D2 for the IC-04. The IC-02 is modified by simply removing the diode at position D2. To modify the IC-04, remove the diode at position D2 and replace it with a 1N914-type connected from the top pad (anode) to the lower right pad (cathode).

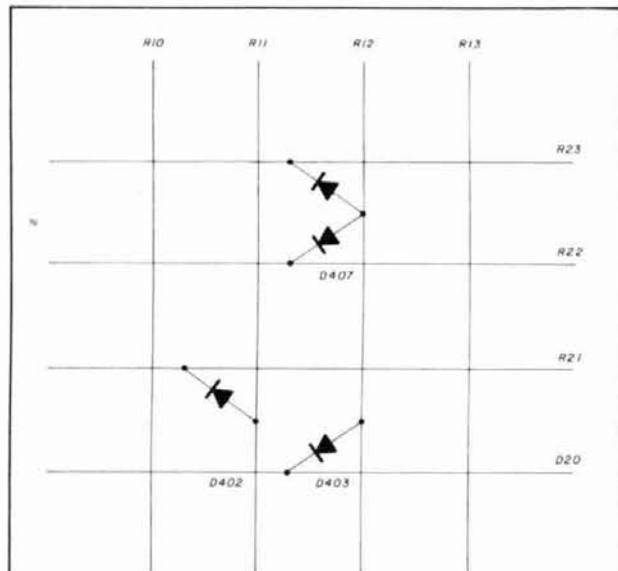


fig. 1. Initialization matrix for the factory IC-02. Removing D402, which is a type D3 located at position D2 in fig. 3, will remove the upper receive frequency limit of the rig.

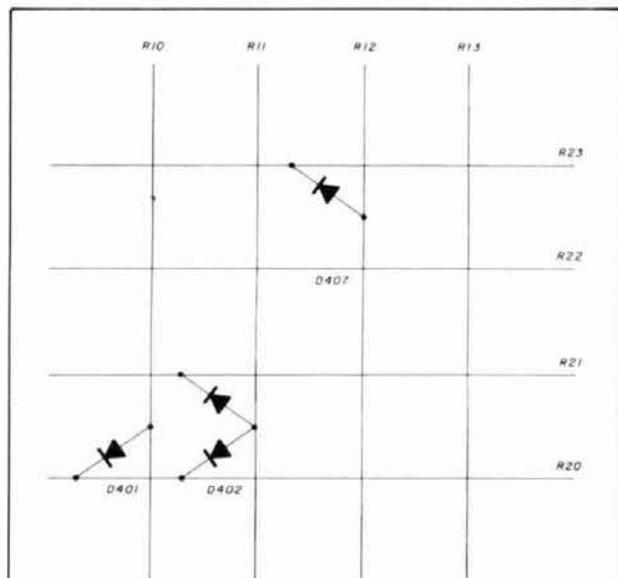


fig. 2. Initialization matrix for the factory IC-04. Removing D402 and connecting a 1N914-type silicon diode between R11 (anode) and R20 (cathode) will remove the upper receive frequency limit of the rig.

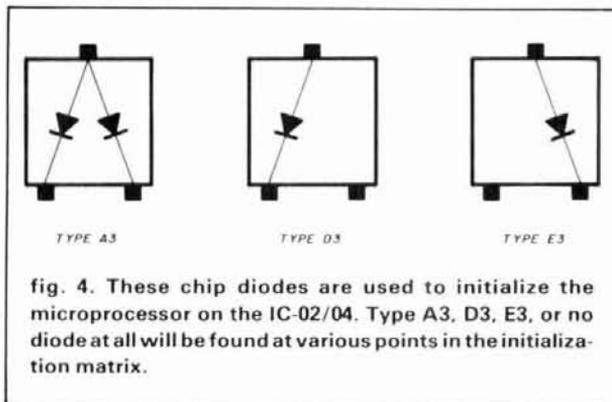


fig. 4. These chip diodes are used to initialize the microprocessor on the IC-02/04. Type A3, D3, E3, or no diode at all will be found at various points in the initialization matrix.

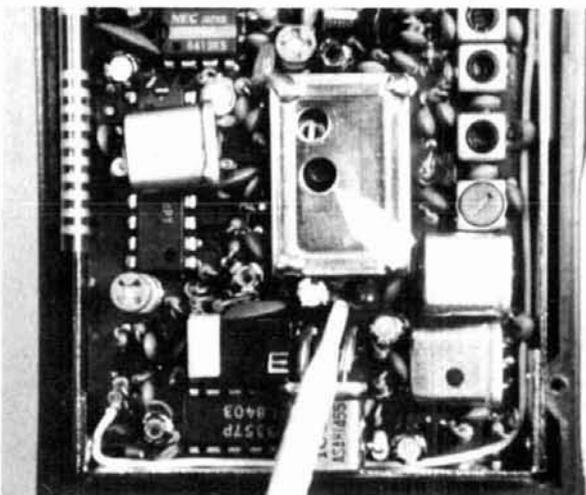
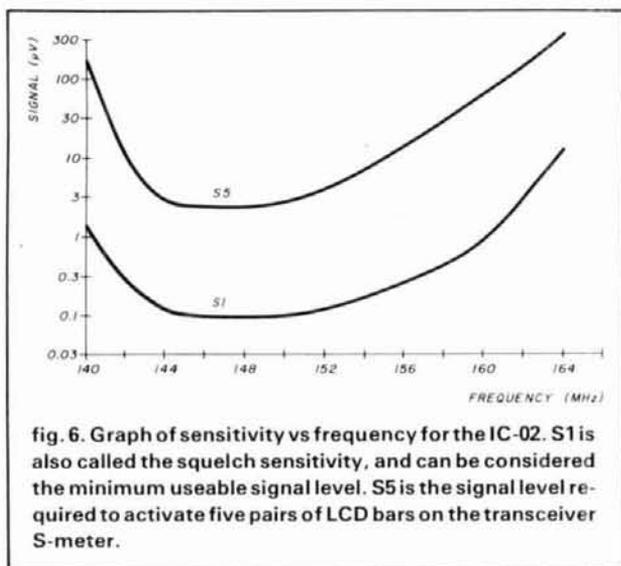


fig. 5. The IC-02 is shown completely reassembled except for the back panel. The test clip is connected to the VCO test point, which is the only vertically mounted resistor in the area with a bare upper lead. The arrow on the VCO shield points to the coil which should be adjusted for 0.75 VDC at the test point.



gram the initialization matrix; in this way component count and size are minimized (fig. 4). Do not confuse diode *types* with their *locations*, (D1, D2, D3, D4) printed directly on the microprocessor circuit board. These locations are labeled D401, D402, D403, and D404 on the ICOM schematic, but only for the diodes which are actually present.

IC-02 modification

The IC-02 is factory-wired with a type D3 diode at position D2 and a type E3 diode at position D3. The diode at position D2 restricts the receiver to the 140-151.995 MHz range. Remove this diode with care.

Now reassemble the IC-02, but leave the back cover off. Connect a high-impedance voltmeter to the VCO test point shown in fig. 5, attach the battery pack, and turn on the rig. Select 144.0 MHz from the keyboard.*

Adjust the coil in the VCO shield (lower hole) for a reading of 0.75 VDC. Be sure to use a properly fitting plastic alignment tool (or try whittling down a standard one with a razor blade). This alignment procedure maximizes the receive frequency range by setting the VCO near its lower voltage limit at the lowest transceiver frequency desired. The receiver will now operate from slightly below 140 MHz to slightly above 163 MHz, and the transmitter will generate a clean signal throughout the 2-meter band. Figure 6 shows receiver sensitivity for the entire VCO range. Now reinstall the back cover.

IC-04 modification

The IC-04 is factory-wired with a type E3 diode at position D1 and a type A3 diode at position D2. Carefully remove the diode at position D2 and replace it with a 1N914-type silicon diode connected from the top pad at D2 (anode) to the bottom right pad at D2 (cathode). This removes the receive limit portion of the matrix but still initializes the processor at 440 MHz.

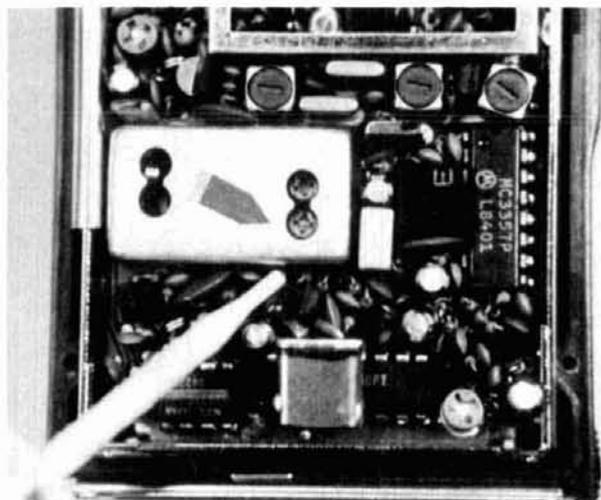
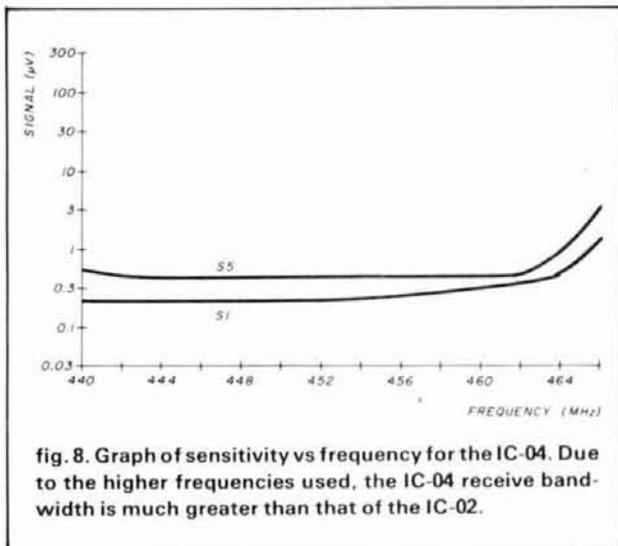


fig. 7. The IC-04 is shown completely reassembled except for the back panel and shield, and the metal tape has been removed from the VCO can. The test clip is connected to the VCO test point which, like the IC-02, is the only vertically mounted resistor in the area with a bare upper lead. The arrow on the VCO shield points to the variable capacitor which should be adjusted for 0.25 VDC at the test point.



Now reassemble the IC-04 except for the installation of the PLL shield and back cover. Carefully peel away the metal tape covering the VCO shield. Connect a high-impedance voltmeter to the VCO test point shown in fig. 7. Attach battery pack, turn on the rig, and select 440.0 MHz from the keyboard.**

Adjust the capacitor through the lower right hole in the VCO shield for a reading of 0.25 VDC. This sets the VCO at its lower limit to maximize receiver cover-

*This modification is for units with serial numbers below 34,000. Units with serial numbers above 34,000 have a new CPU with different programming; diode matrix is also different. — Ed.

**If the display should power-up in the wrong 10-MHz band segment, follow the procedure under "operation" to put the rig in the proper 10 MHz segment, or press reset button on main chassis.

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age above the 70-cm band. Note that this voltage is lower than the voltage for the IC-02; this is because of a smaller negative VCO shift in the IC-04 when transmitting. The IC-04 receiver will now operate from slightly below 440 MHz to slightly above 466 MHz, and the transmitter will operate cleanly throughout the upper half of the 70-cm band. (Figure 8 shows receiver sensitivity for the entire VCO range.) Now reinstall the VCO metal tape, PLL shield, and back cover.

operation

With the modification completed, normal transmit/receive capability of the IC-02 and IC-04 is unaffected. Within a particular 10-MHz band segment, the frequency may be selected by direct keyboard entry or by using the step-up or step-down keys. To change to a different 10-MHz segment, use the step-up or step-down keys after entering the highest or lowest frequency within the present band segment. Any frequency entered will store properly in memory. If you select a receive frequency outside the VCO limits the PLL will unlock; no indication of this condition will be given on the display. However, if you push the transmit switch with an unlocked PLL, the display will blink.

conclusion

This simple modification increases the versatility of the IC-02/04 without affecting normal operation.

Incidentally, the display and microprocessor will support initialization to the 23-cm (1260-1300 MHz) band. Is this an indication of things to come?

I'll be happy to answer any questions; please enclose an SASE for a prompt reply.

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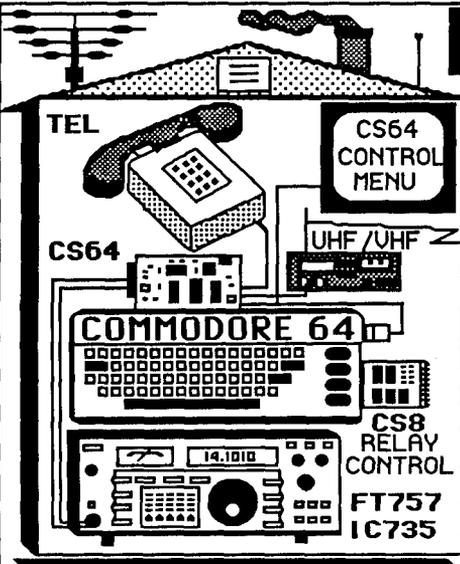
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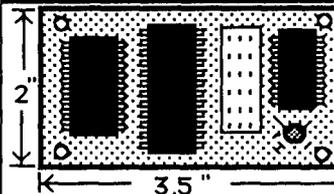
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VHF/UHF WORLD

Joe Reiser
W1JR

microwave and millimeter-wave propagation: part 1

Summer is traditionally the time when Amateurs take to the higher bands (and to the hills) for mountain-topping; the weather is agreeable, and the pioneering spirit is spurred on by several major VHF/UHF contests.

Regardless of season, the frequencies above 900 MHz are still the region of exploration and discovery. This is true because, in comparison with the HF/VHF frequencies, so little Amateur work has been conducted there. Until recently, equipment was scarce and anyone interested in exploring microwave frequencies had to "roll their own" equipment.

But this is changing rapidly. Commercial gear is now available through 13 cm (2320 MHz), as are Amateur Gunnplexers for the 3-cm (10-GHz) and 12.5-mm (24-GHz) bands.¹ One equipment manufacturer is rumored to have 3-cm weak signal gear almost ready for market!

Although much has been written on VHF and UHF propagation, information on microwave and millimeter propagation is scattered hither and yon.^{2,3} With all the interest in the microwave bands, the addition of our newest band at 33 cm (902-928 MHz)⁴ and the increased availability of microwave gear, this seems like a good time to start pushing these bands and promoting propagation research.

our microwave bands

Before we can talk about our micro-

wave and millimeter bands we have to know what frequencies are available. I guess it's fair to say that — in Amateur terminology — the frequencies between 900 and 10,500 MHz are probably best referred to as the microwave bands while the Amateur frequencies above 10.5 GHz are really in the millimeter territory.

The major worldwide Amateur frequency allocations on and above 33 cm were listed in last January's column.⁵ Since that time, the FCC has implemented the WARC '79 frequencies and changed the United States frequency allocations significantly. Therefore, I've updated last winter's list, (table 1), to show the latest USA frequency allocations. (I don't have any post-WARC '79 worldwide frequency allocation lists to compare it to at this time; I'd appreciate it if readers would share some with me.)

challenges

Once microwave and millimeter gear is constructed or purchased, there's always the question of what to do with it. Obviously it can be used in a variety of ways such as communications links, ATV, repeaters, or beacons. However, the real challenge is to see what performance can be attained primarily by DXing. This will truly exercise power, receiver sensitivity, and antenna gain to their fullest.

To show the whole perspective of the possibilities of DX on the microwave and millimeter bands, I've updated the records first shown here in last July's column.³ Tables 2 and 3 show the worldwide claimed DX records for terrestrial and EME operation. Note

that the 13-cm band is still the upper frequency for a completed EME QSO.

In keeping with the spirit of regional DX, the North American DX records have also been updated in table 4. You'll note that since these records were first published, several have been broken.

Because the 33-cm band didn't even exist last summer, the DX record on that band can't begin to compare with the adjacent bands. I expect this, too, will rapidly change. Nevertheless, it offers a big challenge to see what kind of propagation is in store.

Amateur 33-cm gear is already commercially available, though it's primarily limited to the FM citizens-band type. Information on homebrew gear was recently published in this column⁴; commercial weak-signal gear is, as I indicated above, reportedly just around the corner. Because of the 33-cm band's proximity to the land mobile communications band, suitable components — especially high-power transmitting tubes — should become available; far more equipment, certainly, than can be expected to be available for the 23-cm band.

microwave and millimeter tradeoffs

These bands offer many advantages over the VHF/UHF bands. First, there's over 13,000 Megahertz — not counting the unlimited territory above 300 GHz. This is more than 275 times the bandwidth of all of the dozen lower-frequency bands combined! How long do you think it will be before microwave and millimeter wave QRM will be a problem?

These bands have very little noise

and static. Except for a small potential for VCRI around 915 MHz, TVI and RFI are virtually nonexistent. Very compact antennas are the norm, with a 1-meter diameter dish considered a moderate to large antenna, especially on 3 cm and above.

Loop Yagis are often used on the lower microwave bands. Parabolic dishes are the most common antenna type as the frequency increases because they're usually inexpensive, easy to feed, low in noise pickup, and have high gain.^{6,7} As a result, QRP operation (often much less than 1 watt) can be very productive.

There are a few disadvantages, however, to operating on the microwave and millimeter wave bands. The higher antenna gain makes precise aim a serious concern. For example, a 1-meter parabolic dish antenna at 12 mm (24 GHz) has a 45-dBi gain and a beamwidth of only 1 degree!

Other problems are associated with operating above the UHF bands. Solid-state RF power generation is in the early developmental stages. Feedline losses are considerable, propagation modes are somewhat limited, and foliage attenuation and water vapor can also present difficulties.

There is hope, however. Solid-state RF power is rapidly increasing, with power GaAs FETs (up to several watts) now in commercial production. Short feedlines are the norm, with transmitters and receivers often mounted right at or only a short distance away from the antenna feed. And many of the apparent propagation problems can be solved, as we'll see shortly.

microwave propagation

The types of propagation modes available on the microwave and millimeter wave bands are more limited than on the VHF/UHF bands. Some of the lower-frequency propagation modes such as meteor scatter, sporadic E, F2, TE, and FAI, for example, are not usable.^{2,3} Other exciting scatter propagation modes are available, however, that may be either poor or simply not feasible on the VHF/UHF bands.

The most common microwave propagation modes are line-of-sight (LOS), tropospheric bending, tropospheric ducting, and EME. Less used but readily accessible are various scatter modes using the troposphere, weather-related phenomena such as lightning and rain scatter, aurora, and both man-made and natural objects.

Because describing the various microwave and millimeter wave propagation modes and how they can best be exploited would take considerable space, only LOS microwave and millimeter-wave propagation will be discussed this month. The other modes will be discussed in detail in next month's column.

line-of-sight propagation

The most common mode of propagation on the microwave and millimeter wave frequencies is probably LOS, for apparently obvious reasons. If two stations' antennas can see each other without intermediate obstructions, it is assumed that communication is possible.

This does, however, assume several things. First, there must be sufficient transmitter power and receiver sensitivity for communication to take place.

Table 1: This table lists the latest USA frequency allocations for Amateur microwave and millimeter wave bands. Many of the listings were recently changed, as indicated in the notes.

Band	Frequencies	Notes
33 cm	902-928 MHz	Restrictions in CO, WY, White Sands, NM & Region III areas. Available as of Sept. 28, 1985.
23 cm	1240-1300 MHz	1215-1240 MHz removed on March 1, 1986.
13 cm	2300-2310, 2390-2450 MHz	2310-2390 MHz removed on November 6, 1984.
9 cm	3300-3500 MHz	
6 cm	5650-5925 MHz	
3 cm	10-10.5 GHz	
12 mm	24-24.25 GHz	
6 mm	47-47.2 GHz	48-50 GHz removed on March 1, 1986.
4 mm	76-81 GHz	71-75.5 GHz removed on March 1, 1986.
3 mm	119.98-120.02 GHz	New assignment on March 1, 1986.
2 mm	142-149 GHz	165-170 GHz removed on March 1, 1986.
1 mm	300 GHz & up	240-250 GHz removed on March 1, 1986.

Table 2: This table shows the latest claimed worldwide microwave and millimeter wave terrestrial DX records.

Frequency	Record Holder	Date of QSO	Prop. Mode	DX Miles(km)
903 MHz	AF1T-WB1FKF	1-13-86	Tropo	53(85)
1296 MHz	KH6HME-N6CA	6-24-86	Tropo duct	2472(3977)
2.3 GHz	VK5QR-VK6WG/P	2-17-78	Tropo duct	1170(1883)
3.4 GHz	VK5QR-VK6WG	1-25-86	ducting	1171(1884)
5.7 GHz	G3ZEZ-SM6HYG	7-12-83	ducting	610(981)
10 GHz	I0SNY/EA9-I0YLI/IE9	7-08-83	ducting	1032(1660)
24 GHz	I3SOY/3, IW3EHQ/3-14BER/6, I4CHY/6	4-25-83	LOS	180(289)
47 GHz	HB9AMH/P-HB9MIN/P	6-11-84	LOS	33(53)
474 THz	K6MEP-WA6EJO	6-09-79	LOS	15(24)

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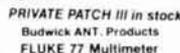


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Second, the gain of the antenna at both ends of the path must be sufficient. And third, the weather must be cooperative. (More on this next month.)

But what is sufficient power, sensitivity, and antenna gain? These parameters are all interrelated. If sufficient RF power — say 100 to 1500 watts — is available, the effective radiated power, even from a low-gain antenna (less than 10 dBi) will be high.

Conversely, if transmitter power is low, even in the milliwatt range, communication is also possible, providing that the gain of the antennas at both ends of the path is sufficient and that the receiver has sufficient sensitivity. These tradeoffs will be addressed in a future column. This month's column will be limited to a discussion of "path loss," the apparent number of dBs of attenuation that a transmitted signal will incur between two isotropic antennas. This is the standard method used in the communications industry to determine whether there will be a high probability that communications is possible between two stations.

path loss

What is path loss and how is it determined? We all know that as you go higher in frequency, losses become more critical. We also hear that the path losses increase. Yet at the same time, we hear about tremendous DX accomplishments on the microwave frequencies, using low power and relatively small antennas. How can this be?

The main reason for this is the "wavelength factor." As you go higher in frequency, the size of a half-wavelength dipole antenna becomes smaller. Therefore its "capture area" becomes smaller⁸ and it consequently picks up less RF. For example, the "effective aperture" of a half-wavelength dipole is approximately 0.75 by 0.25 wavelengths.⁸ At 33 cm this represents a capture area of about 32 square inches (0.21 square meters). However, at 3 cm (10 GHz) the effective aperture is still 0.1875 square wavelengths,⁸ but because of the shorter wavelength, the

Table 3: This table shows the latest claimed worldwide microwave EME DX records.

Frequency	Record Holder	Date of QSO	Prop. Mode	DX Miles(km)
903 MHz	None reported.			
1296 MHz	PA0SSB-ZL3AAD	6-13-83	EME	11595 (18656)
2304 MHz	PA0SSB-W6YFK	4-05-81	EME	5491 (8836)
3300 MHz and above	none reported.			

Table 4: This table shows the latest claimed North American microwave and millimeter wave DX records listed by suspected propagation modes. Note that most of these records are far short of the worldwide claims and therefore offer a great challenge to North American Amateurs. (Note: the records are listed alphabetically by propagation mode. Where the path is mostly over water, ducting is suspected. No efforts are made to separate out ducting on overland paths, so it's grouped under tropo.)

Frequency	Record Holder	Date	Prop. Mode	DX Miles(km)
903 MHz	AF1T.WB1FKF	1-13-86	Tropo	53 (85)
1296 MHz	KH6HME-N6CA	6-24-84	Ducting	2472 (3977)
	K2UYH-VK5MC	12-06-81	EME	10,562 (16,995)
	W4WSR-WA5TKU	6-03-85	Tropo	1112 (1790)
2.3 GHz	PA0SSB-W6YFK	4-05-81	EME	5491 (8836)
	W4ODW-WB5LUA	2-20-86	Tropo	624 (1003)
3.4 GHz	K6HIJ/6-W6IFE/6	6-18-70	LOS	214 (344)
5.6 GHz	K5FUD-K5PJR	9-20-77	Tropo	267 (430)
10 GHz	WA4GHK/4-WD4NGG	8-07-84	Ducting	297 (478)
	W7JIP/7-W7LHL/7	7-31-60	LOS	265 (426)
24 GHz	KX0O/0, W0MXY/0-NK0P/0, WA0VSL/0	8-24-85	LOS	74 (119)
48 GHz	W2SZ/1-WA2AAU/1	9-08-84	LOS	0.3 (0.5)
50-300 GHz	None reported.			
474 THz	K6MEP-WA6EJO	6-09-79	LOS	15 (24)

capture area is reduced to 0.2612 square inches (0.00017 square meters), a reduction of over 120 times.

It's said that the answer to this dilemma is simple: just increase the capture area of the antenna commensurately and you'll gain back what you lost because of the wavelength factor. This is only partially true. Antenna gain is usually a two-way street, receiving and transmitting (if the same antenna is used for both). Hence, if the antenna size is increased to offset the capture area loss, you gain considerable advantage, depending on frequency.

Herein lies the secret of successful use of low power on the microwave and millimeter frequencies. If the antenna gains is increased sufficiently, the overall signal-to-noise ratio can actually increase for the same transmitter power and receiver sensitivity.

How is the path loss determined?

There are straightforward formulas for this. The most common one is:

$$\text{Path loss} = 37.6 + 20 \log F + 20 \log R \text{ (eq 1)}$$

where path loss is in dB referenced to an isotropic radiator (2.15 dB less gain than a dipole), F is frequency in MHz, and R is range in miles.

If you prefer to work in kilometers, the formula can be modified as follows:

$$\text{Path loss} = 33.6 + 20 \log F + 20 \log R \text{ (eq 2)}$$

where path loss is in dB referenced to an isotropic radiator, F is frequency in MHz, and R is range in kilometers.

For example, the path loss for 10 miles is approximately 116.7 dB at 903 MHz and 137.6 dB at 10 GHz. If the range is increased to 20 miles, the path loss is 122.7 and 143.6 dB, respectively. You'll note that every time the fre-

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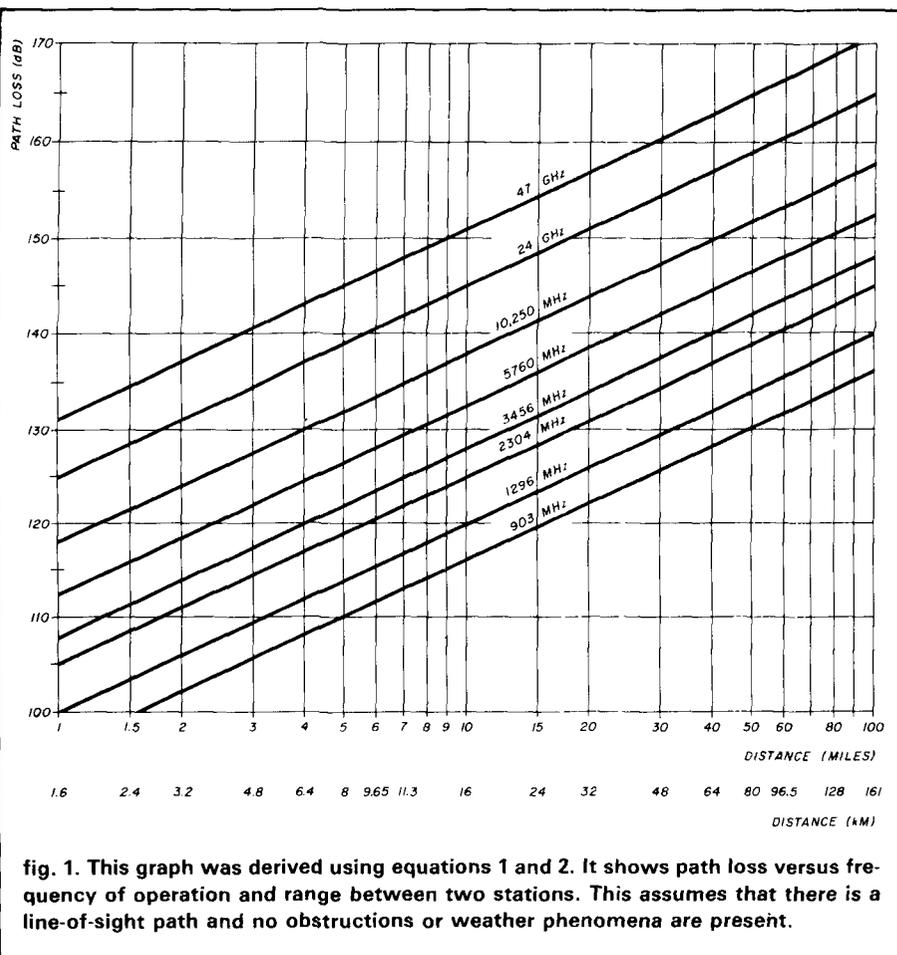


fig. 1. This graph was derived using equations 1 and 2. It shows path loss versus frequency of operation and range between two stations. This assumes that there is a line-of-sight path and no obstructions or weather phenomena are present.

quency or range is doubled, the path loss increases by 6 dB.

Calculations of path loss are often computer-aided.⁹ For those not so inclined, I've prepared fig. 1, which shows at a glance the path loss on each of the microwave and lower millimeter Amateur bands.

summary

This month's column served as an introduction to radio propagation on the microwave and millimeter wave Amateur bands. FCC frequency allocations and DX records were also shown. The latter will quickly reveal the challenges available to the adventuresome Amateur.

Time and space allowed us to investigate only line-of-sight propagation, presently the most common use of these bands. Next month's column will explore the other modes of propagation, with particular emphasis on those useful for DXing. A review of references 2 and 3 is strongly recommended.

references

1. Joe Reisert, W1JR, "VHF/UHF World: VHF/UHF Exciters," *ham radio*, April, 1984, page 84.
2. Joe Reisert, W1JR, "VHF/UHF World: The VHF/UHF Primer — An Introduction to Propagation," *ham radio*, July, 1984, page 14.
3. Joe Reisert, W1JR, "VHF/UHF World: Propagation Update," *ham radio*, July, 1985, page 86.
4. Joe Reisert, W1JR, "VHF/UHF World: 33 cm — Our Newest Band," *ham radio*, April, 1986, page 83.
5. Joe Reisert, W1JR, "VHF/UHF World: Amateur Microwave Bands," *ham radio*, January, 1986, page 44.
6. Joe Reisert, W1JR, "VHF/UHF World: Reflector Antennas — Part 1," *ham radio*, February, 1986, page 51.
7. Joe Reisert, W1JR, "VHF/UHF World: Reflector Antennas — Part 2," *ham radio*, March, 1986, page 68.

Important VHF/UHF Events

- July 2: ± 2 weeks. Look for European openings on 6 meters.
- July 18-20: CQ VHF WPX contest.
- July 19: EME perigee
- July 20: Look for 2-meter sporadic E ± 2 weeks of this date.
- July 25-27: Central States VHF Conference, St. Louis, MO (contact N0IS).
- July 29: Predicted peak of the Delta Aquarids meteor shower at 0930 UTC.
- August 2-3: ARRL UHF Contest.

August 12: Predicted peak of the Perseids meteor shower at 0700 UTC.

August 16: EME perigee

August 28-31: Microwave Update 1986 Conference, Estes Park, CO (contact W0PW).

ham radio

short circuits

meteor shower program

In a footnote to W1JR's June column, "VHF/UHF World: Meteor Scatter Communications" (page 68), the address of Gary Field, WA1GRC, was shown incorrectly. Gary's correct address is 5 Pluff Avenue, North Reading, Massachusetts 01864.

solving transmission line problems on the C-64

Gary Myers, K9CZB, author of "Solving Transmission Line Problems on the Commodore 64" (May, 1986, page 74), recently learned that some of the older C64s have an operating system that doesn't poke the graphic symbol in lines 180-240 properly. On these machines, the arrow symbol is generated in the same color as the background, thus rendering it invisible. This won't affect the program's operation, but there will be no visual confirmation that the desired key was pressed.

Gary reports that WB9PGO has devised a program modification that will make the symbol visible on these machines. Those who don't see the graphic arrow after selecting the transmission line type should change line 20 to read as follows:

20

POKE53281,14:PRINTCHR\$(147):

POKE53281,6

and change the last statement in line 670, which currently reads GOTO70, to GOTO20.

credit where it's due

Credit lines were inadvertently omitted from the art in Walter Kunde's June article, "Direct Currents Reduce Core Permeability" (page 58). All figures appeared courtesy of Magnetics, Inc., P.O. Box 391, Butler, Pennsylvania 16003.

a tone burst generator for European repeaters

Use 7168 kHz crystals,
divided down output
for 1750 Hz output

Before a recent trip to Europe, I received licenses to operate and decided to take my ICOM 2AT along with me. While searching through *Radio Communication* and other journals to find information on repeaters, I noticed that most European repeaters must be brought up with a 1750 Hz tone. Obviously my 2AT could not do this.

Looking through the ads, I noticed that ICOM makes a European version of the 2AT called the ICOM 2E. Besides offering coverage from 144 to 145 MHz only, this model appeared to employ either a switch-operated 1750 Hz tone or a 1750 burst at the beginning of each transmission. A phone call to ICOM confirmed this. I considered converting my 2AT to a 2E . . . but the touchtone pad on the 2AT is located where the burst components would have to be and uses several tracks on the circuit board for different functions. In addition, the tone switch on the 2AT is a push-button switch activated by pushing the volume control; one look into the possibility of removing that control eliminated that idea. I concluded that while conversion would be possible, it wouldn't be reasonable to make the conversion, use the unit abroad, and then reconvert it when I returned home.

My initial thought was to use a 555 timer. But I wasn't sure it would survive the trip and still make the 25 Hz frequency tolerance required. Without test equipment, I would be unable to make any repairs while in Europe.

The ICOM service manual for the 2AT showed that the tone burst circuitry consisted of a single integrated circuit, a crystal, and several discrete components. The integrated circuit, which functions as an oscillator/divider, was a TC5082 packaged in a 9-pin single-in-line package with an SK3733 indicated as its replacement. A quick phone call showed the device, also known as an ECG1197, was available locally for

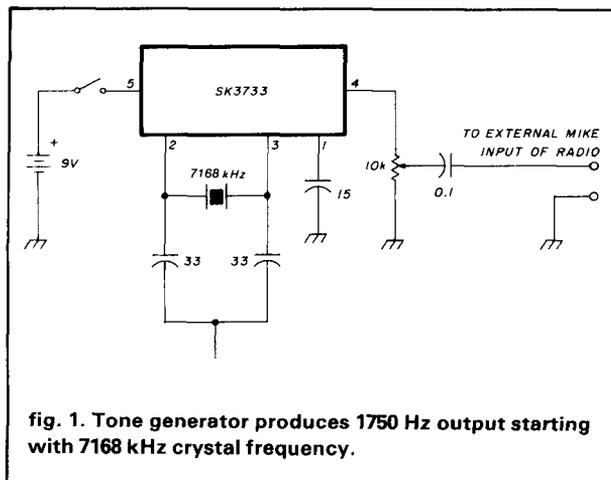


fig. 1. Tone generator produces 1750 Hz output starting with 7168 kHz crystal frequency.

under \$10.00. It contains a crystal oscillator and divide-by-256, 1024, 2048, and 4096 and is often used in CB radios as a reference oscillator for the PLL.

The final circuit, shown in fig. 1, is almost identical to the ICOM burst generator. A 7168-kHz crystal was used so the divide-by-4096 output would be 1750 Hz. The output was capacitively coupled to the external microphone jack of the 2AT. Since the 2AT requires DC continuity for transmit, the PTT bar on the side had to be pushed for transmit.

Construction was on a small piece of 3-pad-per-hole board. The chip is CMOS, so standard CMOS handling procedures — i.e., using a grounded soldering iron, inserting the chip last, etc. — were used. The case, recycled from an old GE pager, had enough room for the circuit and a 9-volt battery. The press-to-silence switch already on the case was used to activate the burst. A short audio cable coupled the two units.

Tuneup was easy. I just asked a friend to listen to my simplex signal and report on its loudness. I adjusted the pot until the level was approximately the same as my voice or the touchtone pad.

Coupling to another rig should be simple. Since most HTs have external microphone jacks, that should be the way to go. One could build an adapter to enable this unit and the external microphone to be used simultaneously.

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By Ladimer S. Nagurney, WA3EEC, 73 Blackberry Lane, Amherst, Massachusetts 01002

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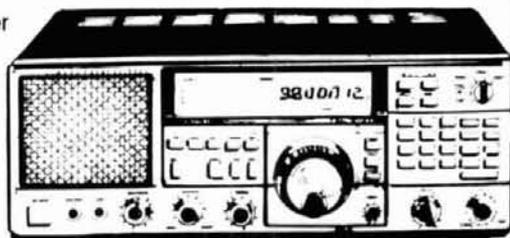
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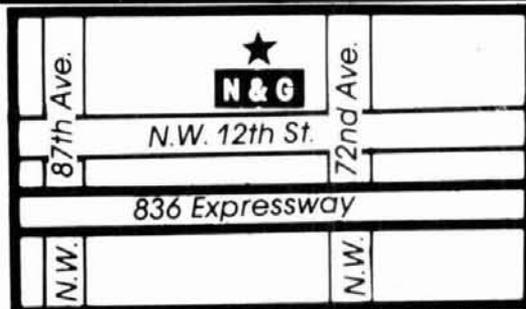
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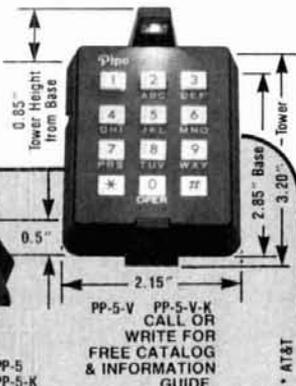
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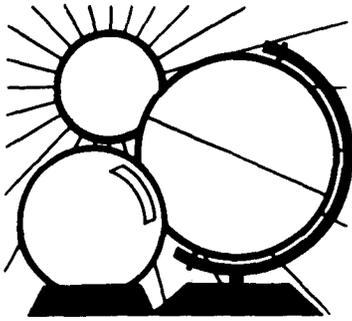
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a geomagnetic-ionospheric disturbance

Because the full effects of solar flares and storms will be upon us again in a year or so, a brief review of the solar flare-to-ionospheric storm sequence may be beneficial, particularly for those who've joined the DXing ranks since 1982.

Several years have passed since the sun has been active enough to cause concern over the weak signals resulting from geomagnetic-ionospheric disturbances in any great number or intensity. Although one or two disturbances a year have been of the geomagnetic-ionospheric variety, most of those we've experienced during the last four years have been mild solar wind enhancements. However, single events — such as that witnessed from the 5th through the 10th of February, 1986 — do occur unexpectedly.

When a sunspot region flares or brightens, ultraviolet and x-rays cause increased ionization in the D and E regions of the ionosphere. Signals are immediately weakened on the daylight side of the earth. This sudden ionospheric disturbance lasts about an hour. With the eruption of the flare, many solar particles (protons and electrons) ejected into the solar wind start toward the earth along a spiral path toward the polar regions. The higher-energy protons arrive within approxi-

mately one to five hours, causing polar cap absorption — even blackout — of signals crossing the top and bottom of the earth above 80 degrees latitude during each period of daylight for a couple of days. The more numerous, but slower, electrons arrive within 20 to 30 hours; their arrival often causes a shock wave which suddenly begins to move the geomagnetic field around, then lasts for two to three days. This phenomenon is called SC, or "sudden commencement." The presence of many particles results in further weakening and level fluctuation of signals as a result of movement in the auroral zone (70 to 80 degrees latitude).

The ionospheric F region is affected after the SC, first by an increase in maximum usable frequency (MUF) for a few hours over the transmission path that's in sunlight. Over the path that's in darkness, the MUF decreases from the auroral latitudes southward, depending upon the intensity of the storm. (See the MUF distribution tables in the January and February, 1986, columns.)

Figure 1 provides a graphic representation of the effects of the February 1986 ionospheric disturbance. The top curve (fig. 1A) is the percentage change in foF2; the middle curve (fig. 1B) is the solar flux value; the lower curve (fig. 1C) is the geomagnetic A index for each day during February. By looking at each day individually and then reading across the days, one can see the storm variation. To see how the storm actually developed from February 5th to the 10th, see table 1,

Table 1. Percentage of MUF change and geomagnetic K figure (in parentheses) associated with 2-hour period.

Date	1300 UT	1500	1700	1900	2100
5	5.9(1)	0.0(1)	6.3(2)	0.0(2)	0.0(2)
6	9.8(1)SC 1313	5.3(3)	7.9(3)	22.6(2)	5.1(3)
7 SC 0500	3.9(5)	-8.8(5)	7.9(6)	11.4(6)	-11.9(7)
8	-19.6(7)	-38.6(8)	-20.6(8)	-32.3(9)	-25.7(9)
9	-19.6(4)	-5.3(4)	-15.9(5)	-6.5(5)	3.4(3)
10	-11.8(1)	-8.8(1)	-14.3(1)	-8.1(3)	-5.1(3)
Median foF2	5.1	5.7	6.3	6.2	5.9

which shows the percentage of foF2-MUF change, and in parenthesis the geomagnetic K figure associated with that 2-hour period. The median foF2 for that hour of the month is indicated in the bottom line of the table.

The storm MUF decrease was probably not as extreme as the geomagnetic field A and K figures indicate because the solar flux was high and the initial SC 1313 UT was coincident with sunrise, the foF2 rise of the day. A second SC was on the 7th at about 0500 UT; the main decrease in foF2-MUF began about 1100 UT with the large K figures. The 8th, which was a Saturday, was particularly bad, as anyone trying to communicate over any significant distance will remember. Several days later MUFs returned to normal. Such is the morphology of a geomagnetic-ionospheric disturbance.

last-minute forecast

The higher frequency bands, 10 through 20 meters, are expected to improve during the first week of the month. They should be best during the

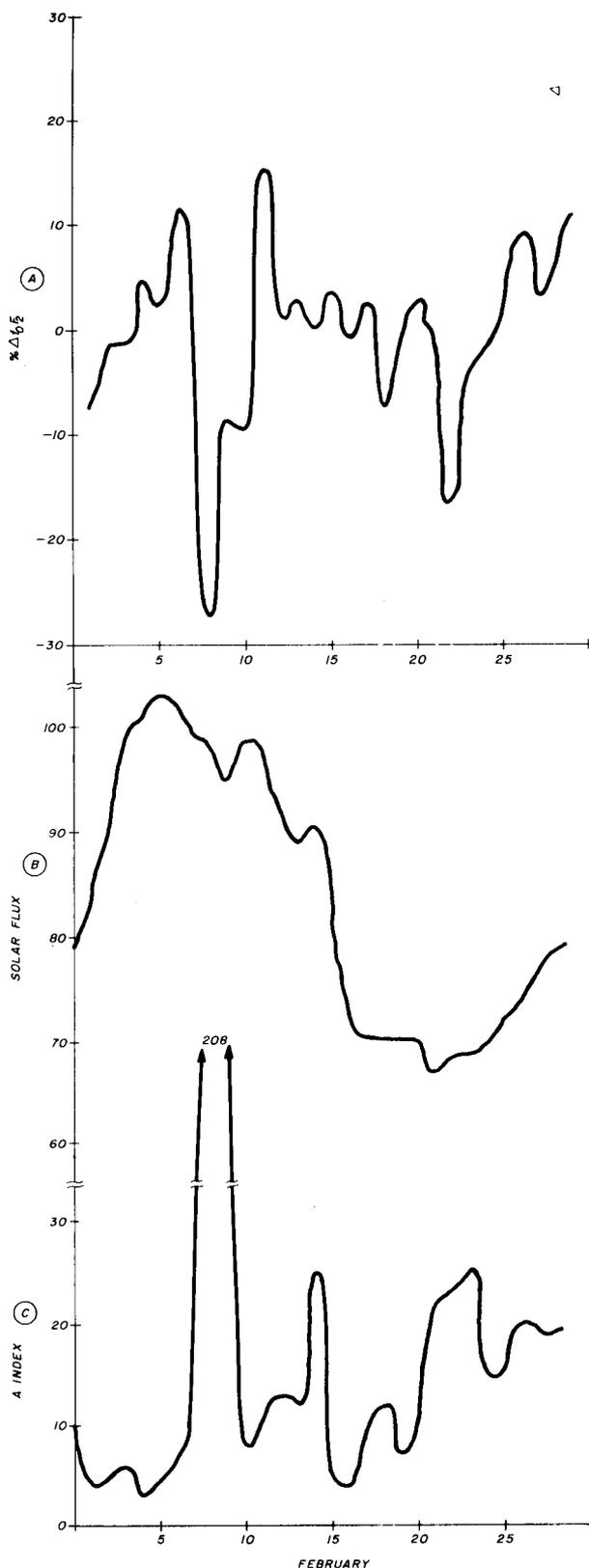


fig. 1. Pronounced effect of solar flare on: (A) MUF (percentage change in MUF); (B) solar flux; and (C) geomagnetic field "A" index.

second and third weeks, when the solar flux 27-day maximum is expected. Though still not very good, the lower bands will be best during the fourth and last weeks of the month. Disturbances are more probable on the 3rd to the 4th, the 17th to the 18th, and on the 23rd through the 25th during the solar flux transition and minimum time periods. Lunar perigee (closest approach of the moon) is on the 19th, with a full moon occurring on the 28th. The Aquarids meteor shower begins July 18, peaks on the 28th, and lasts until August 7. The radio-echo rate at maximum is expected to be about 34 per hour.

band-by-band summary

Six meters will have occasional openings to South Africa and South America around local noon via E_s short skip. These can occur at any time of the month and favor a five-to-six day cycle.

Ten and fifteen meters will have many short-skip openings near local noontime and long-skip, especially during any solar flux rise, to most southern areas of the world during daylight. No long-hop transequatorial openings are expected to occur at this time of the year.

Twenty, thirty, and forty meters will have DX conditions from most areas of the world during the daytime and into the evening almost every day, either long-skip to 2500 miles per hop or short-skip E_s to 1000-mile hops. The length of daylight is still near maximum, providing many hours of high maximum usable frequencies for good DXing.

Thirty, forty, eighty and one-sixty meters are all good for nighttime DX if you can beat the buildup of thunderstorm QRN in the evenings. Some enhanced signal strength levels via short-skip E_s may help overcome the noise. Some operators get up during the predawn hours, after the thunderstorms have dissipated, taking advantage of quieter conditions to the east. Time-and-frequency station MSF, in Rugby, England, can be used to monitor 2.5 and 5 MHz for band conditions.

WESTERN USA

GMT	PDT	Directional Indicators									
		N	NE	E	SE	S	SW	W	NW		
0000	5:00	20	30	20	12	20	10	10	15		
0100	6:00	20	30	20	12	20	10	10	15		
0200	7:00	15	30	20	15	20	10	10	15		
0300	8:00	15	30	30*	20	20	10	10	15		
0400	9:00	20	30	30	20	20	10	10	15		
0500	10:00	20	20	20	20	30	10	10	15		
0600	11:00	20	20	15	20	30	12	12	20		
0700	12:00	20	20	15	20	40	12	12	20		
0800	1:00	20	20	20	20	40	15	20	20		
0900	2:00	20	20	20	30*	40	15	20	20		
1000	3:00	30	20	20	30	40	20	20	20		
1100	4:00	30	20	20	20	40	20	20	30		
1200	5:00	20	20	15	20	40	20	20	30		
1300	6:00	20	20	12	20	40	20	20	30		
1400	7:00	20	20	12	15	40	20	30	20		
1500	8:00	20	15	10	15	40	20	30	20		
1600	9:00	20	15	10	12	40	20	30	20		
1700	10:00	20	15	10	12	40	20	30	20		
1800	11:00	20	15	12	10	20	15	30	20		
1900	12:00	30	20*	12	10	20	12	20	20		
2000	1:00	30	20	15	10	20	12	12	20		
2100	2:00	20	20	20	10	20	10	10	20		
2200	3:00	20	20	20	10	20*	10	10	20		
2300	4:00	20	20	20	10	20*	10	10	20		

MID USA

GMT	MDT	Directional Indicators									
		N	NE	E	SE	S	SW	W	NW		
0000	6:00	20	30	20	12	20	10	10	15		
0100	7:00	20	30	20	12	20	10	10	15		
0200	8:00	15	30	20	15	20	10	10	15		
0300	9:00	15	30	30*	20	30	10	10	20		
0400	10:00	20	30	30	20	30	10	10	20		
0500	11:00	20	30	20	20	30	12	12	20		
0600	12:00	20	20	20	20	40	12	12	20		
0700	1:00	30	20	20	20	40	15	15	20		
0800	2:00	30	20	20	20	40	20	20	20		
0900	3:00	20	20	15	30*	40	20	20	30*		
1000	4:00	20	20	15	30	40	20	20	20		
1100	5:00	20	20	12	20	40	20	20	20		
1200	6:00	20	20	12	20	40	20	20	20		
1300	7:00	20	20	10	15	40	20	30	20		
1400	8:00	20	20	10	15	40	20	30	20		
1500	9:00	20	20	10	12	40	20	30	20		
1600	10:00	20	15	10	12	40	20	30	20		
1700	11:00	20	15	10	10	30	20	30	20		
1800	12:00	20	15	12	10	20	15	30	20		
1900	1:00	20	20	12	10	20	12	20	20		
2000	2:00	30	20	15	10	20	12	12	20		
2100	3:00	30	20	20	10	20	10	10	20		
2200	4:00	20	20	20	10	20	10	10	20		
2300	5:00	20	20	20	10	20	10	10	15		

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GMT	EDT	Directional Indicators									
		N	NE	E	SE	S	SW	W	NW		
0000	8:00	20	20	20	12	20	10	10	15		
0100	9:00	20	20	20	12	20	10	10	15		
0200	10:00	20	20	20	15	20	10	10	20		
0300	11:00	20	20	30*	20	30	10	10	20		
0400	12:00	20	20	30	20	30	12	12*	20		
0500	1:00	30	30	20	20	40	12	12	20		
0600	2:00	30	30	20	20	40	15	15	20		
0700	3:00	20	30	20	20	40	20*	15	20		
0800	4:00	20	20	20	20	40	20	20	30*		
0900	5:00	20	20	20	30*	40	20	20	20		
1000	6:00	20	20	15	20	40	20	20	20		
1100	7:00	20	20	15	20	40	20	20	20		
1200	8:00	20	20	12	15	40	20	30	20		
1300	9:00	15	20	12	15	40	20	30	20		
1400	10:00	20	20	10	12	40	20	30	20		
1500	11:00	20	20	10	12	40	20	30	20		
1600	12:00	20	20*	10	10	40	20	30	20		
1700	1:00	20	15	10	10	30	20	30	20		
1800	2:00	20	15	12	10	20	15	30	20		
1900	3:00	20	20	12	10	20	12	15	20		
2000	4:00	30	20	15	10	20	10	12	20		
2100	5:00	30	20	20	10	20	10	10	20		
2200	6:00	20	20	20	10	20	10	10	20		
2300	7:00	20	20	20	10	20	10	10	15		

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next higher band for possible openings.

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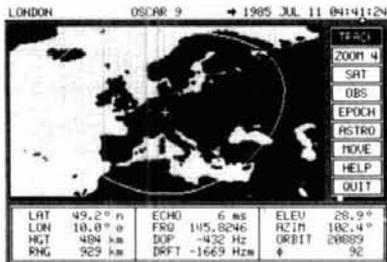
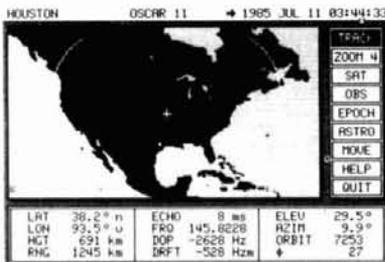
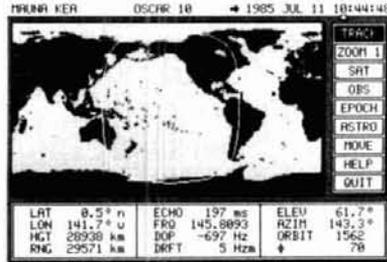
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	(MHz)	(W)	(W)	NF GAIN
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0508G	50-54	170	1	.6 15
0510	50-54	170	10	- -
0510G	50-54	170	10	.6 15
1410	144-148	160	10	- -
1410G	144-148	160	10	.6 15
1412	144-148	160	30	- -
1412G	144-148	160	30	.6 15
2210	220-225	130	10	- -
2210G	220-225	130	10	.7 12
2212	220-225	130	30	- -
2212G	220-225	130	30	.7 12
4410	420-450	100	10	- -
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See Data Sheet for surge limitations.

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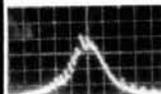
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personal pocket DMM

This compact, inexpensive, new instrument from North American Soar features simplicity of operation and rugged design. The fully autoranging Model 3010 doesn't require fuses because it's electronically protected from operator misuse. Even applying 250 volts AC to this meter in the ohms position won't hurt it.



Several features, such as permanently mounted test probes that can't be lost or connected incorrectly, have been added to ensure good performance in the field. The lightweight design, durable ABS plastic housing, and the carrying case all afford "drop-proof" protection at modest cost: only \$29.95.

For further information, contact North American Soar Corporation, 1126 Cornell Avenue, Cherry Hill, New Jersey 08002.

Circle #302 on Reader Service Card.

new IC-28A and IC-28H 2-meter mobiles

ICOM has announced the availability of the new IC-28A 25-watt and IC-28H 45-watt packet-compatible 2-meter rigs with all the features necessary for mobile operation. These features include compact size (the IC-28A measures 5-1/4 x 5-1/2 x 2 inches, the IC-28H 7-1/4 x 5 1/2 x 2 inches) and a large LCD readout with an automatic dimmer circuit to reduce brightness.

The units operate from 138-174 MHz, with specifications guaranteed from 144.00-148 MHz, making them ideal for MARS and CAP operation. Twenty-one memory channels are included. It's possible to scan the entire band or the

memory channels from the provided HM-12 mic. Easy to operate, each unit features only 11 front panel controls.

Options include the IC-HM14 DTMF mic, PS-45 13.8V, 8A-power supply, UT-29 tone squelch unit, SP-10 external speaker, HM-16 speaker mic and HS-15/HS-15SB flexible boom mic, and PTT switchbox.

For information, contact ICOM America, Inc., 2380 116th Avenue N.E., Bellevue, Washington 98009-9029.

Circle #303 on Reader Service Card.

antenna switch

MFJ Enterprises, Inc., is now producing the MFJ-1701, a six-position antenna switch that allows switching antennas with the turn of a knob. It organizes tangles of coax cables and eliminates the need to keep plugging in and unplugging cables.

The MFJ-1701 retails at an affordable \$29.95 (plus \$5.00 shipping and handling). The equipment is mounted in a rugged, yet handsome, black aluminum cabinet that matches most rigs.

This six-position antenna switch has SO-239 connectors, negligible insertion loss, low VSWR, and low crosstalk between adjacent outlets. All unused terminals are automatically grounded for static/lightning/RF protection. The MFJ-1701 can be used for 52- to 75-ohm systems and can be mounted with equal ease on a desk or on a wall. In addition, the MFJ-1701 handles 2000 watts SSB or 1000 watts CW.

This product is backed by MFJ's one-year unconditional warranty. If ordered directly from MFJ, it has an additional 30-day guarantee — return it within 30 days for a full refund (minus shipping and handling) if not completely satisfied.

For details, contact MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, Mississippi 39762.

Circle #304 on Reader Service Card.

new amateur equipment from Heath

Four new Amateur Radio kit products have been introduced by Heath Company, the world's largest manufacturers of high-technology electronic kit products. The new products are the HD-1420 VLF Converter, HD-1422 Antenna Noise Bridge, HD-1424 Active SWL Antenna, and the HD-1530 Touch-Tone Decoder.

The HD-1420 Very Low Frequency (VLF) Converter allows a standard shortwave receiver to tune the 10 to 500 kHz band using the receiver's 3.5 to 4.0 MHz band.

The HD-1422 Antenna Noise Bridge is a useful antenna tuning aid which reveals the cause of any mismatch between a station's transmitter and its antenna.

The HD-1424 Active SWL Antenna allows a shortwave radio to receive signals between 300 kHz to 30 MHz.

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2MVC5	2MT vertical	52.95
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TBR160S	160m add on	45.00
MPS	mfg. post sleeve	5.50
CUSHCRAFT		
A4	4 el. triband	300.00
A3	3 el. triband	224.00
R3	10, 15, 20 remote tuned vert.	275.95
AV5	5 band trap vert.	105.00
32-19	19 el. 2mt. boomer	96.95
215WB	15 el. wide band 2mt. boomer	79.95
424B	24 el. 70cm boomer	82.95
416TB	16 el. OSCAR 435 MHz	60.00
A144-10T	10 el. OSCAR 145.9 MHz	53.00
AOP-1	OSCAR pack 2mt. & 70cm	150.00
AR-2	2mt. vert. ringo	24.50
ARX-2	2mt. vert. ringo ranger	30.00
ARX-2B	2mt. vert. ringo ranger II	37.00
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6BT	6 band trap vert.	128.95
5BT	5 band trap vert.	108.95
4BT	4 band trap vert.	84.95
G7-144	Fix stat. 2mt.	116.95
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M200	10" mast	22.25
SB25G	short base	26.25
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KR-500	elevation 12 sq. ft.	161.95

ALLIANCE ROTOR		
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ETS-210	79"	\$107.00
AAZ-7A	Thrust Bear	\$ 36.00
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See Alinco Ads for Details

TET		
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MV3AH	7.21/28 vert.	48.95
MV3AHR	7/21/28 vert.	80.45 with radio
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MLA-4	loop 3.5/7/21/28	139.95
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Radios

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The HD-1530 Programmable Touch-Tone Decoder is used in series with the speaker of a receiver or scanner.

These Amateur Radio products are just a few of many products offered by the Heath Company. To receive a free copy of the current catalog, contact Heath Company, Department 150-592, Benton Harbor, Michigan 49022. (In Canada, write Heath Company, 1020 Islington Avenue, Department 3100, Toronto, Ontario, M83Z).

Circle #305 on Reader Service Card.

miniature VHF GaAs FET preamps

Low in cost and small in size, these new amplifiers from Hamtronics are easily used in a variety of applications. Amplifiers in the LNW series, available in eight different models tuning from 25 to 500 MHz, are designed around dual-gate FETs that provide stable operation over a wide range of load impedances. At frequencies below 120 MHz, gain runs from 22 to 28 dB with a typical noise figure of 0.8 dB.

The price is \$19 (in kit form) and \$34 (assembled and tested). Further details on these preamps and many other Hamtronics products are available in a 40-page catalog available for \$1. Contact Hamtronics, Inc., 65-F Moul Road, Hilton, New York 14468-9535.

new software for RC-850 repeater controller

Advanced Computer Controls, Inc. has announced Version 3.4 software that adds many new features to repeater systems.

The controller's autopatch is enhanced to support multiple telephone lines, including up to three remote phone lines linked by radio. Remote phone lines allow autopatch and autodial services on repeaters at inaccessible sites and allow the repeater's patch coverage to match its RF coverage, with calls automatically directed to the proper line.

Additional access and control modes allow custom tailoring of PL and touchtone access to the repeater. Eight hundred individual user-access codes may be enabled and disabled by the repeater owner, for secure controlled access to selected functions.

Four links or remote bases are supported, with touchtone command entry permitted from the remotes. Additional remote base frequency memories are included, with programmable memory name responses.

Numerous additional paging formats are supported for selective call to users with decoders or paging receivers. New formats include five-

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 Convert your personal computer and transceiver into a full featured RTTY station w/ the CP-1 Computer Patch interface and software by AEA.

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- Complete with cables for the AEA CP-1.
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KANTRONICS UTU
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 Bird 43—elements—loads

tone sequential, DTMF, CTCSS, and HSC for numeric display paging. Pager information is stored in memories for easy two-digit reference to any pager.

Available to all current owners, the software is supplied in 48K of EPROM, plus an 8K RAM upgrade. The non-volatile EPROM memory is optionally upgradable to 8K. The upgrades are included as standard in newly shipped equipment.



For additional information, contact Advanced Computer Controls, Inc., 10816 Northridge Square, Cupertino, California 95014.

Circle #306 on Reader Service Card.

Kantronics Packet Communicator II™

The complete Kantronics Packet Communicator II (KPC-2) is an AX.25 Version 2.0 TNC that features a completely new design, the latest in technology updates, and over 100 software commands. A serial RS232 or TTL port allows connection to any computer. KPC-2 is also compatible with existing TNCs. The unit is ready to use and easy to operate.

Priced at \$219, the KPC-2 is compatible with any computer having a serial, asynchronous I/O. It offers standard computer-to-communicator baud rates between 300 and 9600, and packet radio baud rates of 300, 400, 600, and 1200.

Software selectable VHF and HF modems are included. Six software selectable tone pairs including Bell 103, 202, CCITT V.21, and CCITT V.23, and full duplex capability are also featured. Full 16K is RAM standard, with memory expandable to 32K RAM.

Any terminal or communications software program can be used to establish communication between your computer and the KPC-2.™ Kantronics offers *Pacterm™*, a special packet terminal program for many popular computers.



Power supply, connectors, and cables are provided with the KPC-2, but the user must supply the transceiver mic jack and the computer RS232/TTL connector.

For information contact Kantronics, Inc., 1202 E. 23rd Street, Lawrence, Kansas 66046.

Circle #307 on Reader Service Card.

new Transi-trap™

Alpha Delta has just announced availability of a new improved version of its Transi-trap™ electrical surge protector.

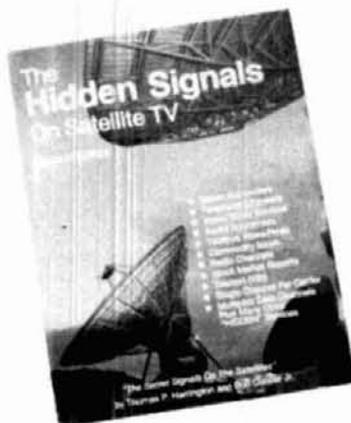
The Transi-trap "Arc-plug" has been redesigned to meet industrial and governmental protection standards for protection against Electromagnetic Pulse (EMP), in accordance with the National Communications System report, NCS TIB 85-10. The new "Arc-plug" has a DC clamping level of 350 volts to provide proper transmitter protection. The pulse clamping level (per NCS EMP test: 4,500 volts at 50 ohms) is 230 volts. The unit will respond in 80 to 100 nanoseconds and has a very low interelectrode capacitance of less than 1 pF.

For more information, contact Alpha Delta, P.O. Box 571, Centerville, Ohio 45459.

Circle #308 on Reader Service Card.

hidden signals

Universal Electronics has announced the release of the second edition of *The Hidden Signals on Satellite TV*, the first book to completely cover the field of non-video satellite services carried on domestic satellites.



These services include stereo subcarriers, telephone channels, world news and press services, Teletext, and other VBI Systems, Single Channel Per Carrier (SCPC) Systems, plus other data and business services.

Hidden Signals deals with all phases of this expanding side of the satellite business: the systems, how they work, who uses them, how they are received, and how the services can be utilized. Despite its sophisticated content, the illustrated 240-page book is easy to read and understand.

The book is available for \$19.95, plus \$2.00 shipping and handling from Universal Electronics, Inc., 4555 Groves Road, Suite 13A, Columbus, Ohio 43232. (Also available from Ham Radio's Bookstore, Greenville, New Hampshire 03048 for \$19.95 plus \$3.50 shipping and handling.)

Circle #309 on Reader Service Card.

ICOM REPEATER PROGRAM UPGRADE

The RPS-1 is an entirely new repeater program written for the ICOM REPEATER controller board that will add NEW FEATURES and CUSTOM PROGRAMMING to your ICOM RP-1210, RP-2010, and RP-3010. The RPS-1 will take your generic sounding repeater and give it a whole new personality.

New CW ID operation provides two separate cw id messages, and can include city/state, or club name. Plus the cw messages are sent at the speed you request. The new Courtesy Beep tone prompt allows a short courtesy wait period before beeping and resetting the timeout timer — while the repeater transmitter stays on. New timeout operation clears timeout immediately with no down delay, and provides cw warning messages to reduce confusion. Custom programming of all cw and timing parameters.

The ICOM REPEATER is a well built, reliable repeater, and adding the PROCESSOR CONCEPTS RPS-1 will add new features and personalized programming to make a good repeater even better.

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127

ATV

This converter covers all the 420 - 445 MHz ATV frequencies. This converter uses a crystal reference to lock onto the 439.25 MHz standard — or — a second channel at 421.25 or 426.25 or 436.25 MHz. This converter also supports a manual tuning mode for non-standard frequencies. The IF output can be ordered for channel 2 or 3.

This ATV module is small and only requires +12VDC. A small 12V transformer is supplied with this assembled and tested converter. This converter uses a GAS FET RF amp with a highly selective band-pass filter that will cut-out strong UHF, TV and other strong out-of-band RF!

Typical rejection @ 500 MHz = -50 db, @220 MHz = -65 db, and @144 MHz = -70 db or greater.

Voltage regulation is very stable under varying DC input. Conversion gain is approximately 20 db with input and output surge protection. Input is via type "N" connector. Output is via a type "F" connector. Size is 5.125" x 5.5" x 1.5"

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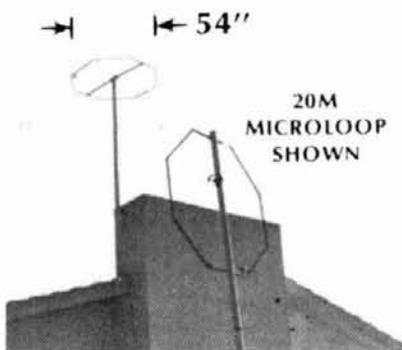
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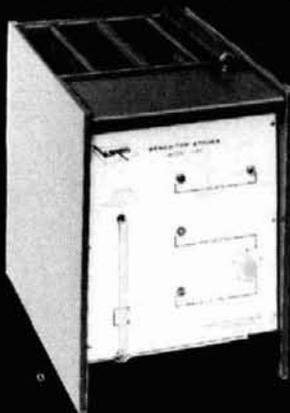
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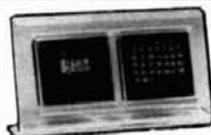


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Get Connected to Packet Radio is available from Ham Radio's Bookstore, Greenville, N. H. 03048, for \$12.95 plus \$3.50 shipping and handling.

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Microwave Filter Company, Inc. has sold its Unadilla/Reyco Amateur Radio Products Division to Ralph H. Jannini of Antennas, Etc., of Andover, Massachusetts. The division produced baluns, traps, switches, and antenna kits that were distributed through approximately 200 dealers nationwide and to exporters in Canada, South America, and Europe. Jannini will add Unadilla/Reyco to his present operations and will continue to serve MFC's Amateur Radio customers.

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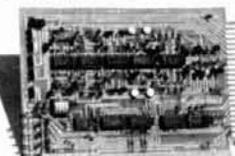
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CHASSIS and cabinet kits. SASE K3JWK, 5120 Harmony Grove Road, Dover, PA 17315.

COMING EVENTS

Activities — "Places to go . . ."

PENNSYLVANIA: The Nittany Amateur Radio Club's annual Mt. Nittany Ham Festival, July 12, Firemen's Carnival Grounds, Pleasant Gap. 8 AM to 4 PM. Admission \$3.00 per ham. Spouses and children free. Flea market space \$5 includes admission. Program and good food available. Talk in on 146.16/.76 (north and west) 146.25/.85 (south and east) and 146.52. For information: Chuck McMullen, K3CM, 7 Holly Circle, State College, PA 16801.

MARYLAND: BRATS Hamfest and Computerfest, sponsored by the Baltimore Radio Amateur Television Society, Sunday, July 27, Howard County Fairgrounds, Rt. 144 at Rt. 32, West Friendship. Indoor tables with AC power \$20 each; 4/\$75. Without AC power \$10 each; 10/\$95 by advanced registration only. Dealer setup Saturday 2 PM. Sunday tailgating space \$4 per space. Free VE exams 11 AM Sunday, no advanced registration required. Talk in on 63/03, 16/76 and 52. For information and reservations: W3GKK, BRATS, PO Box 5915, Baltimore, MD 21208.

MICHIGAN: The 38th annual upper Peninsula Hamfest, sponsored by the Delta County Amateur Radio Association, Saturday, August 2, Bay De Noc Community College, Escanaba. Registration \$2. Activities, meetings, swap and banquet. For information: Aileen Gagnon, WA8DHB, Co-Chairman, 9159 Bay Shore Drive, Gladstone, MI 49837.

WEST VIRGINIA: The 27th annual West Virginia State ARRL Convention, Friday evening July 4 through Sunday, July 6, Jackson's Mill State 4-H Camp near Weston, Lewis County. Reception Friday evening. Exhibits, test forums, equipment auction and pizza party. Free flea market space for registrants. Plenty of family fun. For information: Sue Goodwin, 103 Cleveland Avenue, Nitro, WV 25143.

KENTUCKY: The Central Kentucky ARRL Hamfest, sponsored by the Bluegrass Amateur Radio Society, Sunday, August 10, 8 AM to 4 PM, Scott County High School, Longlick Road and US Rt. 25, Georgetown. Tickets \$4.00 advance; \$5.00 at the gate. Tech forums, license exams, awards and exhibits. Air-conditioned facilities. Free outdoor flea market space. For information or tickets: SASE to Scott Hackney, KI4LE, 629 Craig Lane, Georgetown, KY 40324.

PENNSYLVANIA: The 49th annual Hamfest sponsored by the South Hills Brass Pounders and Modulators ARC, Sunday, August 3, south campus of Allegheny Community College, West Mifflin, 7 miles south of Pittsburgh. Talk in on 146.13/73 and 146.52. For information: Doug Wilson, WA3ZNP, 185 Orchard Avenue, Emsworth, PA 15202.

NEW YORK: Electronics Extravaganza sponsored by the Putnam Emergency Amateur Repeater League, Saturday, August 16, J.F. Kennedy Elementary School, Brewster. 9 AM to 4 PM. Admission \$3.00. Children under 12 free with adult. Food and refreshments available. Indoor tables, with one admission, \$10.00. Tailgating \$5.00. FCC exams. Limited walk-ins. Talk in on 144.535/145.135. For table reservations or information: R. Dillon, N2EFA, RFD 7, Noel Court, Brewster, NY 10509.

PENNSYLVANIA: The Mid-Atlantic Amateur Radio Club's annual Hamfest, Sunday, August 10, Bucks County Drive-in Theater, Rt. 611, Warrington. 8 AM to 3 PM. Rain or shine. Admission \$3.00 plus \$2.00 for each tailgate space. Bring your own tables. Talk in on WB3JOE/R, 147.66/.06 or 146.52. For information: MARCBox 352, Villanova, PA 19085 or call Bob Josuweit, WVA3PZO (215) 449-9727.

TEXAS: Texas State ARRL and Texas VHF/FM Society's joint convention, July 11-13, El Tropicano Hotel, 110 Lexington, San Antonio. Hospitality suites, licensed day-care, QCWVA breakfast, Saturday evening banquet, ARRL forum. For information: Melvin H. Anderson, Jr, 8532 Saddle Trail, San Antonio, TX 78255 (512) 698-1712 or 698-1714.

NEW JERSEY: SCARC '86, sponsored by the Sussex County ARC, July 19, Sussex County Fairgrounds, Plains Road, Augusta. Doors open 8 AM. Registration \$3.00. Indoor tables \$7.00 each. Tailgate space \$5.00. Food and refreshments. Free parking. Talk in on 147.50/30 and 146.52. For information: Donald R. Stickle, K2OX, Weldon Road, RD 4, Lake Hopatcong, NJ 07849. (201) 663-0677.

PENNSYLVANIA: The Murgas Amateur Radio Club's 7th annual Hamfest, July 6, Ice-A-Rama in the Coal Street Sports Complex, Wilkes-Barre. Setup 6 AM. General admission 8 AM. Tables available by advance reservation. VE exams. Talk in on 146.61, 53.61 and 146.52. For information or to register for VE exams call (717) 388-6863.

INDIANA: The WA9SNT Amateur Radio Club will hold its annual Swapfest, August 9, ITT Technical Institute, 9511 Angola Court, Indianapolis. 8 AM to 4 PM. General admission \$2.00. Students \$1.00. Flea market space \$1.00 additional. Setup time 6 AM. Auction, large flea market, refreshments available. ITT Technical Institute will hold an open house during the Swapfest. All interested are invited to tour the facilities. For additional information: Dave Johnston, K9HDO, c/o ITT Technical Institute, 9511 Angola Court, Indianapolis, IN 46368. (317) 875-8640.

WISCONSIN: The Eau Claire Amateur Radio Club's annual Hamfest, Saturday, July 12, 4-H Buildings in Eau Claire. 8 AM to 4 PM. Tickets \$3.00. Free tables and coffee. Talk in on 31/91 and 52 simplex. For information/tickets SASE to Gene Lieberg, KA9DWH, 2840 Saturn Avenue, Eau Claire, WI 54703.

WISCONSIN: The South Milwaukee Amateur Radio Club's annual Swapfest, Saturday, July 12, American Legion Post 434, 9327 South Shepard Avenue, Oak Creek, 7 AM to 4 PM. Parking, picnicking, food and refreshments available. Admission \$3.00 includes "happy time" with free beverages. The Milwaukee Volunteer Core Group will conduct Amateur Radio exams during the day. For more details, including a map, write: South Milwaukee ARC, PO Box 102, South Milwaukee, WI 53172-0102.

1986 "BLOSSOMLAND BLAST" Sunday, October 5, 1986. Write "BLAST", PO Box 175, St. Joseph, MI 49085.

CALIFORNIA: FCC exams, Novice-Extra. Sunnyvale VEC ARC. (408) 255-9000 24 hour. 73, Gordon, W6NLG, VEC

PENNSYLVANIA (Meadville) - July 5. Firecracker Hamfest by Crawford Amateur Radio Society. Electronics, radios, computers. New location at Meadville Recreation Center just off Rt. 27 E in Meadville. All indoors; no rain out. One olympic and two child-size deluxe swim pools with lockers and showers and other sports available in Center. Free indoor flea market space; bring table. Dealers: free indoor space and table(s) available by preregistration; reserve early. Admission adult \$2.00, children free, swimming for small extra. Talk in 144.53/145.13, W3MIC/R. For information write CARs Hamfest-86, PO Box 653, Meadville, PA 16335 or call Ben Ferer, KF3F, 814/724-2432.

BRITISH COLUMBIA: Maple Ridge Hamfest, July 12 and 13, St. Patricks Center, 22589 121 Avenue, Maple Ridge. Admission Hams \$6.00; non-hams over 12 \$3.00. Under 12 free. Two hams in family \$9.00. Commercial displays, flea market, food, children's programs. Nearby shopping and recreation areas. Camper space, no hookups. Talk in on 146.20/80 and 146.34/94. For more information: Bob Haughton, VE7BZH, Box 292 Maple Ridge, BC V2X 7G2 or phone (604) 467-4915.

WEST VIRGINIA: The 8th annual TSRAC Wheeling Hamfest/Computer Fair, Sunday, July 20, Wheeling Park. 9 AM to 4 PM. WV's largest. Dealers welcome. 30,000 sq. ft. under roof. 5 acres of flea market. Family activities at Park. Admission \$3.00 in advance, \$4.00 at door. To reserve space contact: Jay Paulovicks, KD8GL, RD 3 Box 238, Wheeling, WV 26003 (304) 232-6796. For tickets, TSRAC, Box 240, RD 1, Adena, OH 43901 (614) 546-3930.

INDIANA: The 16th annual Indiana ARRL Convention and Indianapolis Hamfest, Saturday and Sunday, July 12 and 13, Marion County Fairgrounds, Indianapolis. Featuring the largest electronic flea market and new Amateur Radio equipment display in the state. Gate fees \$5.00 with free parking on grounds. Gates open 6 AM. Large covered flea market. Inside tables \$8 each. 2m Fox Hunt, homebrew contest. QSL card contest. Free camper hookups available on grounds. Nearby restaurants and motels. For information contact Bill Evans, WB9BEN (317) 745-6389

MASSACHUSETTS: The MIT UHF Repeater Association and the MIT Radio Society offer monthly Ham Exams. All classes Novice to Extra. Wednesday, July 23, 7 PM, MIT Room 1-134, 77 Mass Avenue, Cambridge MA. Reservations requested 2 days in advance. Contact Ron Hoffmann (617) 253-0160/646-1641 or Craig Rodgers (617) 494-1986. Exam fee \$4.25. Bring copy of current license (if any), two forms of picture ID and completed form 610 available from FCC in Boston (223- 6609)

OPERATING EVENTS

"Things to do . . ."

OHIO STATE FAIR Special Event, August 1-17. Listen for W8TO 80-10 meters. Exchange QTH and RST. All correspondence and requests for awards to ARS W8TO, att: State Fair event coordinator, 280 East Broad St, Columbus, Ohio 43215.

The Eastern Michigan ARC will operate K8EPV during the annual Port Huron to Macinac Island Yacht Race, July 19-20. 1400Z to 0200Z both days. For certificate send QSL and SASE to CBA or 654Georgia, Marysville, MI 48040.

High Plains ARC will operate K7YPT at historic Fort Laramie, July 4 and 5. QSL for business SASE to K7YPT, PO Box T, Torrington, WY 82240.

The Texas ARRL and VHF/FM Society convention, Alamo City, W5SC continues the San Antonio Sesquicentennial celebration of Texas independence. July 12 to 13, 10, 15 and 20 meters. QSL. No. 10 envelope, SASE to W5SC, 90 Brees Blvd, San Antonio, TX 78209.

ALBANY, NY, is celebrating its 300th anniversary. The year long activities will peak during Tricentennial Week, July 18-22, 1986. The Albany Amateur Radio Association will be providing public service communication for events and special QSL cards as well as sponsoring the "Worked Albany Radio Members" - WARM Award.

OKLAHOMA Amateur Radio operators will conduct their 3rd annual "Field Day" exercises Saturday and Sunday, July 12 and 13, Lake Canton beginning 2 PM Saturday and continuing through noon Sunday in conjunction with the annual IARU Radiosport DX Contest. For information: Tim Mauldin, WA5LTM, Lake Canton Field Day, PO Box 19097, Oklahoma City, OK 73144. (405) 521-5048.

EAST AURORA, NY. July 27. 12th annual Racing Day. Pioneer Radio Operators Society will operate W2QFC to help the community celebrate its heritage as a turn-of-the-century capital of

breeding and racing champion horses. QSL with business SASE to W2QFC, 308 Parkdale Avenue, East Aurora, NY 14052.

The Illinois Valley ARC will operate special event station KD9UL to commemorate the 25th anniversary of manned spaceflight in conjunction with the Spaceweek event. 1300 UTC to 0100 UTC. For a certificate and QSL, send SASE and your QSL to Bruce Boston, KD9UL, 815 East Third Street, Beardstown, IL 62618.

ACB RADIO AMATEURS a special-interest affiliate of the American Council of the Blind (ACB) will operate special event station KW4U from 0000Z June 29 to 2400Z July 5 from the Hilton Hotel in Knoxville, TN in conjunction with ACB's silver anniversary convention. Submit QSL card confirming QSO with KW4U during convention week and receive an attractive commemorative certificate. Send QSL's to John McCann, KW4U, 2105 N. Illinois Street, Arlington, VA 22205.

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THE GUERRI REPORT by Ernie Guerri, W6MGI

new technique uses lasers to etch microchips

In the traditional process for manufacturing ICs, as many as 100 individual steps may be required. Each step introduces the possibility of error and increases the risk that the finished product will contain some flaw that renders the chips unusable. Depending on the size and complexity of the chip, less than half of the finished wafer may yield acceptable chips, leaving the surviving chips to recover the entire cost of fabrication.

Not surprisingly, IC manufacturers are constantly seeking ways to improve yield and reduce costs. In one new technique, a laser used as a photoetching device scans the surface of a silicon wafer in the presence of certain gases. Under static conditions, these gases have no effect on silicon; the energy of the laser, however, decomposes the gases into compounds that define active elements and interconnects by either etching away unwanted material or by deposition onto the substrate. The source and drain regions of a transistor are made by doping the silicon with phosphorus, which the laser creates by breaking molecules of phosphine gas. Hydrogen chloride, which serves as an etchant, is activated by the thermal energy of the laser beam. Interconnects on the chip are made by similarly decomposing gases that contain tungsten, nickel, and polysilicon.

One of the major incentives for this new method is a national program, led largely by the Departments of Defense and Energy, to develop new classes of supercomputers. Much of this work has been done at the Lawrence Livermore National Laboratory, where ex-

periments indicate that the technique can produce as many as 1000 transistors per second. At this rate, it would be possible to fabricate supercomputer chips — consisting of about 100,000 transistors each — at the rate of one per day.

Other exciting possibilities include repairing damaged high-value chips and turning a new design into a prototype chip in one day or less, as opposed to today's turnaround time of one to four weeks.

One company (XMR of Santa Clara, California) already offers commercial equipment for this technology. If the technique achieves its promise, we can expect a whole new generation of advanced-capability semiconductors.

"WaferScale" integration

Still on the subject of semiconductors, and one of the major beneficiaries of laser fabrication, is another technique just coming into its own — WaferScale integration. This technique uses the surface of a silicon wafer to implement an entire functional capability. Examples include complete 32-bit microprocessors, with memory and all relevant I/O functions, a "silicon" hard disk with 20Mb of storage, RAM speed, and all disk controller functions on a single wafer.

This technique promises to make very complex functions available in a single package. But this improvement is not without peril. Because of the large amount of circuitry and the extensive processing required on such devices, any mistake in fabrication results in a very expensive piece of scrap. Also, the large number of circuits and functions possible with WSI makes packaging considerations a major concern; it may be necessary to

have hundreds of pins on a very complex functional element — more than can now be accommodated. However, the general benefits of WSI seem to justify the complexities of making such devices, and within the next few months the first few WSI products are expected to be announced.

new super-magnet makes smaller motors

An essential component of many motors is the large, heavy permanent magnet associated with the non-excited element of the motor. Magnequench™, a new product developed by the Delco Division of General Motors, is about 25 percent stronger than any other known magnetic material.

Currently, the most widely used high-power magnets, composed of samarium-cobalt, are expensive and difficult to manufacture. But GM's new material is so low in cost that the auto maker plans to use the material in starter motors on some 1986 cars. GM reports that only 5 ounces of the material are needed for the newly designed motors.

This tremendous saving in weight and size offers several benefits. Using a smaller, lighter starter, for example, simplifies design of the engine area. Using Magnequench instead of conventional magnets in all the control motors of a car would presumably produce a measurable effect on fuel economy as well.

Because samarium-cobalt is the material sometimes used to make very small, high-performance loudspeakers, it should be interesting to see if the speakers manufacturers put in our HTs get any better as supermagnets become more widely available.

ham radio

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This new anthology has been taken from DeMaw's '84 and '85 series in QST magazine. It has been written to give beginners the basic electronic theory needed for upgrading and the ins and outs of how radios work. Using a building block approach, DeMaw first explains what the different components are, then assembles them into basic circuits and ends up with how these circuits work in your radio. You also get articles on antennas, propagation and beginners level RFI problems and suggestions on how to resolve them. Great review for more experienced Hams. Perfect for the beginner. © 1985.

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LANDMOBILE AND MARINE RADIO TECHNICAL HANDBOOK

by Edward Noll, W3FQJ

This is THE HANDBOOK for those who operate, install or service two-way radios. Covers private landmobile services, marine radiotelephone and radiotelegraph, marine navigation and Citizen's Band. An excellent reference book for those studying to pass the NABER technician certification exam. Areas covered include: transmission characteristics and modulation systems, basic solidstate theory, digital and microprocessor electronics, antenna systems, test equipment, repeaters and much more. © 1985 1st edition 576 pages.

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THE COMMODORE

HAM'S COMPANION by Jim Grubbs, K9EI

Here's your guide to using the Commodore C-64 computer in your Ham shack. Good solid information on where to find software and hardware for CW, RTTY, AMTOR, SSTV, propagation prognostication, antenna modeling, satellite tracking and much more. Includes a list of over 80 sources of software and hardware. Also includes a bibliography of over 60 magazine articles and reviews about using the Commodore. ©1985, 160 pages, 1st edition.

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Ham Radio's Bookstore
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**Real-voice message system
For any repeater or base**



Now you can communicate vital information even when the station you are calling is not on the air — with Message Master. Message Master is a solid state voice recording system which can record messages just by listening to you speak, store messages in memory, and deliver messages on demand. If you can't be there to deliver your messages let Message Master deliver them for you - any messages in any language and in your own voice!

Message Master connects easily to any radio system for remote access: repeaters, base stations, even transceivers. It can even be connected to an autopatch device to exchange messages between your radio system and the telephone network.

Message Master is a multi-user system with mailbox style personalized message service for a hundred users. With 8 minutes of message storage it can store hundreds of messages simultaneously making it ideal for large, active repeater groups.

Would you like your callsign identifications, tail messages, and bulletin messages sent in real-voice? Message Master can send them too. Record several identification messages and it will even send a different ID each time. Almost like magic, Message Master knows when to send identifications and tail messages so it needs no special control signals from your base or repeater.

Call or write for further information before you make another wasted call.

Commercial users: Ask for a brochure on the Message Master Electronic Dispatcher with group and all call messaging.

- **Create messages just by talking.** Message Master's 'real-voice' technique saves YOUR VOICE in digital memory to deliver messages in your own voice, language and dialect.
- **Mailbox-style operation gives individual message delivery service to 100 system users.**
- **Easily added to any repeater or base station for remote operation with only four connections.**
- **Special features include callsign identifications, tail messages, and bulletin messages.**
- **Digital message storage provides instant playback of stored messages.**
- **Modular memory meets your exact needs from 2 to 8 minutes of total message storage.**

Serving all your repeater needs

- *Mark 4 Repeaters and Repeater Controllers are THE PERFORMANCE LEADERS with real voice, more autodial numbers, more synthesized voice and more features.*
- *Mark 3 Repeaters offer the winning combination of high performance and high value.*
- *LR-1 Repeaters boast superb RF circuitry at an economical price.*
- *MR-4 Receivers with 7 helical resonators are the only receivers to choose in harsh RF environments.*
- *PA-100 Amplifiers with rugged TMOS power FETs give you a continuous duty high power signal.*

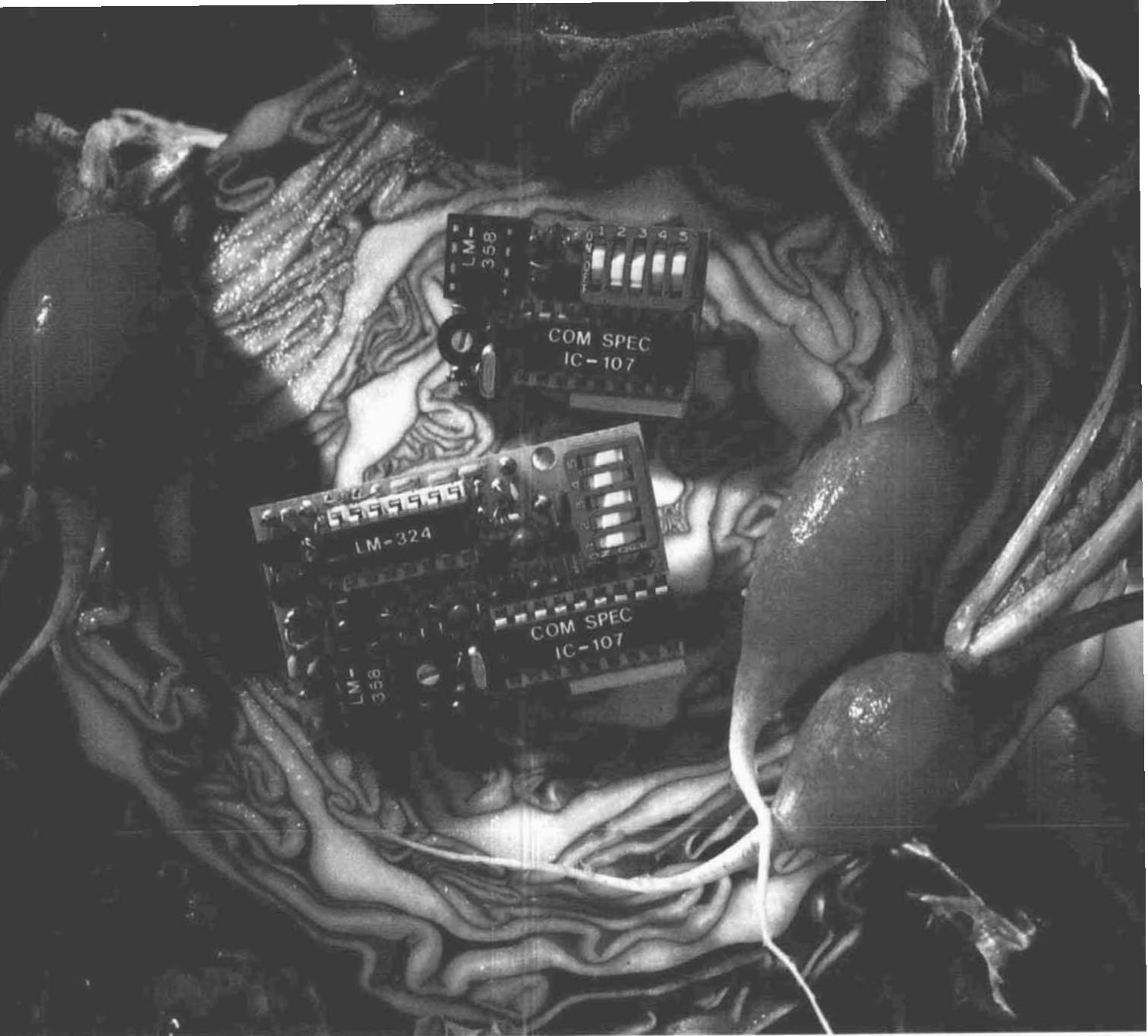


COMING SOON: A 4-channel receiver voting system which operates on true signal-to-noise ratio to extend your coverage by linking to remote receivers.



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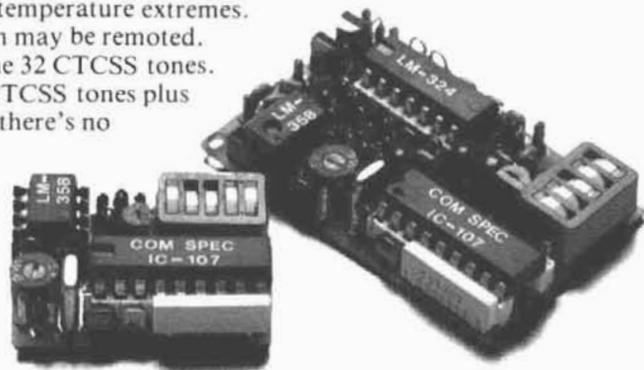


A fresh idea!

Our new crop of tone equipment is the freshest thing growing in the encoder/decoder field today. All tones are instantly programmable by setting a dip switch; no counter is required. Frequency accuracy is astonishing $\pm .1$ Hz over all temperature extremes. Multiple tone frequency operation is a snap since the dip switch may be removed. Our TS-32 encoder/decoder may be programmed for any of the 32 CTCSS tones. The SS-32 encode only model may be programmed for all 32 CTCSS tones plus 19 burst tones, 8 touch-tones, and 5 test tones. And, of course, there's no need to mention our one day delivery and one year warranty.

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SS-32 \$29.95, TS-32 \$59.95





Yaesu's big gun. The FT-980.

DX and contest operation is no place for a lightweight.

That's why the FT-980 combines the latest in HF technology to give you the muscle to get you through.

To begin with, its front panel gives you unsurpassed operating flexibility.

Store your favorite frequencies and operating mode independently in each of the 12 memory channels.

Review the contents of any memory location without disturbing the QSO in progress with the checking function.

Quickly go from one programmed channel to another, or meet your buddy "five up" by simply touching a button.

And you'll be hard-pressed to find a cleaner transmitter. In fact, our conservatively designed final amplifier loads at just a fraction of its rated output. And cuts distortion to new lows.

Then consider the receiver: A triple-conversion design with separate front ends for ham and general coverage reception. That way, ham-band operation is not compromised.

Also, cascaded IF filtering assures outstanding rejection of unwanted signals close to your operating frequency.

Even imperfect antennas are no problem for the FT-980. There's essentially no turn-down with an SWR of 2:1 and just 25% turn-down at 3:1.

Finally, if all this isn't enough, hook up the FT-980 to your personal computer for 21 advanced functions including mode, frequency and band shift. An assortment of interfaces and software are available.

So when you really want to flex your muscles, go with Yaesu's FT-980. The serious radio for the serious operator.

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Here Now
TM-3530A
220 MHz

Power-Full...70 Watts!

TM-2570A/2550A/2530A/3530A

Sophisticated FM transceivers

Kenwood sets the pace again!

The all-new "25-Series" brings the industry's first compact 70-watt 2-meter FM mobile transceiver.

There is even an auto dialer which stores 15 telephone numbers! There are four versions to choose from: The TM-2570A 70-watt, TM-2550A 45-watt, TM-2530A 25-watt and the TM-3530A 220 MHz, 25-watt.

- First 70-watt FM mobile (TM-2570A)
- First mobile transceiver with telephone number memory and auto-dialer (up to 15 seven-digit phone numbers)
- Direct keyboard entry of frequency
- Automatic repeater offset selection—a Kenwood exclusive!
- Extended frequency coverage for MARS and CAP (142-149 MHz; 141-151 MHz modifiable)
- 23 channel memory for offset, frequency and sub-tone
- Big multi-color LCD and back-lit controls for excellent visibility

- Front panel programmable 38-tone CTCSS encoder includes 97.4 Hz (optional)
- 16-key DTMF pad, with audible monitor
- Center-stop tuning—another Kenwood exclusive!
- Frequency lock switch
- New 5-way adjustable mounting system
- Unique offset microphone connector—relieves stress on microphone cord

Large heatsink with built-in cooling fan (TM-2570A)

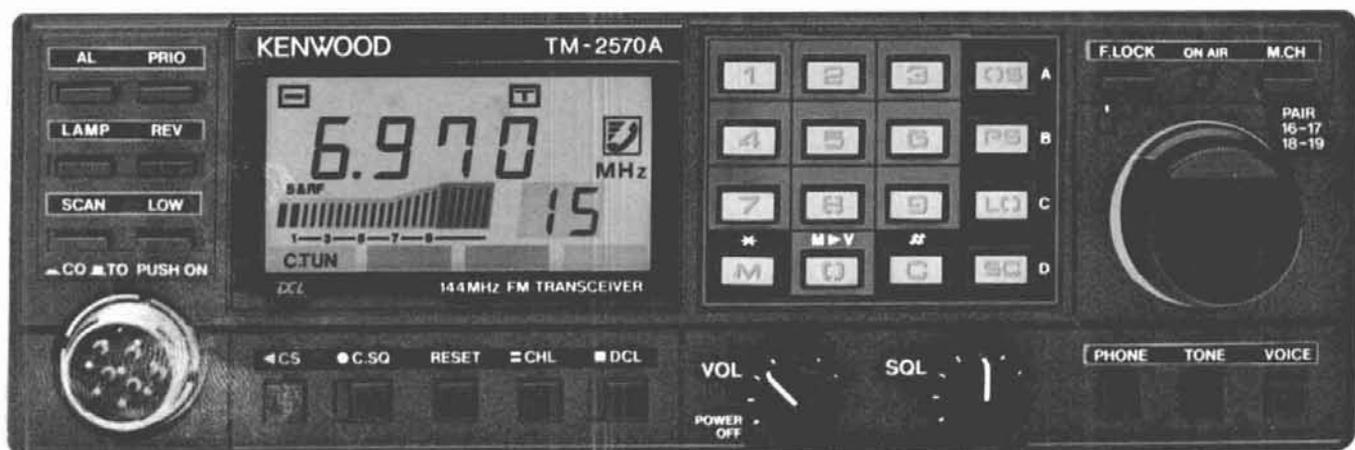


- High performance GaAs FET front end receiver
- HI/LOW Power switch (adjustable LOW power)
- TM-3530A covers 220-225 MHz
- Digital Channel Link (optional)

DCL Introducing... Digital Channel Link

Compatible with Kenwood's DCS (Digital Code Squelch), the DCL system enables your rig to automatically QSY to an open channel. Now you can automatically switch over to a simplex channel after repeater contact! Here's how it works:

The DCL system searches for an open channel, remembers it, returns to the original frequency and transmits control information to another DCL-equipped station that switches both radios to the open channel. Micro-processor control assures fast and reliable operation. The whole process happens in an instant!



Optional Accessories

- TU-7 38-tone CTCSS encoder
- MU-1 DCL modem unit
- VS-1 voice synthesizer
- PG-2K extra DC cable
- PG-3A DC line noise filter
- MB-10 extra mobile bracket
- CD-10 call sign display
- PS-430 DC power supply for TM-2550A/2530A/3530A

- PS-50 DC power supply for TM-2570A
- MC-60A/MC-80/MC-85 desk mics.
- MC-48 extra DTMF mic. with UP/DWN switch
- MC-42S UP/DWN mic.
- MC-55 (8-pin) mobile mic. with time-out timer
- SP-40 compact mobile speaker
- SP-50 mobile speaker
- SW-200A/SW-200B SWR/power meters
- SW-100A/SW-100B compact SWR/power meters
- SWT-1 2m antenna tuner

Actual size front panel

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Complete service manuals are available for all Trio Kenwood transceivers and most accessories. Specifications and prices are subject to change without notice or obligation. Specifications guaranteed on Anritsu units only.