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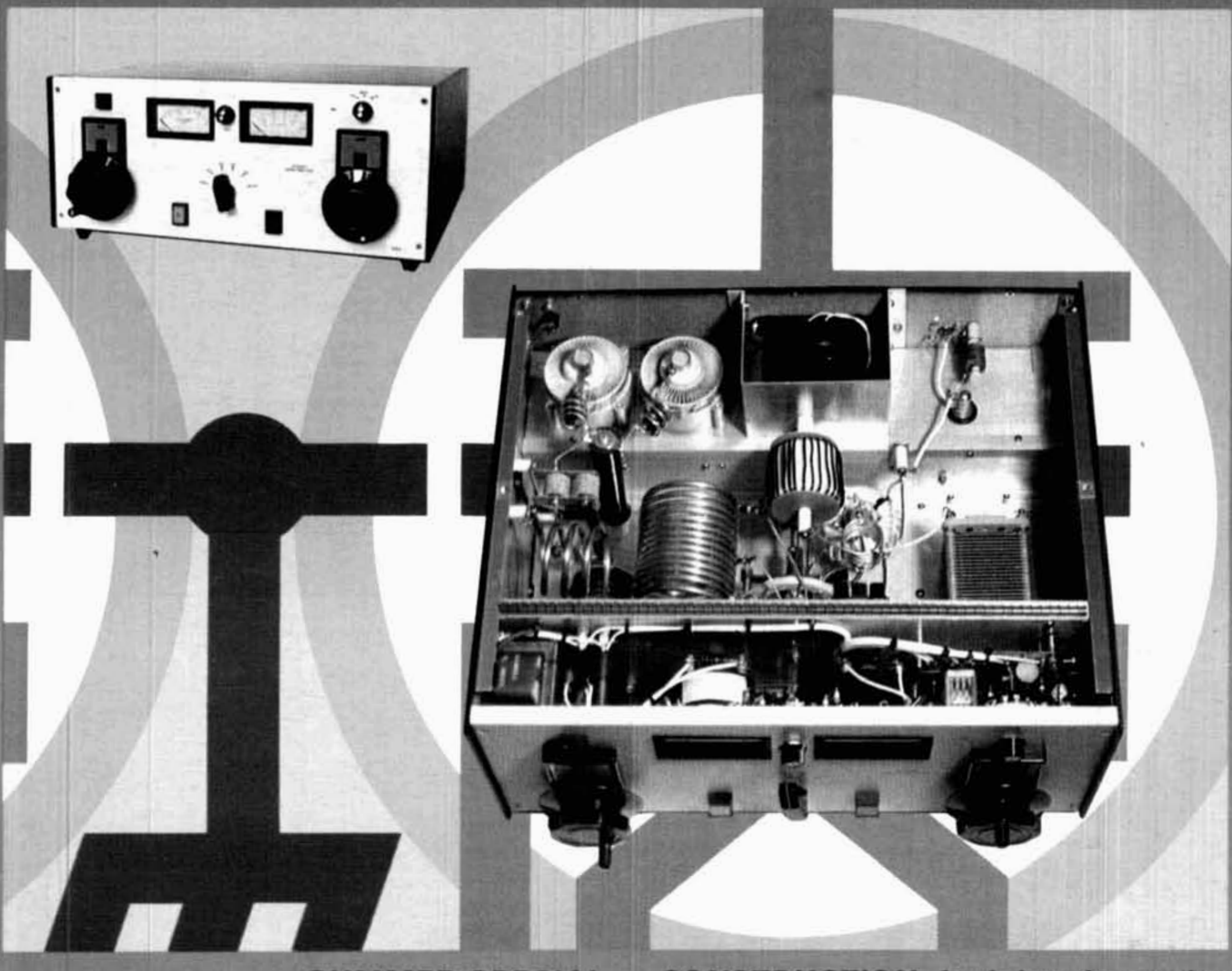
BUILD A 10 TO 160-METER
LINEAR AMPLIFIER
WITH EIMAC'S NEW 3CX800A7'S

ham radio magazine



SUMMER SPECIAL — CONSTRUCTION: junk-box ingenuity • building better boxes • improving ALC • make your own air-wound coils • cooling semiconductors • ALSO: using grayline — with or without computer • a 50 MHz Tilton/Greenblum Yagi • W1JR on filters • W6SAI's ham radio techniques

hr

focus on communications technology

ICOM IC-27H

Ultra Compact 45 Watt, 2-Meter Mobile!

Now ICOM offers the best choices in compact 2-meter FM mobiles...the IC-27H 45-watt compact (1⅝"H x 5½"W x 9⅜"D) and the IC-27A 25-watt super compact mobile. The IC-27A and IC-27H are the smallest full-featured 2-meter mobile transceivers available, and feature an internal speaker for easy installation. For the ultimate portable station, the IC-37A 220MHz and IC-47A 440MHz 25 watt compact mobiles are also available.

45 Watts. The IC-27H provides 45 watts of output power, while the IC-27A provides 25 watts of output power.

32 PL Frequencies. The IC-27A and IC-27H come complete with 32 PL frequencies ready to go and are controlled from the front panel knob. Each PL frequency may be selected by the main tuning knob and stored into memory for easy access along with frequency and offset.

9 Memories. The IC-27A and IC-27H have nine memories available to store receive frequency, transmit offset, offset direction, and PL tone. Memories are backed up by a lithium backup battery, which will store memories for up to seven years.

Speech Synthesizer. As an added plus, the IC-27A/H features an optional speech synthesizer to verbally announce the receiver frequency of the transceiver through the simple touch of a button.

Scanning. Included with the IC-27A/H is a scanning system which allows scanning of the entire band.

Priority Scan. Priority may be selected to be either a memory channel or a VFO channel. By using sampling techniques, the operator can determine if a frequency of interest is free or busy.

See the IC-27A/H compact mobile transceivers at your loca ICOM dealer. For superb perform ance, reliability, and the ultimat in a VHF mobile radio, your only choice is an ICOM.

The IC-25A 2-meter 25-watt mobile and its 45-watt companion, the **IC-25H**, are also available.

IC-HM23
Scanning mic
with DTMF pad

IC-27H
45 Watts
1⅝"H x 5½"W x 9⅜"D

IC-27A
25 Watts
1⅝"H x 5½"W x 7"D

Also Available: IC-37A 220MHz and IC-47A 440MHz Compact Mobiles

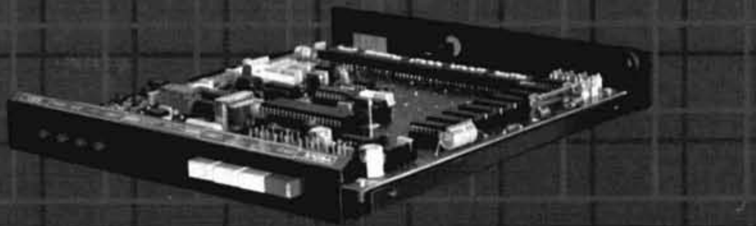
ICOM
The World System

✓ 147

ICOM America, Inc., 2112-116th Ave NE, Bellevue, WA 98004 / 3331 Towerwood Drive, Suite 307, Dallas, TX 752

With SMART PATCH You are in CONTROL

With CES 510SA Simplex Autopatch, there's no waiting for VOX circuits to drop. Simply key your transmitter to take control.



SMART PATCH is all you need to turn your base station into a personal autopatch. SMART PATCH uses the only operating system that gives the mobile complete control. Full break-in capability allows the mobile user to actually interrupt the telephone party. SMART PATCH does not interfere with the normal use of your base station. SMART PATCH works well with any FM transceiver and provides switch selectable tone or rotary dialing, toll restrict, programmable control codes, CW ID and much more.

To Take CONTROL with Smart Patch – Call 800-327-9956 Ext. 101 today.

'hat To ook For In A hone Patch

e best way to decide iat patch is right for you to first decide what a tch should do. A patch ould:

Give complete control to he mobile, allowing full break in operation.

Not interfere with the normal operation of your base station. It should not require you to connect and disconnect cables (or flip switches!) every time you wish to use your radio as a normal base station.

Not depend on volume or squelch settings of your radio. It should work the same regardless of what you do with these controls.

You should be able to hear your base station speaker with the patch installed. Remember, you have a base station because there are mobiles. ONE OF THEM MIGHT NEED HELP.

The patch should have standard features at no extra cost. These should include programmable toll restrict (dip switches), tone or rotary dialing, programmable patch and activity timers, and front panel indicators of channel and patch status.

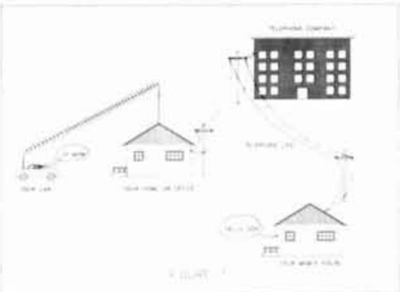
ONLY SMART PATCH HAS ALL OF THE ABOVE.

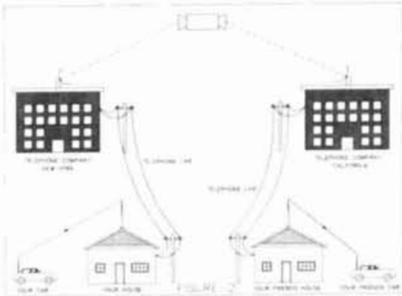
low Mobile)perators Can njoy An ffordable 'ersonal Phone 'atch. . .

Without an expensive repeater.
Using any FM tranceiver as a base station.
The secret is a SIMPLEX autopatch, The *SMART PATCH*.

MART PATCH s Easy To Install

) install *SMART PATCH*, onnect the multicolored omputer style ribbon cable mic audio, receiver iscriminator, PTT, and ower. A modular phone ord is provided for conection to your phone sys-m. Sound simple? . . . ' IS!





How To Use *SMART PATCH*

Placing a call is simple. Send your access code from your mobile (example: *73). This brings up the Patch and you will hear dial tone transmitted from your base station. Since *SMART PATCH* is checking about once per second to see if you want to dial, all you have to do is key your transmitter, then dial the phone number. You will now hear the phone ring and someone answer. Since the enhanced control system of *SMART PATCH* is constantly checking to see if you wish to talk, you need to simply key your transmitter and then talk. That's right, you simply key your transmitter to interrupt the phone line. The base station automatically stops transmitting after you key your mic. *SMART PATCH* does not require any special tone equipment to control your base station. It samples very high frequency noise present at your receivers discriminator to determine if a mobile is present. No words or syllables are ever lost.

SMART PATCH Is All You Need To Automatically Patch Your Base Station To Your Phone Line.

Use *SMART PATCH* for:

- Mobile (or remote base) to phone line via Simplex base. (see fig 1.)
- Mobile to Mobile via interconnected base stations for extended range. (see fig. 2.)
- Telephone line to mobile (or remote base).
- *SMART PATCH* uses SIMPLEX BASE STATION EQUIPMENT. Use your ordinary base station. *SMART PATCH* does this without interfering with the normal use of your radio.

WARRANTY?

YES, 180 days of warranty protection. You simply can't go wrong.
An FCC type accepted coupler is available for *SMART PATCH*.

Communications Electronics Specialties, Inc.
P.O. Box 2930, Winter Park, Florida 32790
Telephone: (305) 645-0474 **Or call toll-free (800)327-9956**

✓ 126

KENWOOD

...pacesetter in amateur radio

Scan the World.

R-2000

Kenwood's R-2000 receiver has opened the doors to a new world in the 150-kHz to 30-MHz HF bands, with microprocessor controlled operating features and an UP conversion PLL circuit for maximum flexibility and to enhance the excitement of listening to stations from east to west, and from pole to pole. An optional VC-10 VHF converter, for 118 to 174-MHz, allows access to police, aviation, marine, commercial, and two meter Amateur frequencies. With dual digital VFO's, ten memories that store frequency, band and mode information, memory scan, programmable band scan, fluorescent tube digital display, and dual 24-hour clock with timer, this outstanding radio has the versatility needed to reach out and catch those distant and elusive stations in the most remote areas of the world.

The R-2000 receives in the USB, LSB, CW, AM, and FM modes, and its ten memories allow moving from band to band without concern for mode of operation. The programmable band scan feature permits scanning over operator selected limits, reducing scan cycle time. Memory scan allows the operator to scan all, or only specific memories. Lithium battery memory backup (Estimated 5 year life) is built-in.

With the sensitive R-2000, only the best in selectivity will do. It has three built-in IF filters, with NARROW/WIDE selector switch, and an optional 500-Hz narrow CW filter is available. A noise blanker, and an all-mode squelch circuit further enhance the operators control of his listening environment. An AGC switch, and an RF attenuator switch allow selection of the best signal-to-noise ratio. It has a large, front mounted speaker, a tone control, an "S" meter, high and low impedance antenna terminals, and operates on 100/120/220/240 VAC, or on 13.8 VDC, with an optional DCK-1 DC cable kit. Other features include a record output jack, an audible "beeper," a carrying handle, a headphone jack, and an external speaker jack.

The R-2000 places the world at your finger tips.

R-2000 optional accessories:
VC-10 VHF converter • HS-4, HS-5, and HS-6 headphones • DCK-1 DC cable kit • YG-455C 500-Hz CW filter.

R-1000 High performance receiver • 200 kHz—30 MHz • digital display/clock/timer • 3 IF filters • PLL UP conversion • noise blanker • RF step attenuator • 120-240 VAC (Optional 13.8 VDC).

R-600 General coverage receiver • 150 kHz—30 MHz • digital display • 2 IF filters • PLL UP conversion • noise blanker • RF attenuator • front speaker • 100-240 VAC (Optional 13.8 VDC).

More information on these products is available from authorized dealers of Trio-Kenwood Communications, 1111 West Walnut Street, Compton, California 90220.

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magazine

contents


Mason Logan, K4MT

REFLECTIONS

. . . with a little help from our friends


Forrest Gehrke, K2BT

We hate to admit it, but we don't know everything there is to know about Amateur Radio. What's more, the field is so vast, and expanding so quickly, that we can't even *hope* to know it all. We try — but there are times when our individual and collective wisdom fails and we have to turn to others for help. Perhaps the subject at hand is an idea so new that we need to learn more about it ourselves. Or perhaps all we need is confirmation of our opinion that an idea may be unworkable because of some flaw in the concept or method proposed.

When we need a knowledgeable friend to turn to — to review a questionable manuscript, or to clarify, confirm, or correct some detail or theory or practice — we turn to one of the four distinguished members of *ham radio's* editorial board. We look to them for two things: first, for their expertise in their specific areas of knowledge and experience; and second, for their unique perspective on Amateur Radio. Spanning the past and present, with an eye on the future of Amateur Radio, these gentlemen give us a perspective that's easy to lose sight of in the day-to-day business of making sure your copy of *ham radio* arrives each month.

While we'd like to introduce each one of the members of our editorial board to you personally, that's obviously impossible. So we'll do the next best thing and introduce them to you in print.

Ed Wetherhold, W3NQN, first encountered Amateur Radio in 1947 while in training as an Air Force radio technician. A buddy in the barracks had set up a station next to his bunk. Ed was "hooked." He went on to study Radio Engineering at Tri-State University in Angola, Indiana, and graduated in 1956. Since 1962 he's been with Honeywell in Annapolis, Maryland, where he's responsible for testing communications systems. In addition, he distributes surplus 44- and 88-mH toroidal inductors in the United States and in the U.K. to facilitate easy assembly of his filter designs, and writes extensively in the international Amateur press. Ed also serves as technical advisor to the ARRL in the area of his specific interest, passive LC filters.

While Ed found Amateur Radio, Amateur Radio "found" **Forrest Gehrke, K2BT**. At 10, he was building one-tube regenerative broadcast band receivers, using UV-199's and 201A's. One day he inadvertently omitted some turns around the oatmeal box, and some fascinating activity on the 160-meter band spilled into his earphones. First licensed as W9WJD in 1936, Forrest says he was "bitten by the DX bug shortly afterward when, during sunspot peak openings, you could work the world on 10 meters with no discernible power output." He earned an E.E. degree from the University of Wisconsin and spent 30 years trying to "push the state of the art" in electron tubes. By the early 1960's, he was working in the development of a 10 GHz solid-state power source for the MoonLander's retro-rocket landing control radar. He now works in the data communications industry, developing packet networks that communicate at 56K bits per second.

World War II, marriage, and sharing in the raising of eight children caused what K2BT calls "slight intermission" in Amateur Radio activities until 1968, when he resumed the push for DXCC he'd begun in 1939. He reached 5BDXCC in 1974, Honor Roll in 1978, and is currently aiming for Honor Roll Status solely in the 80-meter band. His special interest: antennas.

Mason Logan, K4MT, studied physics at CalTech and Columbia and worked with Bell Telephone Laboratories for 50 years. His early work was in telephone transmission and signalling research; later he designed circuits for underwater acoustic and magnetic proximity fuzes, high-loop gain negative feedback amplifiers, and servomechanism circuits for the development model of the NIKE guided missile analog computer.

Now and then a problem will come along that demands a theoretical solution. If it pertains to any aspect of electromagnetics, we turn to **Bob Lewis, W2EBS**. Bob started out in Amateur Radio in 1921 (as did K4MT) when he was a 13-year old Boy Scout leafing through the pages of his handbook in search of another merit badge to win. The "Wireless" badge caught his eye and he ran to the store for some oatmeal — not for the cereal, or course, but for the box that it came in. Finally licensed in the early 1930's, he attended Virginia Military Institute and graduated from the University of Pennsylvania. Graduate study — including an M.B.A. — followed.

Bob worked in research at RCA from 1932 through 1939, when he left to join the research team at CBS. (While at RCA, incidentally, he worked in the design of the television transmitting antennas atop the Chrysler Building in New York City.) He served overseas during World War II, working in radar countermeasures, with the office of Scientific Research and Development. After the war he returned to CBS and then went to Federal Telegraph and Radio. After ITT bought Federal, he joined the ITT research group in Nutley, New Jersey. He joined a small group of friends and colleagues in Prodelin, Inc., and spent the following 20+ years, until retirement, working in the development of transmission lines and antennas.

Over the coming months we'll be looking to expand the editorial review board to include others of similar standing, but with different areas of expertise. If you have an area of special interest and achievement in Amateur Radio — and aren't too modest to admit it — get in touch with us. You don't have to be one of the Founding Fathers of Amateur Radio; if you "know your stuff," and want to play a meaningful role in the production of a high-quality technical publication, let us know. *We'd like to know you.*

Dorothy Rosa, KA1LBO
Assistant Editor

FREE MFJ SOFTWARE

Free MFJ RTTY/ASCII/CW software for VIC-20 or C-64 with purchase of MFJ-1224, MFJ-1225 or MFJ-1228 from MFJ. Send/receive Baudot, ASCII, CW. Type ahead buffer. 24 hour clock. Supports VIC printer. Menu Driven. MFJ-1224/1225 cable. On tape. Available separately for $29.95.

RTTY/ASCII/AMTOR/CW INTERFACE CARTRIDGE FOR VIC-20/C-64

MFJ-1228 $69.95

FREE MFJ RTTY/ASCII/CW Software
INCLUDES MFJ-1228, SOFTWARE ON TAPE. ADD VIC-20 OR C-64 AND RIG TO ENJOY COMPUTERIZED RTTY/ASCII/CW. ORDER MFJ-1228/MFJ-1264 FOR VIC-20, MFJ-1228/MFJ-1265 FOR C-64.

Most versatile RTTY/ ASCII/AMTOR/CW Interface cartridge available for VIC-20 and Commodore 64. Gives you more features, more performance, more value for your money than any other interface cartridge available.

Same interface cartridge works for both VIC-20 and Commodore 64. Plugs into user's port.

Choose from wide variety of RTTY/ASCII/CW, even AMTOR software. Not married to one on-board software package. Use MFJ, Kantronics, AEA plus other software cartridge, tape or disk.

850 Hz and 170 Hz shifts on receive **and** transmit.

Has mark and space outputs for scope tuning.

Normal/Reverse switch eliminates retuning.

True dual channel mark and space active filters and automatic threshold correction gives good copy when one tone is obliterated by QRM or selective fading.

Easy, positive tuning with twin LED indicators.

Narrow 800 Hz active CW filter. Automatic PTT.

Exar 2206 sine generator for AFSK output.

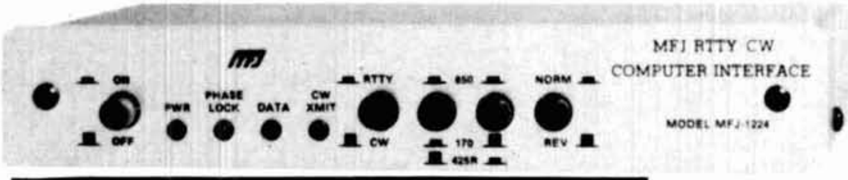
Shielded XCVR AFSK/PTT interface cable provided. Plus or minus CW keyed output. FSK out.

Powered by computer (few ma.), no power adapter to buy or extra wire to dangle or pick up/radiate RFI.

Glass epoxy PCB. Aluminum enclosure. 4½x4½x1".

UNIVERSAL RTTY/ASCII/AMTOR/CW COMPUTER INTERFACE

Lets you send and receive computerized RTTY/ASCII/AMTOR/CW. Copies all shifts and all speeds. Copies on both mark and space. Sharp 8 pole active filter for 170 Hz shift and CW. Plugs between your rig and VIC-20, Apple, TRS-80C, Atari, TI-99, Commodore 64 or other personal computers. Uses MFJ, Kantronics, AEA software and other RTTY/CW software.



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COMPLETE PACKAGE INCLUDES MFJ-1224, SOFTWARE ON TAPE, CABLES. YOU NEED ONLY VIC-20 OR C-64 AND RIG TO ENJOY COMPUTERIZED RTTY/ASCII/CW. ORDER MFJ-1224/MFJ-1264 FOR VIC-20. MFJ-1224/MFJ-1265 FOR C-64.

MFJ-1224 $99.95

New MFJ-1224 RTTY/ASCII/AMTOR/CW Computer Interface lets you use your personal computer as a computerized full featured RTTY/ASCII/AMTOR/CW station for sending and receiving. Plugs between rig and VIC-20, Apple, TRS-80C, Atari, TI-99, Commodore 64 and most others.

Use MFJ software for VIC-20, Commodore 64 and Kantronics for Apple, TRS-80C, Atari, TI-99 and most other software for RTTY/ASCII/AMTOR/CW.

Easy, positive tuning with twin LED indicators.

Copy any shift (170,425,850 Hz and all other shifts) and any speed (5-100 WPM RTTY/CW and up to 300 baud ASCII).

Copies on both mark and space, not mark only or space only, to improve copy under adverse conditions.

Sharp 8 pole 170 Hz shift/CW active filter gives good copy under crowded, fading and weak signal conditions. Automatic noise limiter suppress static crashes for better copy.

Normal/Reverse switch eliminates retuning. +250 VDC loop output drives RTTY machine. Speaker jack.

Automatic tracking copies drifting signal.

Exar 2206 sine generator gives phase continuous AFSK tones. Standard 2125 Hz mark and 2295/2975 Hz space. Microphone line: AFSK out, AFSK ground, PTT out and PTT ground.

FSK keying output. Plus and minus CW keying. CW transmit LED. External CW key jack.

Kantronics compatible socket.

Exclusive general purpose socket allows interfacing to nearly any personal computer with most appropriate software. Available TTL lines: RTTY demod out, CW demod out, CW-ID input, +5 VDC, ground. All signal lines are buffered and can be inverted using an internal DIP switch.

Use Galfo software with Apple, RAK with VIC-20, Kantronics with TRS-80C, TI-99, N4EU with TRS-80 III, IV. Some computers with some software may require some external components.

Metal cabinet. Brushed alum. front. 8x1¼x6 in. 12-15 VDC or 110 VAC with adapter, MFJ-1312, $9.95.

MFJ-1223, $29.95, RS-232 adapter for MFJ-1224.

UNIVERSAL SWL RECEIVE ONLY COMPUTER INTERFACE FOR RTTY/ASCII/AMTOR/CW

MFJ-1225 $69.95

FREE MFJ RTTY/ASCII/CW Software
TAPE AND CABLE FOR VIC-20 OR C-64. ORDER MFJ-1225/MFJ-1264 FOR VIC-20 OR MFJ-1225/MFJ-1265 FOR C-64.

Use your personal computer and communications receiver to receive commercial, military and amateur RTTY/ASCII/AMTOR/CW traffic.

Plugs between receiver and VIC-20, Apple, TRS-80C, Atari, TI-99, Commodore 64 and most other personal computers. Requires appropriate software.

Use MFJ, Kantronics, AEA and other RTTY/ASCII/AMTOR/CW software.

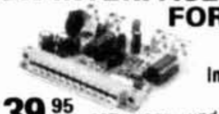
Copies all shifts and all speeds. Twin LED indicators makes tuning easy, positive. Normal/Reverse switch eliminates tuning for inverted RTTY. Speaker out jack. Includes cable to interface MFJ-1224 to VIC-20 or Commodore 64. 4½x1¼x4¼ inches. 12-15 VDC or 110 VAC with optional adapter, MFJ-1312, $9.95.

SUPER RTTY FILTER

MFJ-725 $39.95

Super RTTY filter greatly improves copy under crowded, fading and weak signal conditions. Improves **any** RTTY receiving system. 8 pole bandpass active filter for 170 Hz shift (2125/2295 Hz mark/space). 200 or 400 Hz bandwidths. Automatic noise limiter. Audio in, speaker out jacks. On/off/bypass switch. "ON" LED. 12 VDC or 110 VAC with optional AC adapter, MFJ-1312, $9.95. 3x4x1 inch aluminum cabinet.

CW INTERFACE CARTRIDGE FOR VIC-20/C-64



$39.95 MFJ-1226

High performance CW Interface cartridge. Gives excellent performance under weak, crowded, noisy conditions. Works for both VIC-20 and Commodore 64. Plugs into user's port.

4 pole 100 Hz bandwidth active filter. 800 Hz center frequency. 3 pole active lowpass post detection filter. Exclusive automatic tracking comparator.

Plus and minus CW keying. Audio in, speaker out jacks. Powered by computer.

Includes Basic listing of CW transmit/receive program. Available on cassette tape, MFJ-1252 (VIC-20) or MFJ-1253 (C-64), $4.95 and on software cartridge, MFJ-1254 (VIC-20) or MFJ-1255 (C-64), $19.95.

You can also use Kantronics, AEA other software. **Also copy RTTY** with single tone detection.

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Hamtronics Breaks the Price Barrier!

*

No Need to Pay $80 to $125 for a GaAs FET Preamp.

FEATURES:

- Very Low Noise: 0.7 dB VHF, 0.8 dB UHF
- High Gain: 18 to 28 dB, Depending on Freq.
- Wide Dynamic Range for Overload Resistance
- Latest Dual-gate GaAs FET, Stable Over Wide Range of Conditions
- Rugged, Diode-protected Transistors
- Easy to Tune
- Operates on Standard 12 to 14 Vdc Supply
- Can be Tower Mounted

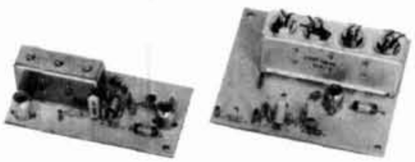
MODEL	TUNES RANGE	PRICE
LNG-28	26-30 MHz	$49
LNG-50	46-56 MHz	$49
LNG-144	137-150 MHz	$49
LNG-220	210-230 MHz	$49
LNG-432	400-470 MHz	$49
LNG-40	30-46 MHz	$64
LNG-160	150-172 MHz	$64

ECONOMY PREAMPS

Our traditional preamps, proven in years of service. Over 20,000 in use throughout the world. Tuneable over narrow range. Specify exact freq. band needed. Gain 16-20 dB. NF = 2 dB or less. VHF units available 27 to 300 MHz. UHF units available 300 to 650 MHz.

- P30K, VHF Kit less case $18
- P30W, VHF Wired/Tested $33
- P432K, UHF Kit less case $21
- P432W, UHF Wired/Tested $36

HELICAL RESONATOR PREAMPS



Our lab has developed a new line of low-noise receiver preamps with helical resonator filters built in. The combination of a low noise amplifier and the sharp selectivity of a 3 or 4 section helical resonator provides increased sensitivity while reducing intermod and cross-band interference in critical applications. See selectivity curves at right. Gain = approx. 12 dB.

Model	Tuning Range	Price
HRA-144	143-150 MHz	$49
HRA-220	213-233 MHz	$49
HRA-432	420-450 MHz	$59
HRA-( )	150-174MHz	$69
HRA-( )	450-470 MHz	$79

RECEIVING CONVERTERS

Models to cover every practical rf & if range to listen to SSB, FM, ATV, etc. NF = 2 dB or less.

VHF MODELS	Antenna Input Range	Receiver Output
Kit with Case $49	28-32	144-148
Less Case $39	50-52	28-30
Wired $69	50-54	144-148
	144-146	28-30
	145-147	28-30
	144-144.4	27-27.4
	146-148	28-30
	144-148	50-54
	220-222	28-30
	220-224	144-148
	222-226	144-148
	220-224	50-54
	222-224	28-30

UHF MODELS	Antenna Input Range	Receiver Output
Kit with Case $59	432-434	28-30
Less Case $49	435-437	28-30
Wired $75	432-436	144-148
	432-436	50-54
	439.25	61.25

SCANNER CONVERTERS Copy 72-76, 135-144, 240-270, 400-420, or 806-894 MHz bands on any scanner. Wired/tested Only $88.

SAVE A BUNDLE ON VHF FM TRANSCEIVERS!

FM-5 PC Board Kit – **ONLY $178**
complete with controls, heatsink, etc.
10 Watts, 5 Channels, for 2M or 220 MHz.

Cabinet Kit, complete with speaker, knobs, connectors, hardware. Only $60.

REPEAT OF A SELLOUT!

While supply lasts, get $60 cabinet kit free when you buy an FM-5 Transceiver kit. Where else can you get a complete transceiver for only $178

TRANSMIT CONVERTERS

For SSB, CW, ATV, FM, etc. Why pay big bucks for a multi mode rig for each band? Can be linked with receive converters for transceive. 2 Watts output vhf, 1 Watt uhf.

	Exciter Input Range	Antenna Output
For VHF,	28-30	144-146
Model XV2	28-29	145-146
Kit $79	28-30	50-52
Wired $149	27-27.4	144-144.4
(Specify band)	28-30	220-222*
	50-54	220-224
	144-146	50-52
	50-54	144-148
	144-146	28-30

	Exciter Input Range	Antenna Output
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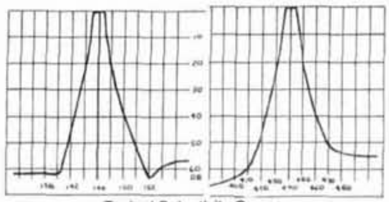

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SOME COMMERCIAL INCURSION INTO THE AMATEUR 220-225 MHZ BAND is still very possible, according to informed observers of the Washington and Land Mobile scene. Despite strong denials at high FCC levels, there's an ongoing belief in some circles that at least a portion of the band (some say as much as half!) could be reallocated to Land Mobile in the near future. If so, it would likely go for a narrowband technology such as ACSB.

A Proposal To Permit Novice Phone Operation On 220 MHz has been submitted to the FCC by WA2MCT and WD5DON as a Petition for Rulemaking. Opposition to their proposal since it was first suggested has been very strong, both at the Dayton Hamvention 220 MHz Forum and in letters to "220 Notes," K9XI's national 220 MHz Newsletter.

In An Unrelated Move, A 224.750 MHz Experimental License has been granted to the University of Illinois' Wallops Island, Virginia, test facility "to support research in ionospheric radio propagation required by U.S. Government contract."

420-430 MHZ IS NO LONGER AVAILABLE TO U.S. AMATEURS located within 75 miles of the Canadian border. The ban results from Canada's decision several years ago to allocate the bottom 10 MHz of the 70-cm band to land mobile, and a consequent agreement between its DOC and the FCC to protect Canadian land mobile users from possible U.S. Amateur interference. Though the protection band, which actually exceeds 75 miles in some areas, has theoretically been in effect for some time, the FCC has not yet begun to actively enforce it.

Included In The Protection Band Are Such Major U.S. Cities as Seattle and Duluth, most of Michigan (including Detroit), Toledo, Cleveland, Erie, at least half of the states of New York, Vermont, and New Hampshire, and most of Maine, including Bangor! A 75-mile band of protection also extends along the Alaska-Canada border, encompassing Juneau and Ketchikan.

U.S. Land Mobile Stations Using Frequencies Between 30 And 470 MHz In The Protected Areas are also affected, but can receive clearance for licensing on a non-interfering basis. U.S. land mobile stations with an ERP under five watts do not require any Canadian coordination. However, there is no such leeway for Amateur operations along the borders.

Unusual Signals May Be Encountered In The 70-cm Band By Amateurs in much of New York, New Jersey, and Pennsylvania in coming months. Grumman Aerospace has received an FCC experimental license to operate on various frequencies between 424 and 446 MHz within a 150-mile radius of Binghamton, New York, in connection with work on the E-2C system.

A THIRD AMATEUR HAS BEEN NAMED TO BECOME AN ASTRONAUT BY NASA. Ron Parise, WA4SIR, a scientist employed by NASA at Greenbelt, Maryland, is scheduled to make his first trip on the Space Shuttle in 1986. He joins W5LFL, who conducted the first Amateur operation from space late last year, and WØORE, who's up for his first Shuttle trip next spring.

Amateur Operation During WØORE's Upcoming Shuttle Flight has been formally proposed by the ARRL and AMSAT. In their joint proposal the two groups stated their goal was to involve as many Amateurs as possible, particularly through school and club stations. In addition to 2-meter FM such as W5LFL used, a 10-meter downlink for 2-meter audio and SSTV pictures from the Shuttle has also been suggested. NASA's decision is expected soon.

SIMPLEX AUTOPATCHES MUST HAVE A SEPARATE CONTROL MEANS ON ANY AMATEUR BAND, not just below 220.5 MHz. Confusion arose with the ARRL Executive Committee's recent adoption of a requirement that all *QST* ads for simplex autopatch devices state their use is not permitted "...in the 2-meter band, or on any other frequency below 220.5 MHz..." without a separate control link. The FCC requires positive transmitter control on all Amateur frequencies—not just 2 meters—but feels the real issue is whether the simplex autopatch is really "Amateur Radio" rather than how existing rules can be bent to fit its operation.

VOLUNTEER EXAMINER COORDINATORS HAVE NOW BEEN ACCEPTED IN ALL AREAS, with the appointment of W5YI Report Editor/Publisher, Fred Maia, as a VEC for all 13 districts. The Zero District now also has a "resident" VEC, the PHD Radio Club from Missouri; until Maia's acceptance, the First District was the last still lacking a VEC.

ARRL Applied To Become A VEC In All 13 Areas June 27. In their 1-1/2 page proposal, down sharply from an earlier 70-80 page draft, the League still remained adamant that its active participation wouldn't begin until the FCC authorized collection of exam fees. However, it still looks very likely that the fee proposal will be adopted in some form before the FCC's summer recess begins August 1. The height of the "Chinese wall" between the League's publishing business and its VEC organization is still a likely problem area.

Well Over 1000 Exams Have Now Been Given Under VEC Direction, and the program seems to be working quite well in most areas. Most VECs expect to be ready to give Advanced and Extra Class exams by the end of July, and the Second District VEC, Metroplex, will be giving Novice through Extra Exams at the ARRL National Convention in New York July 21-22.

ARRL'S PETITION TO HAVE CABLE TV KEPT OFF THE AMATEUR BANDS has been rejected by the FCC. However, in their rejection the Commissioners put the cable TV industry firmly on notice that it has an obligation to prevent and remedy leakage problems, to all services.


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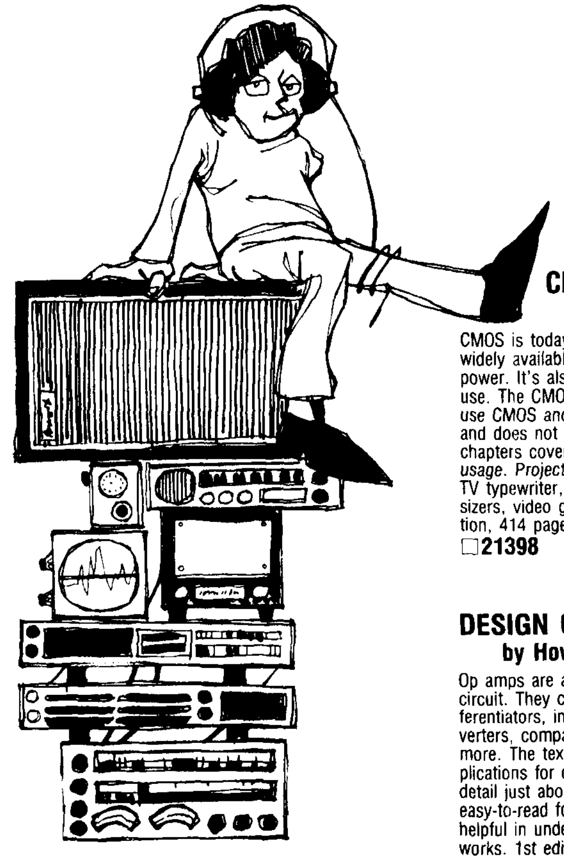

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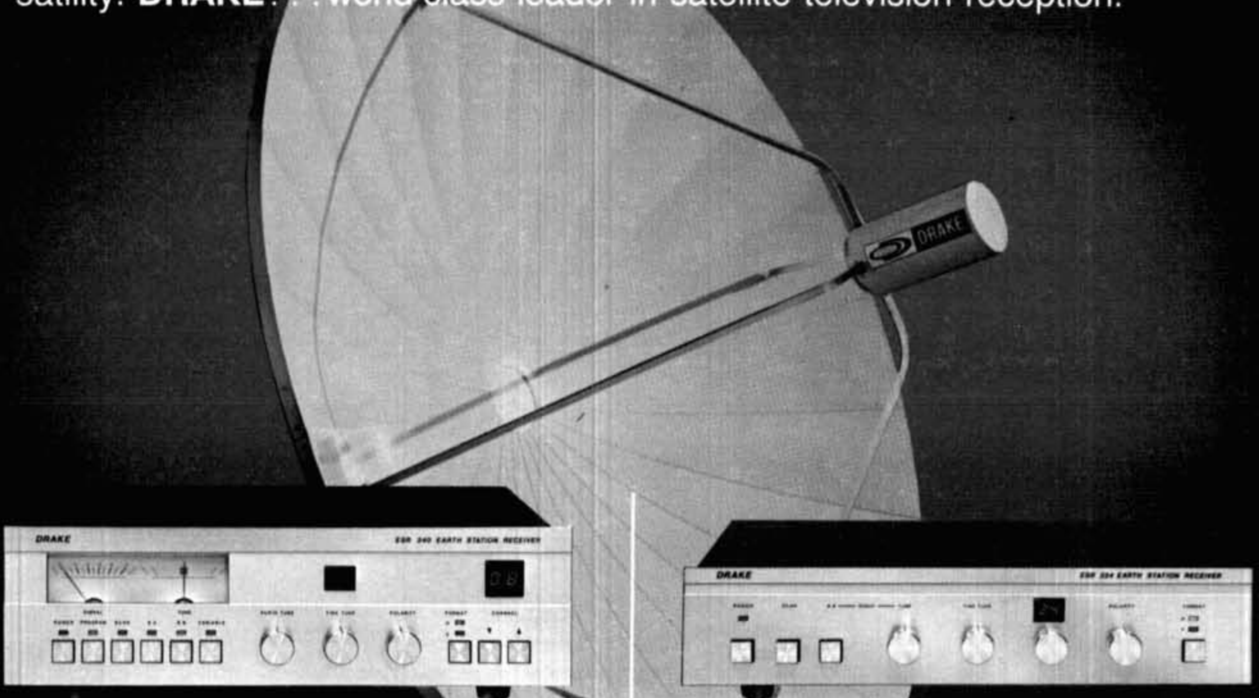

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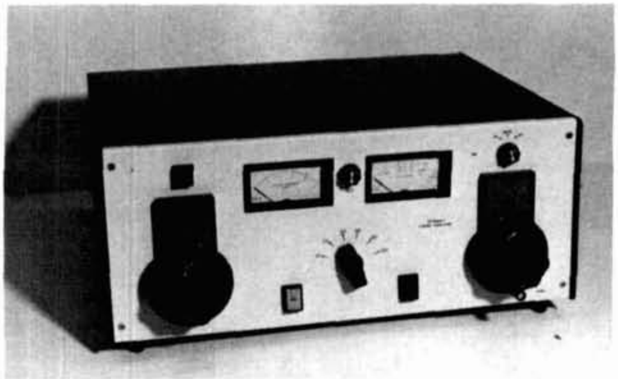


a 3CX800A7 linear amplifier

1500 watts out on 10-160 meters, using a pair of EIMAC's new compact tubes

It took me about thirty seconds to accept *ham radio's* invitation to design and build a new high-frequency linear amplifier centered around EIMAC's new 3CX800A7 triode. I decided immediately that the design should capitalize on the small size of the tubes, cover the 10 through 160 meter bands, and be capable of meeting the new 1500 watt output power limit on a continuous basis. In other words, I wanted a small desk-top amplifier that "growled." My approach to the project was similar to the modular technique described in my previous *ham radio* article[1] and to the structured approach to equipment design outlined earlier in *QST*.[2]

In this article, I have made a special effort to provide the detail necessary to allow readers to easily duplicate my efforts. I have provided detailed layouts of the circuit boards and tried to identify sources for the parts where available. Readers who duplicate the design exactly should experience few problems.

Some unusual parts — a 500 pF/3000 volt vacuum variable capacitor and an RF vacuum relay — for example — are used. In each case, effort has been made to identify these parts and suggest alternative components that are more readily available.

I have also included construction details for a matching high voltage power supply. Remember that a well-regulated power supply is one key to making an amplifier perform well.

RF deck circuit design

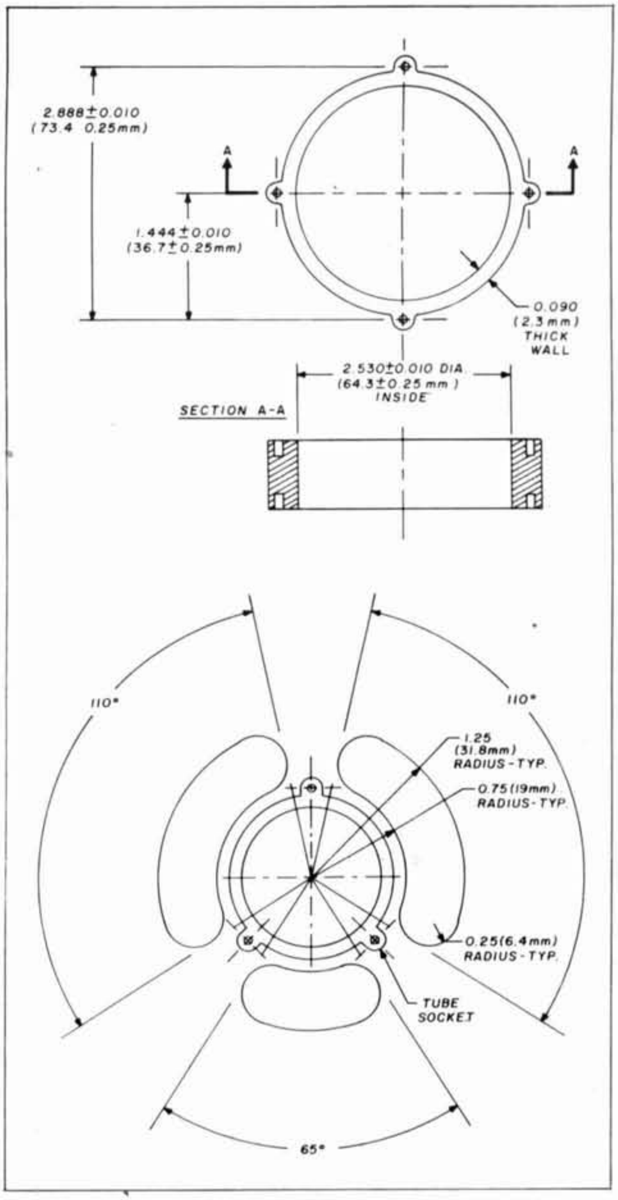
The amplifier is designed around a pair of EIMAC 3CX800A7 high-mu power triodes that are capable of 15 dB gain. The tubes are very compact, measuring only 2-1/2 inches (6.35 cm) high and 2-1/2 inches in diameter. A matching socket, chimney, and plate connector are also available.

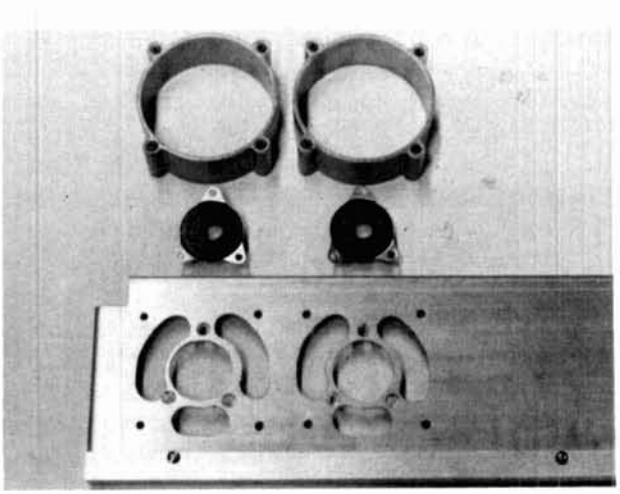
The amplifier uses a tuned input network (**fig. 1**) ganged to the main band switch to minimize distortion products and provide a good match to the exciter. Maximum SWR presented to the exciter is 1.3:1. Because of the high gain of the tubes (i.e. 15 dB) only about 60 watts is needed to drive the amplifier to the new 1500 watt output power limit. Therefore, a very effective ALC circuit (see **fig. 2**) also has been included to control drive power. (See ALC module PC board and component layout.)

Output matching is accomplished using a Pi-L circuit designed for a *Q* of 12. Toroids in both the input and output circuit have been used for compactness.

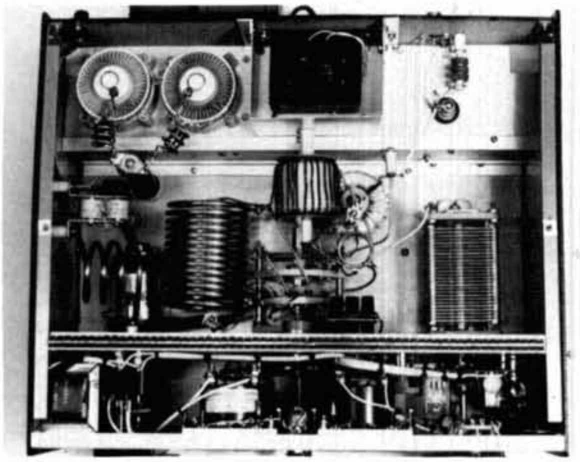
Also included is a very effective grid trip circuit that latches the amplifier out of operation should the grid current exceed 90 milliamperes (45 milliamperes per tube). This feature provides positive protection for the tubes against excessive grid current. This is especially important with these tubes since the grids are capable of dissipating only 4.0 watts. If the protective circuit does trip, it can be reset by pushing a front panel mounted switch. However, the reason it tripped

By Jerry L. Pittenger, K8RA, 2165 Sumac Loop South, Columbus, Ohio 43229





Mounting details for 3CX800A7. Sockets and chimneys available from EIMAC.



Top view of amplifier: Note shield for filament transformer; finger stock isolates meter compartment from main RF compartment.

in the first place should be determined before resetting the switch.

Additional protective devices include a solid-state time delay circuit that prevents operation of the amplifier for approximately 3 minutes until the indirectly heated cathodes of the tubes are properly conditioned. The HV can not be turned on during this period. After warm-up, a relay actuates that allows the amplifier to be keyed up by the exciter and also sends AC power to the HV power supply to allow HV to be applied to the plates of the tubes.

A regulated 26 VDC power supply has been included to provide power for meter and switch pilot lights and relay control. The supply is regulated to avoid pilot light dimming under varying current loads.

amplifier control circuitry

The control circuitry for this amplifier is quite simple. 110 VAC enters the RF deck control circuit (**fig. 3**) from the HV power supply. When the front panel FIL power switch is actuated, AC power is applied to the blower, filament transformer and 26 VDC regulated power supply module. (See PC board and component layout.) The 26 VDC supply, in turn, applies power to the timing module, which starts the three minute warm-up cycle. When the warm-up cycle is over, the meter lights come on indicating that the amplifier is ready to operate. Note, actuating the front panel "HV" power switch will not send power to the HV power supply until the 3-minute warm-up cycle has completed.

The 26 VDC power supply uses an LM317 voltage regulator which can malfunction in the presence of strong RF fields. Consequently good design practices require careful placement. In this design, the 26 VDC supply is located up in the front meter compartment far away from RF.

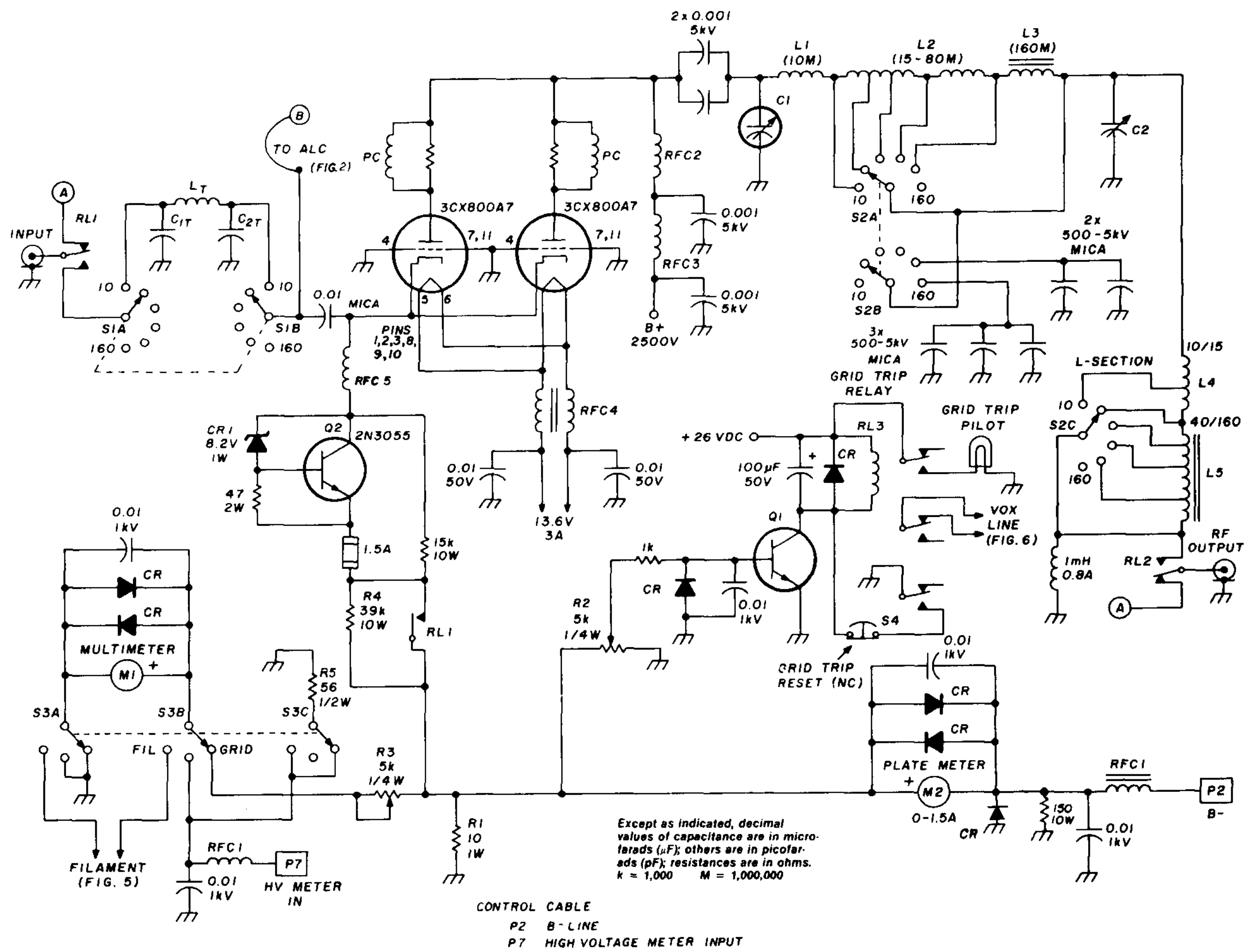


fig. 1. 3CX800A7 RF deck schematic.

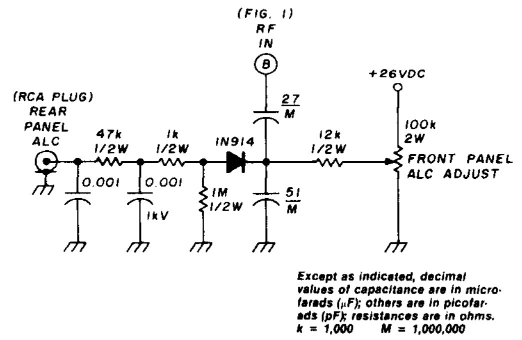
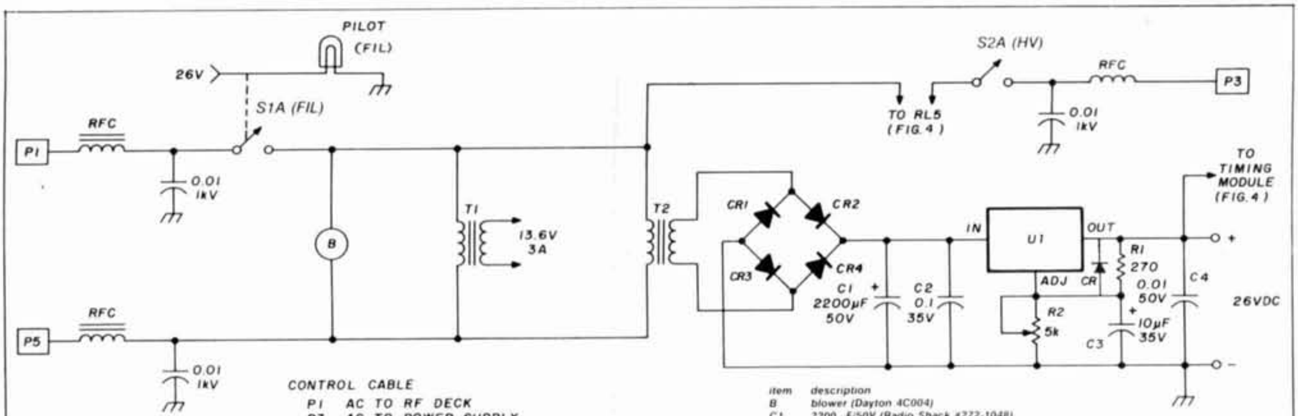


fig. 2. ALC module schematic.

grid-trip protection circuit

A grid trip module has been included to disable the amplifier should the grid current rise to levels dangerous to the tubes. A pair of 3CX800A7s is rated for a maximum grid current of 120 milliamperes (mils). Under normal operation, a pair of tubes draws about 30 mils. Therefore, I have the circuit adjusted to trip at 90 mils of grid current. When the circuit trips, relay RL3 (see **fig. 1**) is actuated which breaks the VOX line, thus deactivating the amplifier and lighting the "grid trip reset" push button on the front panel of the amplifier. It is necessary to push the RESET button to put the amplifier back into operation. Of course, one should determine why the amplifier exceeded 90 mils before resetting.

The circuit is actually quite simple. As grid current flows through R1, a voltage is developed across the resistor. The grid trip actuates when transistor Q1 is turned on (approximately 0.6 volts appears on the base). For example, if the base of Q1 were tied directly to R1, 60 milliamperes would generate 0.6 volt ($E = IR = 0.060 \times 10 = 0.6$ *volts*). But this current is too low in normal operation to trip the grid current protection circuit. Therefore, a voltage divider is needed if a current different than 60 milliamperes is desired to actuate the grid trip. This voltage divider



CONTROL CABLE
P1 AC TO RF DECK
P3 AC TO POWER SUPPLY
P5 AC COMMON

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item	description
B	blower (Dayton 4C004)
C1	2200 µF/50V (Radio Shack #272-1048)
C2,4	0.1 µF tantalum (Radio Shack #272-1432)
C3	10 µF/35V (Radio Shack #272-1025)
CR	bridge diode 50 PIV/1.4A (Radio Shack #276-1151)
IC	LM317 adjustable 1.5A regulator (Radio Shack #276-1778)
RFC	10 turns No. 14 enamel wire on 1/4"-diameter ferrite rod
S1,S2	rectangular pushbutton switch (2 N.O. and 2 N.C.) (Newark) Alcoswitch 16TL5-22 Alcoswitch 6T-4 yellow lens Alcoswitch 6T-2 red lens
T1	13.6VAC/3A custom transformer (Peter Dahl)
T2	24VAC/1A Triad F46-X (Newark) (Radio Shack #273-1480)

fig. 3. Control circuit, 26 volt DC power supply.

parts list for fig. 1

item	description
C1	500 pF/3kV vacuum variable (air variable can be substituted)
C2	850 pF/1kV air variable
CR	1000 PIV/2.5A (RS 276-1114)
CR1	8.2V zener diode, Motorola 1N4738 (Newark)
C_{1T},C_{2T}	(see table 1)
L_T	(see table 1)
L1-L5	(see table 2)
M1,M2	Triplett model 220G, 1 mA movements (152-0152), Bezels No. 13-238 M2 shunted to read 1.5A full scale
PC	4 turns No. 10 buss wire wound around 3 150 ohm 2-watt carbon resistors in parallel
Q1	2N3053 (RS 276-2030)
Q2	2N3055 (RS 276-2041)
RFC1	10 turns, No. 14 enameled wire on 1/4-inch diameter ferrite rod
RFC2	plate choke from Drake L7 amplifier
RFC3	11 turns No. 14 enameled wire, 5/8-inch diameter
RFC4	22 turns bifilar, 4-inches long on a 1/2-inch diameter ferrite rod
RFC5	70 turns No. 18 on 1/2" diameter nylon rod
RL1	(see fig. 6)
RL2	(see fig. 6)
RL3	4PDT Potter and Brumfield KHU17D11/24 VDC coil (Newark)
S1	2 pole/6 position, Centralab PA2003 (Newark 22F603)
S2	model 86 non-shorting switch, 3 pole, 6 position at 30 degree indexing (Radio Switch)
S3	3 pole/3 position 1 section, Centralab PS109 (Newark 22F777) or Centralab 2507 (Newark 22F414)
S4	momentary pushbutton 1 N.O., 1 N.C. ALCO 16SL-11 switch ALCO 6S-2 red lens

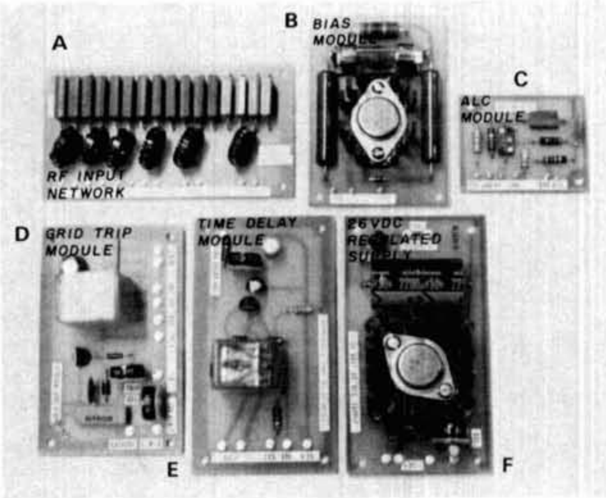
tube sockets: EIMAC SK1900
tube chimneys: EIMAC SK1906
tube clamp: EIMAC SK1916
cabinet 7 × 17 × 14 inches, CTS model MCLS-71714, SPP-714 side panels, CP-1714 chassis plate

*parts suppliers:

name and address	name and address
CTS Interfab 660 Lenfest Road San Jose, California 65133 Tel: 408-251-1600	Newark Electronics 500 N. Pulaski Road Chicago, Illinois 60624 Tel: 312-638-4411
	Radio Shack Local stores
Peter Dahl Transformer Co. 4007 Fort Blvd. El Paso, Texas 79930 Tel: 915-566-5365	Triplett Corporation 286 Harmon Road Bluffton, Ohio 45817 Tel: 419-358-5015
W.W. Granger (Dayton) P.O. Box 44289 Columbus, Ohio 43204 Tel: 614-276-5231	Radio Switch Corp. Marlboro, New Jersey 07746 Tel: 201-462-6100
R.L. Drake Co. 540 Richard Street Miamisburg, Ohio 45342 Tel: 513-866-2421	RS = Radio Shack™

is created with the trim pot R2, which can be used to adjust the level at which the circuit trips (Q1 is turned on).

If Q1 turns on, relay RL3 actuates, grounding the relay coil and taking the load off transistor Q1. If this feature were not provided, the transistor would start gating the amplifier on and off. Therefore, it is essential to latch the grid trip relay closed. When RL3 is closed another set of contacts breaks the VOX line,



All circuit boards are made from glass epoxy boards and laid out using dry transfers from Radio Shack. (Letter codes refer to ready-to-use PC board artwork printed on page 139.)

disabling the amplifier. Another set of contacts applies power to the grid trip reset pilot light on the front panel indicating to the operator what has happened. Pushing the reset button on the front panel breaks the coil line, which in turn unlatches relay RL3 and puts the amplifier back into normal operation. (See grid trip module PC board and component layout.)

I have used this circuit in several different amplifiers. It is a good addition to any amplifier that you might build considering the high price of tubes.

solid-state timing module

The 3-minute timing circuit used to insure proper conditioning of the 3CX800A7s cathodes is shown in **fig. 4**. When the 26 VDC power supply comes on, current begins to flow through the 5.5M resistor R1,

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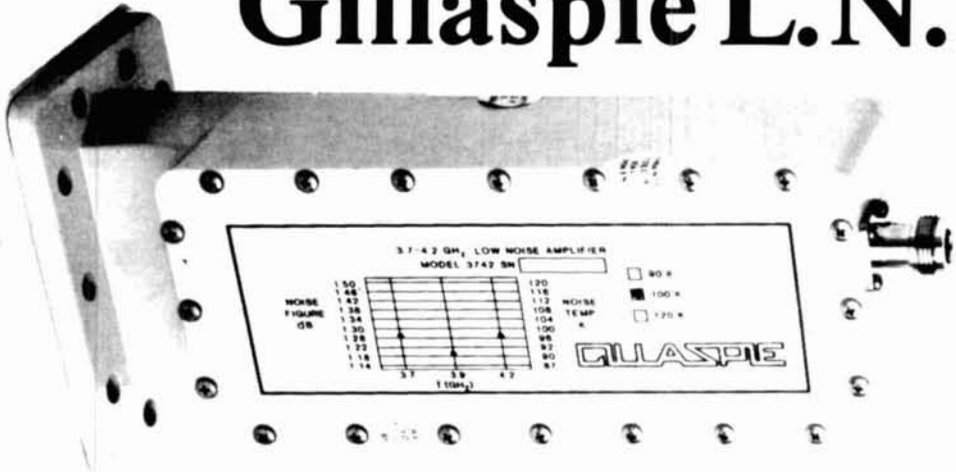

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- 120°K Max. Noise Temperature (GLN - 3742 - 120)
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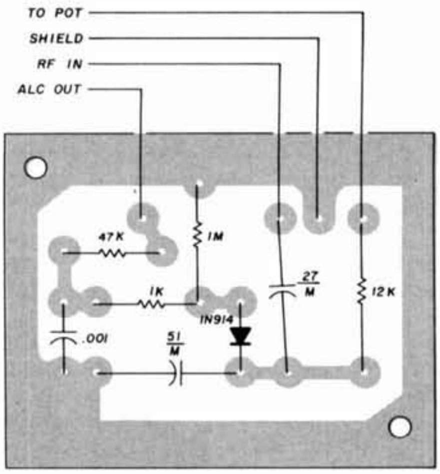
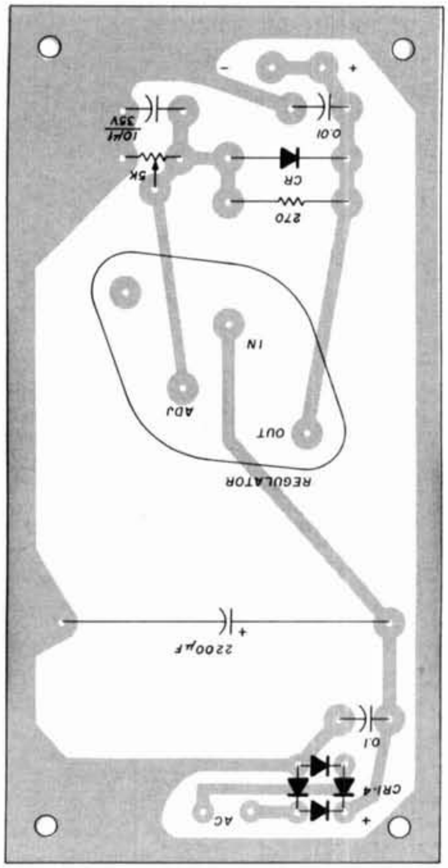


ALC module (component view).

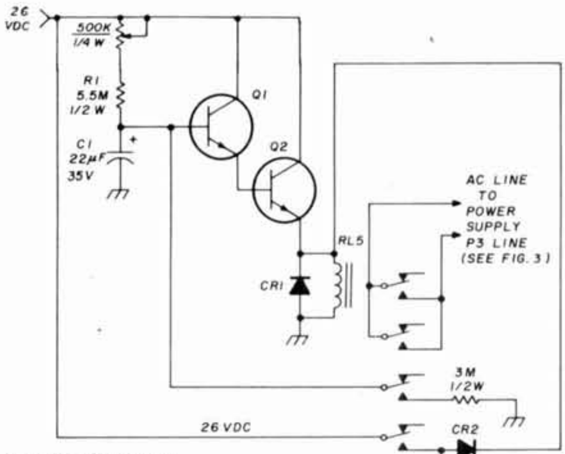
charging the 22 μF capacitor, C1. As C1 charges, the voltage is applied to the base of a Darlington configuration (Q1 and Q2) which forms an emitter follower circuit. Therefore, the emitter of the Darlington follows the voltage charge on capacitor C1. The Darlington is necessary to present a high impedance to C1 which would otherwise drain through the transistor. Relay RL5 is a 12 VDC relay that actuates at approximately 8.1 volts. Therefore when the voltage on C1 causes the emitter of Q2 to reach 8.1 volts, relay RL5 actuates allowing amplifier operation. Of course, this takes approximately 3 minutes.

Relay RL5 is a 4PDT relay. Two poles are wired in parallel and apply power to the HV power switch located on the front panel. Therefore, the HV power supply cannot be turned on during the warm-up period. Another set of contacts on RL5 is used to connect a 3-megohm resistor to C1 to discharge the capacitor thus resetting the timer module. This is a protective circuit to insure that a 3-minute warm-up cycle occurs should the amplifier be turned off for a short time and then turned back on. The fourth set of contacts serves three purposes. First, the meter lights come on, indicating an amplifier-ready condition. Second, 26 VDC is sent to the hot side of relay RL5 in the timing module itself thus latching the relay. This takes the power load off the Darlington and allows the reset function discussed above. Diode CR2 prevents the voltage on the VOX line to rise with the emitter on Q2. Third, 26 VDC is sent to the VOX line to allow the amplifier to be keyed up.

Note that it is extremely important to get a high impedance Darlington with very low leakage current to make this circuit work properly. I originally tried three different single package Darlingtons with no success. The transistors used are readily available



26 VDC regulated power supply (component view).



Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms.
k = 1,000 M = 1,000,000

item	description
CR1,2,3	2.5A/1000 PIV (RS* 276-1114)
Q1	2N2222A (RS* 276-2009)
Q2	2N3053 (RS* 276-2030)
RL5	4 PDT, 12 VDC coil (RS* 275-214)

*Parts supplier

fig. 4. Solid-state time delay schematic.

from Radio Shack and I recommend you use these exact components. (See timer module PC board and component layout.)

operating bias circuit

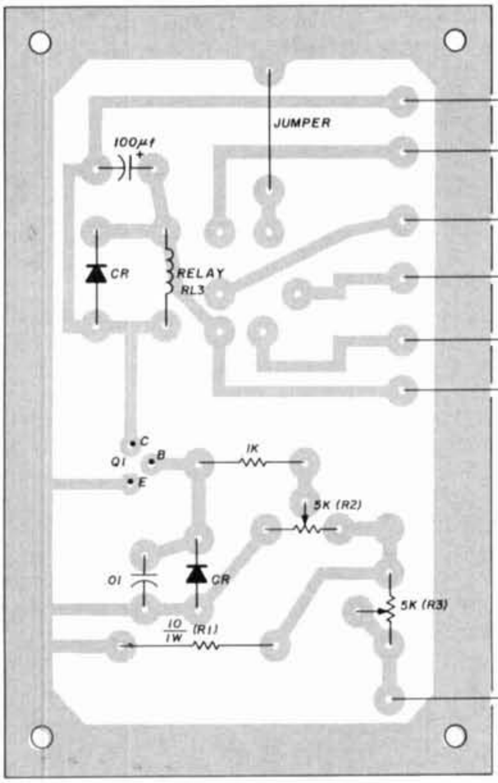
Operating bias is generated through use of a high-power 2N3055 NPN transistor (Q2) which is biased by a 1-watt zener diode to function as a high power zener (see **fig. 1**). This circuit includes readily available components and provides an easy way to adjust the bias voltage merely by changing the 1-watt zener diode between the base and collector of the 2N3055. This amplifier is biased with 8.2 volts which results in a 40 milliampere zero signal resting plate current.

This circuit is much easier to work with than the more conventional 50-watt zener diodes. Here in the Midwest the 50 watt TO3 case zeners are very expensive special order items.

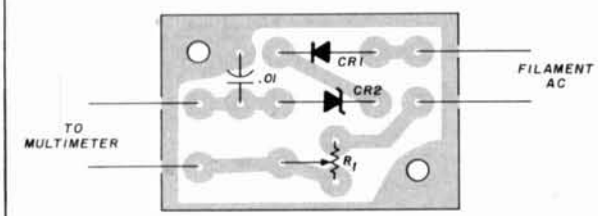
The bias circuit also has a 1.5 amp fuse to protect against excessive current. The current flowing through this circuit is the sum of the plate and grid current drawn by the tubes.

In the standby mode, the amplifier is biased to cut off (i.e. zero static plate current) by voltage generated by the current flow through the 39K resistor, R4. The resistor is shorted in the transmit mode by a set of contacts on the RF input relay RL1.

The bias circuit in the amplifier has been constructed as a single module. The module is located on the side wall of the cabinet next to the tube sockets and RF choke RFC5. (See bias module PC board and component layout.)



Grid trip module (component view).



Filament voltage meter module (component view).

metering circuits

Metering is provided for plate current, grid current, high voltage, and filament voltage.

Plate current is monitored at all times. This meter is in series with the B− lead.

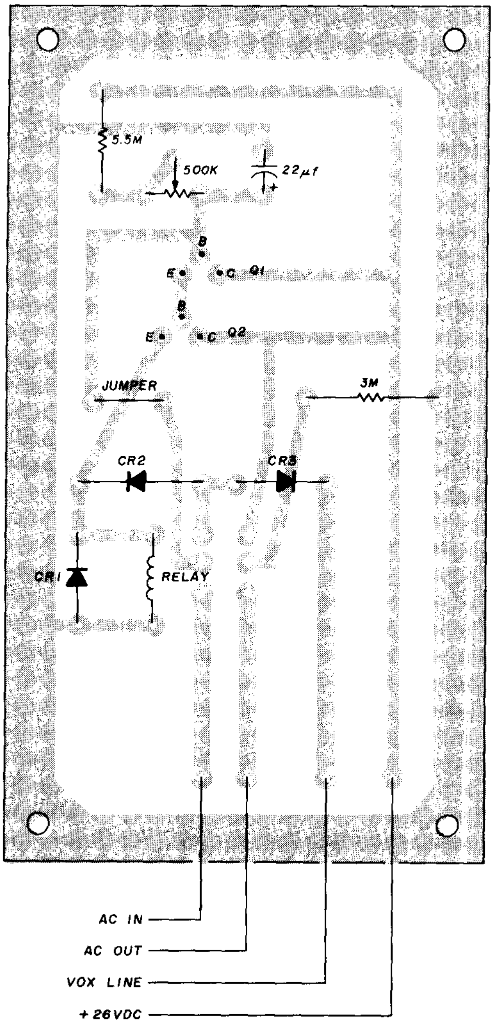
The other metered values are selected on the multimeter. The meter can be anything from a 100 microampere meter to a 5 milliampere meter full scale. You can make any of the meters work by choosing the proper calibration resistor. I used a 1 mA movement.

Grid current is measured by monitoring the voltage across the 10-ohm resistor (R1) through which grid current is drawn (refer to the discussion on the grid-trip module). Trim pot R3 is used to calibrate the meter to read full scale when 100 milliamperes is drawn through R1.

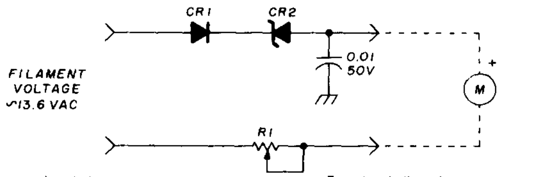
High voltage is measured by monitoring a low voltage value developed by a voltage divider in the power supply. This voltage should be kept very low since it is sent through the control cable that connects the amplifier to the power supply.

Filament voltage is very simple to monitor (see **fig. 5**) and often an ignored value in amplifier designs. A filament voltage that is too high can lead to premature tube failure. The meter has been calibrated from 10 to 15 volts. A 9.1 volt zener diode and a silicon diode are used to convert the AC filament voltage to DC and allow the bottom scale on the meter to be approximately 10 volts. No current flows in the metering circuit until the voltage across the zener diode exceeds 10 volts. (See filament voltage metering PC board and component layout.)

Labeling the meters takes a lot of patience but really contributes to the appearance of the amplifier. It is necessary to choose a meter with an analog scale that has the correct number of divisions. However, the meter labeling makes no difference. In a very clean environment, remove the meter plate from the meter.



Timer module (component view).



item	description
CR1	1 kV/2.5A (Radio Shack #276-1114)
CR2	9.1 volt Zener diode (Radio Shack #276-562)
M	1 mA multimeter
R1	25K potentiometer/1/4-watt

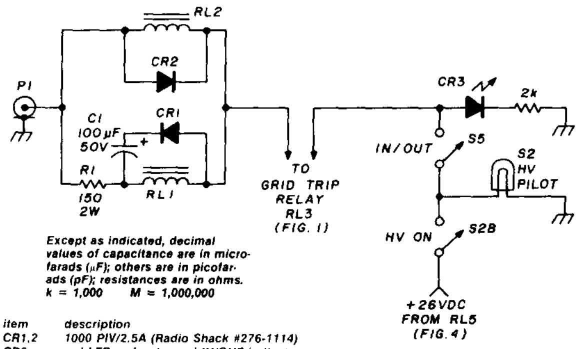
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms. k = 1,000 M = 1,000,000

fig. 5. Filament voltage metering circuit.

Any markings on the meter can be removed with a pencil eraser. Rub lightly, but be persistent. The markings will come off the face leaving a clean surface to which the number and letter markings can be applied. I use dry transfer lettering to mark the meter plates to reflect the scales I want to read. Dry transfers are now available from Radio Shack but the letters may be too large for small meters. Varied assortments of smaller letters are available from most art supply stores.

RF relay sequencing

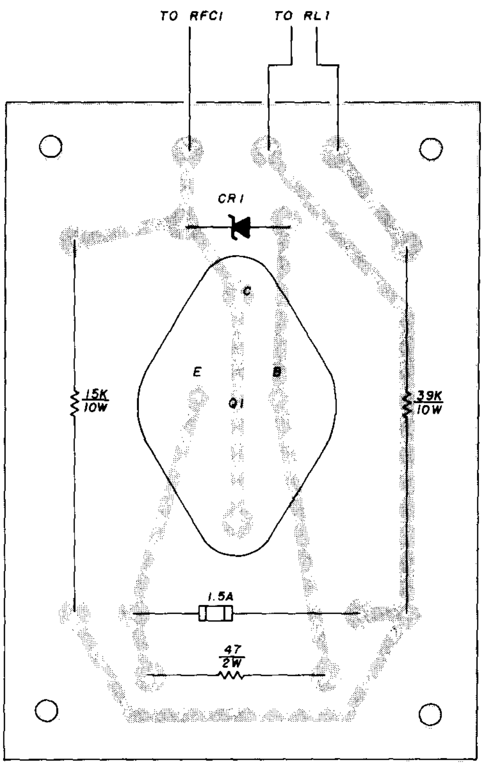
It is important to properly sequence the input RF relay (RLI) and the high power output vacuum relay (RL2) to insure that the antenna is always connected to the amplifier before RF drive power is applied. This



Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms. k = 1,000 M = 1,000,000

item	description
CR1,2	1000 PIV/2.5A (Radio Shack #276-1114)
CR3	red LED — front panel IN/OUT indicator
P1	RCA plug/rear panel
RL1	4 PDT Potter & Brumfield KHU17D11/24 VDC coil (Newark)
RL2	SPDT vacuum relay, 26 VDC coil (Hamfest) alternate — Potter & Brumfield KUP5D15/24VDC coil (Newark)

fig. 6. RF relay sequencing circuit.



Bias module (component view).

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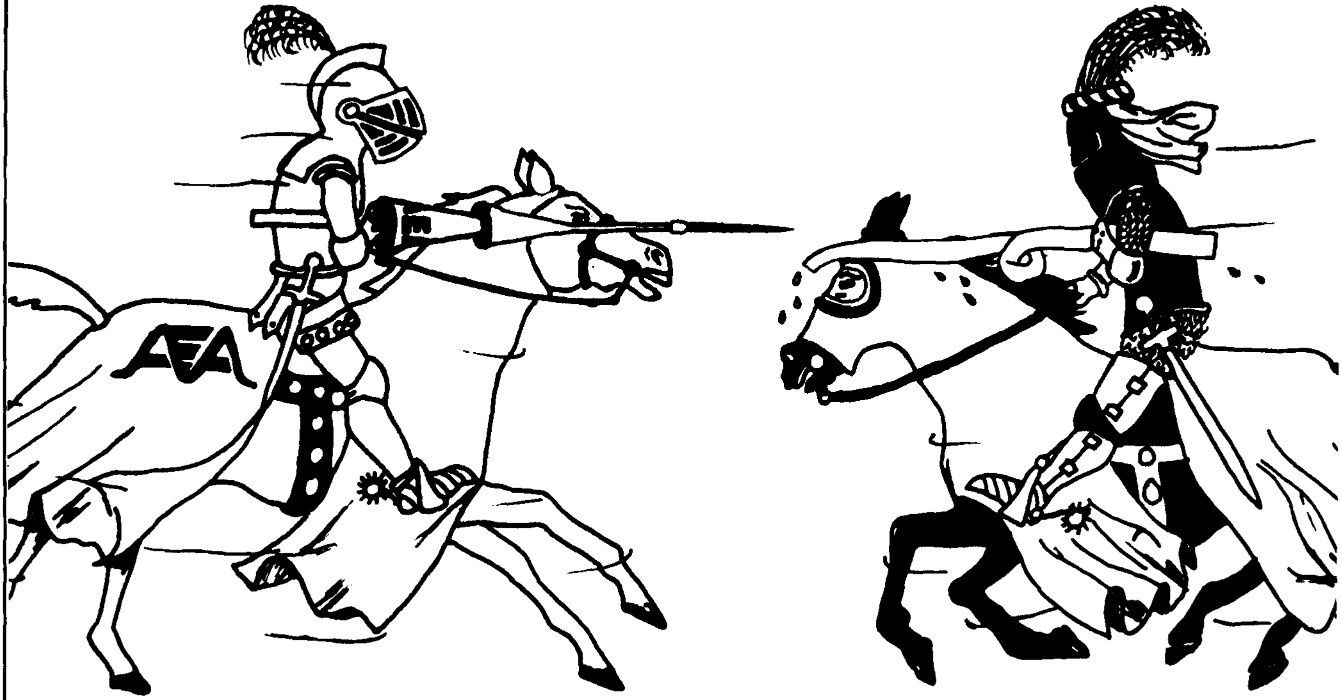

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Lumberton, NC — You really do what you say! The best 2 mtr. antenna I have ever owned!

La Habra, CA — Hooked up today, and it was a perfect match throughout the entire band. For the money, you can not go wrong.

Tok, AK — Truly a fine antenna, working better than the five element yagi it replaced.

Sacramento, CA — Assembly was remarkably easy, I needed an efficient, low profile antenna & your product fit the bill to a "T".

Warsaw, IND — AMAZED!!! Antenna ground mounted on required mast & outperforming a (R.R.) at 55' on top of tower.

Loris, SC — I'm a commercial radio salesman, and the Isopole is THE antenna I recommend.

Seattle, WA — Works well — excellent. Had (R.R.) at 80'. With the Isopole at 20 ft. I now hear repeaters and simplex I never heard with (R.R.) The Isopole will soon be at 80'.

Freehold, NJ — It is everything your ad says and more.

Great Neck, NY — Amazing difference between (R.R.), 10 db or better, raise rept. never heard before — SUPER, 73 and thanks.

Richfield, OH — Works extremely well, broke a repeater at 100 mi using 150 mw !

Vernon, TX — (The dealer) said the antenna WAS THE BEST ON MARKET and I AGREE! It IS AN EXCELLENT antenna & works to specs -Thanks.

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✓ 145

is accomplished by closing the output relay RL2 slightly before the input relay RL1.

The R1-C1 combination, shown in **fig. 6**, causes RF relay RL1 operation to be delayed with respect to RL2.

I checked the timing by applying a small voltage across the contacts of both RL1 and RL2 and watching the voltages on the scope as the amplifier was keyed up. The output relay RL2 closes approximately 25 milliseconds before the input relay RL1. The timing constant provided by R1-C1 is subject to change depending upon the type of relays used for RL1 and RL2.

lead filtering

All control and power leads entering or leaving the RF deck are filtered. This is accomplished through the use of small coils made by winding 10 turns on a 1/4-inch (6.35 mm) diameter ferrite rod. A bypass capacitor is included on each coil to ground. Locate each filter as close to the rear panel as possible.

Also, feedthrough capacitors are used to filter all leads from the under chassis RF section of the amplifier to the front section meter compartment (see bottom view of the amplifier). All circuits that are sensitive to RF are mounted in this front compartment.

Pi-L tank circuit design

The tank circuit uses the popular Pi-L design for two reasons. First, a Pi-L gives approximately 15 dB better attenuation of the second harmonic over a more conventional Pi design. Secondly, a Pi-L allows use of a lower value plate tuning capacitor for the circuit.

The design parameters for the Pi-L circuit are provided in **table 1** (see also reference 3). The values shown in **table 1** are for a plate impedance of 1200 ohms.

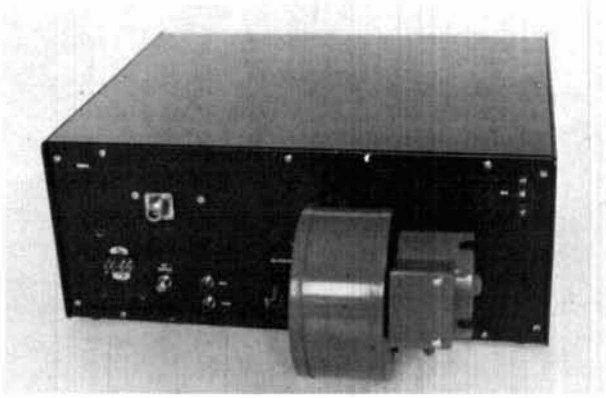
$$\textit{plate impedance} = \textit{plate voltage}/(1.57 \cdot \textit{plate current}) = 2250/(1.57 \cdot 1.2) = 1194.3$$

Because of a limitation of 500 pF for the plate tuning capacitor C1, the design for 160 meters is for a plate impedance of 2500 ohms. This translates to 570 mA plate current at 2250 volts or 1289 watts input. This provides about 700 watts output. I felt that this was sufficient power. If full power is desired on 160, some method of adding additional capacitance is needed.

Several coils are required to obtain the desired inductance. Specifications for these coils are contained in **table 1**. Note that the 160 meter and L coils are wound as toroids for compactness. Also, the self-shielding characteristics of the toroids help especially in isolating the L coil from the rest of the tank circuit.

It has become apparent to me that the one place most Amateurs feel uncomfortable is designing and installing the tank circuit in an amplifier. There always seems to be uncertainty about where to tap the coils to achieve the desired design no matter how many times you do it.

I first use a Heathkit impedance bridge to determine the approximate capacitance at various settings of the tuning knobs. I then take a high-tolerance fixed capacitor and connect it in parallel with the tank circuit at different points to determine approximate inductances of the coil set. This is done with the coil set in place in the amplifier, but with the plate and load tuning capacitors disconnected. The tubes are also re-



Rear view of amplifier shows Dayton 4C004 blower.

table 1. Pi-L tank circuit values.

F(MHz)	C1	C2	L1	L2	*Q*
1.8*	462	2121	22.02	8.90	13.1
3.5	469	1443	6.25	4.45	13.4
7.0	235	656	3.23	2.44	12.4
14.0	116	320	1.65	1.24	12.2
21.0	77	213	1.10	0.83	12.2
29.7	54	146	0.80	0.60	12.0

*R_L = 2500 ohms I = 570 mA or 1289 watts input
(1200 ohms for all other frequencies)

Coil description:

28 MHz — 3/16 inch tubing: 3-1/2 turns with 1-3/4 inch diameter

21 to 3.5 MHz — 3/16 inch tubing; 14 turns with 2-3/4 inch diameter

taps: 21 MHz — 1-1/2 turns
14 MHz — 3-1/2 turns
7 MHz — 7-1/2 turns
3.5 MHz — 13-1/2 turns

1.8 MHz - toroid; 3 × T200-2s covered with fiberglass tape; 26 turns

L-coil

28 to 21 MHz - No. 12 tinned wire; 1-1/8 inch diameter, 5 turns

taps: 28 MHz — 3 turns
21 MHz — 5 turns

14 to 1.8 MHz — toroid; 2 × T200-2S covered with fiberglass tape; 17 turns

taps: 14 MHz — 2 turns
7 MHz — 6 turns
3.5 MHz — 9 turns
1.8 MHz — 17 turns

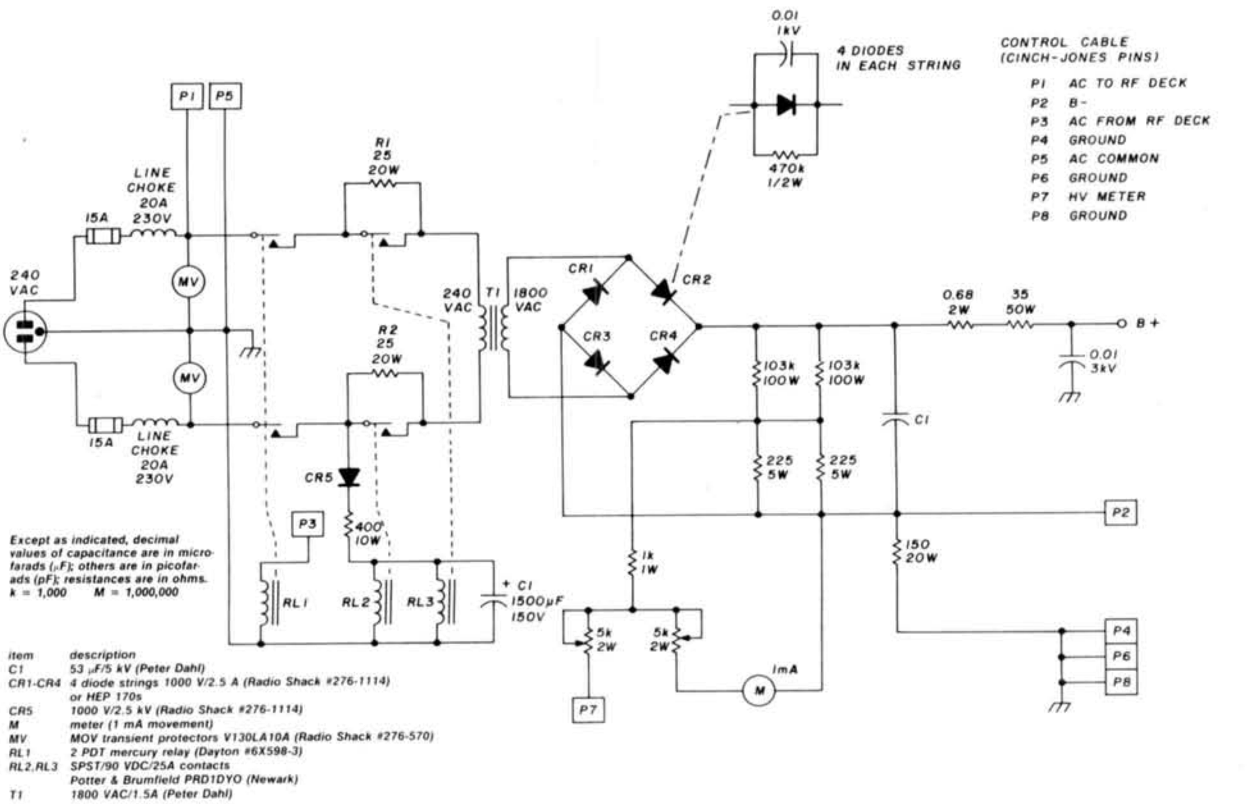
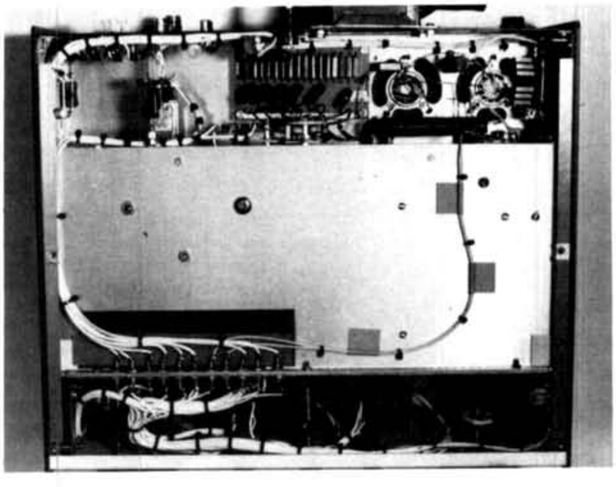


fig. 7. 3CX800A7 amplifier HV power supply.



Bottom view: all leads enter front compartment through 0.001/500-volt feedthrough capacitors.

moved. The frequency is determined by measuring the circuit resonance with a grid dip meter. The frequency (f) is used in the following formula to calculate the inductance:

$$L = (10^{12})/(4\pi^2 f^2 C) \tag{1}$$

The inductances required are listed in **table 1**.

The next step is to put a 50-ohm carbon composition resistor on the output of the tank circuit to simulate an antenna load. Then set the tuning capacitors at the design values for the band being considered, allowing approximately 12 pF for tube interelectrode capacitance. Using the grid dip meter, locate the tap on the coils to obtain resonance of the circuit. The approximate setting was determined by measuring the inductance at various points with the fixed capacitor, earlier.

This method of finding where to tap the coils is effective. In operation, the setting of the tuning capacitors is almost exactly where I had predicted, using the procedure described above.

I recommend that you go through this procedure even though I have presented, in **table 1**, a design complete with taps. Variations in physical layout of the inductors and stray capacitances unique to any single amplifier could affect the exact tap settings in the Pi-L tank circuit.

input network

The input network is designed for a Q of 1. The network, ganged to the main bandswitch, provides a separate pi-network section on each band. **Table 2** summarizes the component values for each pi-section.

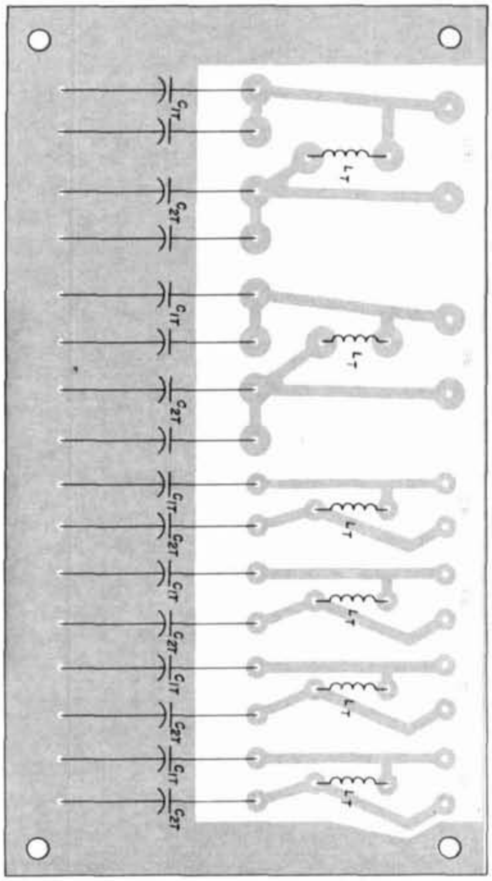
table 2. RF input network.

F(MHz)	C1*	C2*	L(μH)	No. of turns (No. 20 wire)†
1.8	1700	642	2.75	22
3.7	827	312	1.34	15
7.1	428	162	0.69	11
14.1	216	82	0.35	8
21.2	144	55	0.23	6
28.5	107	41	0.17	5

*Use standard values near these theoretical values. Anything close to table values is OK since the Q is so low.
†Coils wound on T68-2 toroid cores. $Q = 1$.

The coils are wound on T68-2 toroid cores. Input impedance for a pair of 3CX800A7s is approximately 29 ohms. The input network is important not only for impedance matching for the exciter but also to minimize distortion products.

Fine tuning of the networks can be accomplished by either spreading or compressing the coil turns on each core for minimum SWR on each band, respectively. Exact replication of the network from **table 2** may still require some small adjustment due to variations in component tolerances and differences in physical layout.



RF input (component view).

The network is built as a module on a separate PC board. A board layout has been provided.

cooling

Sufficient cooling is essential in any high power amplifier.[5] The 3CX800A7s require forced-air cooling to maintain the anodes and seals of the tubes at safe operating temperatures.

The specifications for cooling are summarized as follows:

5000 feet above sea level

dissipation (watts)	flow rate (cfm)	water pressure (inches)
400	7	0.10
600	14	0.23
800	23	0.57

Refer to the 3CX800A7 technical sheet[4] for more information on cooling at different altitudes.

The blower used in this amplifier is a Dayton model 4C004 which is capable of supplying 45 cfm at 0.4 inch static pressure. The operating speed of the blower is 2880 RPM, which is slow enough to assure relatively quiet operation.

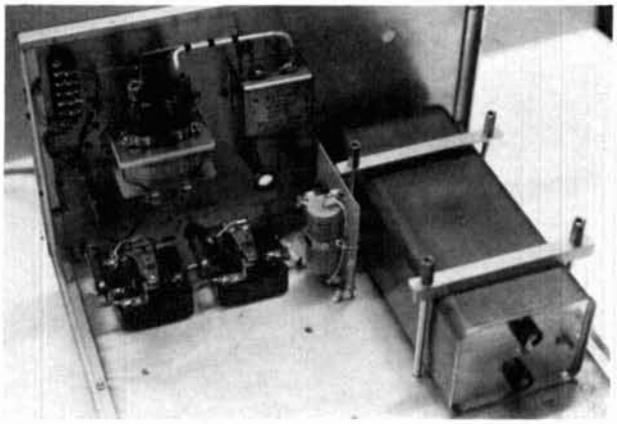
To obtain the legal 1500 watts output requires that the amplifier run at approximately 2500 watts input assuming 60 percent efficiency. This means that the amplifier is dissipating about 1000 watts which is well below the capabilities of the tubes.

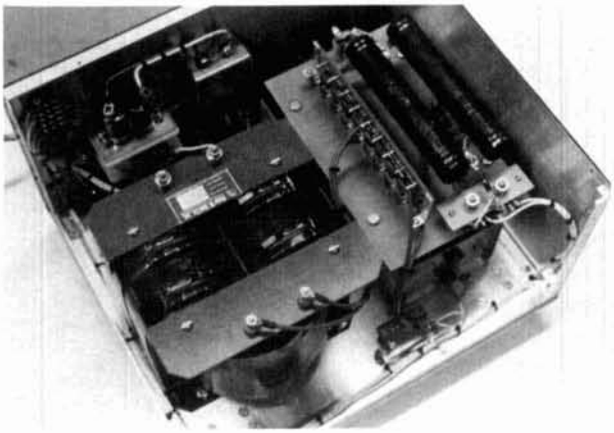
The blower mounts on the rear panel of the amplifier and blows air into a pressurized chassis. The air vents up through the tube anodes and out the top of the cabinet. I plan to eventually make a duct flange to mount in place of the blower on the rear panel and remote the blower where it can not be heard. Flexible hose will duct the air from the remote blower to the amplifier.

high-voltage power supply

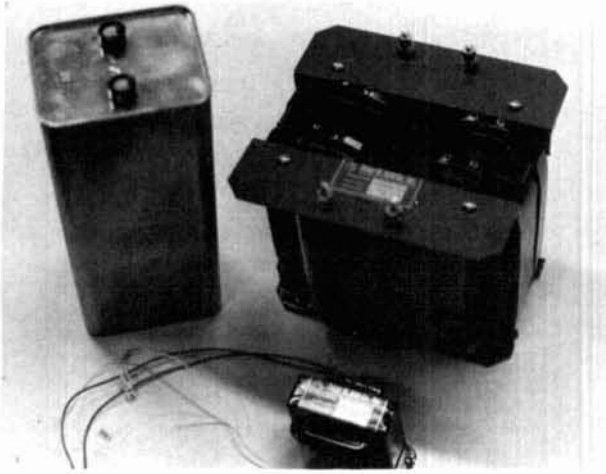
One key to optimal performance of any amplifier is the power supply. It takes a supply that not only holds regulation under maximum current draw but also can supply the needed current. This translates to a quality transformer and plenty of filter capacitance. This is the area in which many commercial amplifiers fall short.

The circuit for the power supply is shown in **fig. 7**. The supply operates off of 240 VAC and incorporates a step-start circuit. When the HV switch is pushed on the front panel of the amplifier (assuming the warmup time delay has expired), 110 VAC is returned to the power supply to actuate the mercury plunger relay, RL1. This sends 240 VAC to the HV transformer through the dropping resistors R1 and R2. This avoids





2500-volt high-voltage power supply. Cabinet is constructed from 1/8-inch aluminum panels joined with 1/2-inch angle stock.



Custom plate and filament transformer, 53-μF filter capacitor. (Available from Peter Dahl Co., Inc.)

a current surge in the supply to charge the 53 μF filter capacitor, C1. A surge could damage the diode bank. After approximately 2 seconds, relays RL2 and RL3 actuate to short out resistors R1 and R2 thus turning the HV supply on to maximum voltage.

The 2-second delay is accomplished by the time constant set up by R3 and C1. 110 VAC is rectified using diode CR5 and proceeds to charge capacitor C1. When the DC voltage on C1 reaches approximately 60 VDC, the DC relays RL2 and RL3 close (relays RL2 and RL3 have 90 VDC coils). This takes about 2 seconds.

Metering is accomplished across the voltage divider created by the 103K bleeder resistors and the pair of 225 ohm resistors. This drops the voltage in the control cable to the amplifier to approximately 5.5 volts. A voltmeter is also included in both the RF deck and power supply cabinets. Note that the meter calibration pots must be adjusted together since they affect one another.

The plate transformer used in the HV power supply was supplied by the Peter Dahl transformer company. A 2.8 kVA CCS hypersil unit is designed specifically for a pair of 3CX800A7s; the unit, now a stock item, is available at a reasonable price. Under no-load conditions, the supply provides 2520 volts. Under a load of 1.2 amperes, the transformer output voltage drops to about 2300 volts! If you want the most out of an amplifier like this one, you need a power supply with a transformer of this high quality.

Peter Dahl also stocks a filament transformer for a pair of the 3CX800A7s (13.6 volts at 3.0 amperes). Both the filiment transformer and the plate transformer are well worth the investment. At the time of this writing, Peter Dahl also stocked the 53 μF filter capacitors rated at 5 kV.

concluding remarks

Building around the 3CX800A7s is a real pleasure. Their compactness and low voltage requirements open up a wide range of projects for compact amplifiers that do not have to sacrifice power capability. The thing that makes the tubes unique is that they are designed for full power operation up to at least 350 MHz.

My thanks to those who contributed so much to this project: Rich Rosen, K2RR, Bill Orr, W6SAI, Dan Redman, K8DR, and Peter Dahl. And last and most important, Jim Garland, W8ZR, who taught me how to build.

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Turn to page 139 for a complete set of ready-to-use PC board artwork (foil side) for the project described in this article. — **Editor**

ham radio

junk-box ingenuity: how to buy, use, and recycle surplus electronic parts

Don't throw away resistors and capacitors — *cook them*

At one time, a well-stocked junk-box was a ham's pride and joy. Parts scavenged from discarded televisions, radios, and record players could be used to build anything from test equipment to transceivers. Using vacuum tubes, 1/2 watt 10 and 20 percent resistors, ceramic disk and dipped mylar capacitors, almost any circuit could be built for use up through 450 MHz.

Today's junk boxes are different; chances are they contain odd parts from scavenged surplus boards or parts bought by mail or as assortments at hamfests. They contain various types of semiconductors, 5 percent tolerance resistors, electrolytic and tantalum capacitors, as well as the old stand-by ceramic disks.

Despite the differences in content, all junk boxes are alike in one regard: by definition, they are where parts are stored for long periods until used. Storage takes a toll on electronic components, although much of it is reversible; before examining this, let's consider the parts themselves.

The average ham always seems to be looking to buy new, prime, MIL-spec parts at hamfest prices. Unfortunately such parts are usually not available to the small buyer at any price, although some manufacturers will sell directly to individuals. As a result we buy blister-packed parts at Radio Shack, or by mail from any number of suppliers. While nearly all of these dealers are reputable, the parts you get may not always be exactly what you originally had in mind.

what is "surplus"?

Consider, for example, the origin of parts termed "surplus." Sometimes a company accidentally overpurchases some new parts and instead of paying a restocking charge, elects to sell them to a surplus agent; *these are the parts you want.* Sometimes a manufacturer discovers that a part from one company — often a semiconductor — works in their circuit, while another company's equivalent doesn't. If no other use for them can be found, they will either be thrown away or sold as surplus. (Since the fault lies within the idiosyncracy of the design, the parts are usually not returnable.) *These may also be good parts.* An important point to remember is that most large buyers of parts have sufficiently amicable relations with their suppliers to return *good* parts for credit.

There's another end of this spectrum: from time to time a manufacturer buys parts that don't meet specifications, but can't be returned for some reason. These will occasionally end up on the surplus market. A component manufacturer, for example, may produce a run of products that is not in "spec." While these are most frequently discarded (although garbage cans are sometimes raided) they may be sold to the surplus market. It has even happened that manufacturing runs of semiconductors have been stolen before testing and culling of rejects can be completed; obviously, you don't want *these* parts.

The surplus boards on the market are of a few basic types:

- those that have lived out their expected life and are now experiencing a high failure rate;
- boards made obsolete by a change in design;
- seriously damaged and therefore non-repairable boards (damage can include degradation of critical areas, such as gold fingers; submersion in a solder wave; cuts from a mass lead trimmer; or other actions rendering the board electrically unfixable);
- boards simply overbuilt by a company; now and then a manufacturer will sell boards from inventory to raise some cash.

While surplus boards should not be expected to perform their original design functions, chances are that most of the components on all but the first type listed are usable. Even the unfixable boards rarely have more than a few bad components.

By Bob Lombardi, WB4EHS, 1874 Palmer Drive, Melbourne, Florida 32935

In general, then, there's no telling where "grab-bag" parts come from. They might be old or new, merely extras, or genuine junk. Given the diversity of parts from so many varied sources, it's no wonder that we occasionally build a project and find that it's a bad component that keeps it from working.

Take a clue from industry, then, and test your parts before using them. For ICs this may be impractical, but for many types of transistors, diodes, and, of course, resistors, capacitors, and coils, it is entirely reasonable.

are they out of spec?

Chances are that if you took out a DVM and tested every one of your ±5 percent carbon composition resistors, you'd find plenty of them out of tolerance. In particular, they'd all be on the high side of their marked value, perhaps as much as 7 to 10 percent above it. *Don't* throw them out.

The reason for these high values is something I alluded to earlier: improper storage. Carbon composition resistors are essentially carbon and impurities mixed into a binder and molded into shape. The resultant mixture is hygroscopic — that is, it absorbs moisture, which raises the resistance value. This phenomenon is entirely reversible, if the parts have not been over a flow solder (or through any other high temperature operation) while loaded with moisture.

The importance of this consideration depends on the intended use. With the exception of precise RC timing circuits, digital circuits are quite forgiving of resistor values. Analog circuits can be fussier, especially those (such as audio filters) requiring balanced parts or matched values. Most other circuits are less particular. In designing homebrew circuits, you frequently make up for these parts by various means, making the actual value, even if it is "wrong," the design value!

If you need to reverse the problem — i.e., *lower* the values — heat the parts to about 200 degrees F (93.3 degrees C) for a period of time appropriate to the size of the part: 25 hours for 1/8 watt, 50 hours for 1/4 watt, 75 hours for 1/2 watt, 130 hours for 1 watt and larger. If running your oven at 200 degrees for 50 hours or more is inconvenient or too expensive, you can construct a plywood box, line it with fireproof insulation, and add a light bulb or two for temperature control. Some experimenting is necessary for a controlled temperature, but I've seen similar boxes used by small companies for many purposes.

If you can't control the temperature accurately, err on the side of too cool rather than too hot; waterlogged parts heated beyond the boiling point of water will explode like popcorn. Using lower temperatures will necessitate leaving the parts in longer; just how long can be determined by removing parts from time to time and checking values.

handling capacitors

Manufacturers of ceramic capacitors also recommend a heat soak of a day or two at 200 degrees F prior to critical value measurement, although I've never seen a problem with this in industry. One manufacturer recommends heat soaking at 125 degrees C for 4 hours or 150 degrees C for 1/2 hour. This "de-ages" the part to its original value and effectively begins its life anew.

Electrolytic capacitors deform with time as a result of a breakdown of the dielectric layer, and should be reformed before use. This is done by applying the rated voltage to the part for 30 minutes through a current-limiting resistor; 1 K ohm is adequate for up to 100 VDC capacitors. Let the part "rest" for a day at room temperature.

The small aluminum electrolytic capacitors popular today may not be much of a bargain if garnered from surplus boards. There are two reasons for this: first, they have a rated life of only 3 to 5 years, if run constantly; second, cleaning these capacitors in hot vapor degreasers will cause premature failure if the parts are not sealed with epoxy over the rubber seal plug on the cap. Of course, because you never know how used parts were handled, you'll have to decide whether to use them or not.

Tantalum, silver mica, polyfilm, and most other capacitors tend to be more stable in storage if their hermeticity is good. In general, if a capacitor is so damaged that the plates are visible, it should be thrown out. Minor chips and cracks may not matter; obviously no electrolytic should be used if its case is punctured or badly dented.

active devices require special handling

Transistors, diodes, and ICs in epoxy packages are quite rugged, but only if the seals are good. Beware of ceramic or glass packages, which can have hairline cracks.

Enough has been written about static damage that all hams should be aware of it. But less widely known is electrical overstress (EOS) due to a static field, rather than a discharge. This causes operation to degrade gradually, resulting in "flaky" operation (subtle timing errors that occur intermittently, some "soft" RAM failures, and so on) until the system degrades to failure. The only solution to this problem is prevention; with parts bought from anyone other than the manufacturer, there can be no guarantee that electrical overstress has not occurred.

By the way, don't think that this problem is only found in CMOS or MOSFETs. All semiconductor families, including bipolar, have been shown to be degradable by low-level fields of less than 1000 volts.

(Actually, once you've read some of the literature available on this topic, you begin to not want to handle semiconductors unless you've strapped yourself to a conductive table top with No. 2 battery cables.)

If you've measured parts and found them to be well out of spec, it may pay to consider the accuracy of your measuring device. Your meter (DVM, cap meter, LCR bridge, or other instrument) also has accuracy tolerances, and they can overlap with the part being measured. If your meter is rated ±3 percent, for example, and is running at the high end of its tolerance, any parts that are only 2 percent higher than their rated value will appear to be *5 percent* above, and thereby possibly out of spec. It's no wonder that calibration is so highly stressed in high quality operations!

Yet another factor is test method. Consider a common case: that hypothetical DVM you're using probably applies about 1 to 1.5 volts to a resistor during ohm measurement, and reads the current flowing in the circuit. With low value parts, such as those of 10K or less, this is fine; assuming 1.5 volts, the current being measured is 150 microamperes. With parts over 100K, say 1 megohm, the current is 1.5 microampere; this is somewhat harder to measure accurately, especially the detection of small differences in current. This is one reason why exacting specifications for resistor tests call out higher voltages for measuring larger value resistors.

Although this article might seem to emphasize problems — first telling you to measure your parts, then urging you to doubt your results — that's not at all my point; what I'm suggesting is that in order to buy parts intelligently, it helps to know where they came from and what to do with them when problems arise.

It seems strange to me that homebrewing should be on the decline today; this should be a "Golden Age" of homebrewing if there ever was one! Why? Just look at what's available! ICs that perform all manner of digital and analog functions are at our disposal, and most are quite cheap. Using reasonable parts counts, we can build circuits capable of performance that was no more than the stuff of dreams in the 1950s and 1960s; in the 50s, who would have dreamed of a 3-terminal voltage regulator! We can even build things more cheaply today than we could then; just look at old issues of the several Amateur Radio magazines, and you'll find that the dollar prices of gear are essentially the same now as they were in the mid-1960s; taking inflation into account, prices have come *down* considerably, while performance has gone *up*.

Keep a well-stocked junk-box, know what's in it, and do your part in restoring the Golden Age of homebrewed gear!

ham radio

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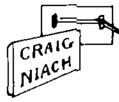

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Given a cost per unit budget for the CP-1, Al designed as much performance as possible into the Computer Patch, including a unique new tuning indicator, referred to by one of our customers as the "Dead Eye Dick" tuning indicator. This indicator is ideal for RTTY and CW, in that it is both fast to tune and (within 10 Hz) as accurate as scope tuning. It also performs under poor signal to noise conditions in which other indicators provide no useful data.

Al's variable shift tuning was designed to move the space filter center frequency from 2225 Hz to 3125 Hz without changing the bandwidth (by varying the Q of the filter). All this is accomplished using a precision ganged potentiometer to assure proper tracking of the multiple filter stages. We could have used a pot costing a tenth as much by simply using a two-pole filter design, but we feel the advantage of a sharper filter reduces the noise bandwidth significantly and allows the variable shift control to be used like passband tuning for extra elimination of adjacent channel interference.

Some manufacturers are concerned that amateurs might try calibrating their own equipment and, therefore, have used non-adjustable components, which results in sub-optimal performance. Although more costly, trimpots used in AEA equipment allow factory adjustment for performance to design specifications. Competently designed active filter circuits need not be adjusted after leaving the factory; however, for specialized use the owner can easily change filter parameters.

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Using this simple technique, professional looking air inductances (**fig. 1**) 2 to 4 inches (5 to 10 cm) in diameter with wire sizes No. 8 to No. 16, can be fabricated, at a cost of no more than about 25 percent of commercial coils.

easily obtained materials

This method is based on the use of a wood cylinder commonly called a *mandrel* (**fig. 2**). **Fig. 3** shows the dimensions of wood blocks which will produce a mandrel to fabricate 3-inch (7.6 cm) diameter coils. I have three such mandrels, 2, 2-1/2, and 3 inches (5, 6.4, and 7.6 cm) in diameter. This selection accommodates all my coil needs. **Fig. 4** shows the dimensions of a 3-inch (7.6 cm) diameter mandrel, in finished form.

Several choices of wire are appropriate. You can use the bare, soft copper wire (grounding wire) available in many sizes at building supply houses, or plastic covered solid wire stripped of its insulation. Enameled wire works well, but may present a problem if you intend to solder taps on the coil; the enameled insulation is difficult to scrape off. Tinned copper makes especially good looking coils, but while it's easy to solder, it may be difficult to obtain.

The coil supports are glass epoxy board cut into strips 12 inches (30 cm) long, 1/2-inch wide (13 mm) by 1/16-inch (1.6 mm) thick. I use discarded printed circuit board material, which can be cut easily with a hack saw. Just insert the blade of a knife under the copper foil and peel it off. Any remaining holes in the board will be filled with epoxy cement.

Sand one side of the PC board strips to remove the glaze and improve the bond between the cement and board. Do not use plexiglass or equivalent, which will deteriorate with exposure to heat or sunlight.

Other materials needed are 5-minute epoxy cement, kitchen type wax paper, some wood screws, a few rubber bands, and twine or plastic covered hook-up wire, the diameter of which will determine the wire spacing.

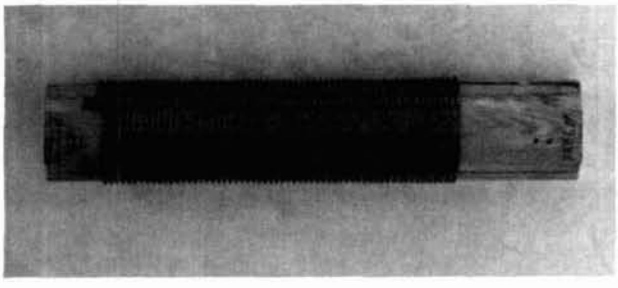

fig. 1. Finished coil on mandrel.

fabricating the mandrel

Fig. 3 shows two blocks of wood held together with wood screws. The screw heads are counterbored deeply enough to prevent interference with the turning operation on the lathe. Place the assembled block in a metal or wood turning lathe on the indicated centers. Shape this assembly into a tapered cylinder — while the tapered dimensions are not critical, tapering *is* necessary — per **fig. 4**. This is a simple job. If you don't have a lathe, a friend with a lathe should be willing to do this for you.

Grooves are cut using a table saw with a dado cutter of correct width. The insulating strips must fit loosely in these grooves; observe the tolerances shown in **fig. 4**. Grooves can also be cut with an ordinary blade on the circular saw by setting the blade to the proper depth. Cut one blade width at a time, rotating the mandrel to widen the groove progressively until it is wide enough. Because of the limited space available on its circumference, a 2-inch (5 cm) diameter mandrel can have only three grooves. These cannot cross the diagonal split; if they did, the mandrel would not slide apart. The finished mandrel is a cylinder split diagonally and tapered from one end to the other. It will slide apart freely after the coil has been wound and cemented.

winding the coil

Take the mandrel apart and insert three layers of wax paper between the two halves. This paper will allow the mandrel to slide apart easily. Put the man-

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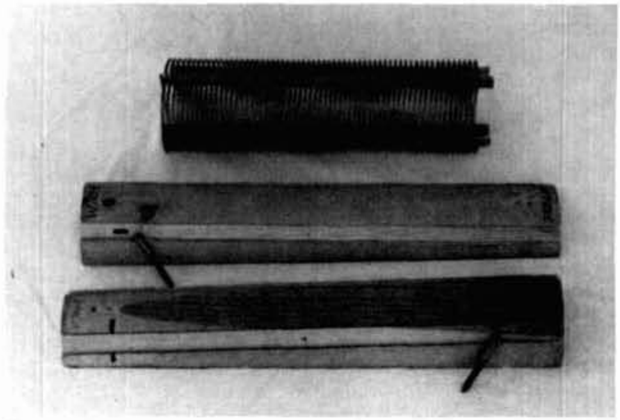

fig. 2. Finished coil with the mandrel removed and disassembled.

drel together with the screws and cover it with wax paper, allowing an overlap of about 1.5 inches (3.8 cm). Lay the glass epoxy strips (or cut epoxy board strips) in each groove, sanded side up, over the wax paper; they should fit in the grooves loosely, with play in the width as well as depth. Slip several tight rubber bands over the mandrel to keep the wax paper and strips in place. Center the strips and paper on the mandrel *lengthwise*.

Calculate the length of wire and twine needed to wind a 12-inch (30 cm) long coil by multiplying the number of turns you need times circumference of the mandrel. While you may not need this much coil, the leftover stock can be used for your next project and it's better to cut a piece too long than too short. Anchor one end of the wire securely, working outdoors if necessary for sufficient work space. Stretch the wire to remove all bends and kinks, then polish the wire with sandpaper for an attractive appearance. The epoxy cement will adhere better to the polished wire than to unpolished wire, and if you have to tap the coil, soldering will be easier.

Bend a hook in the free end of the stretched wire and fasten this hook to the wood mandrel, about 1.5 inches (3.8 cm) from one end with a wood screw. Lay out a length of twine the same length as the copper wire. Then wind the wire and twine on the mandrel tightly, parallel, removing the rubber bands as the winding progresses. The wound wire will hold the wax paper and strips in place. Wind the wire and twine tightly against each other to insure accurate spacing.

After the wire and twine are completely wound, fasten the wire to the mandrel with another wood screw, and remove the twine. Mix and apply only enough 2-part epoxy cement to cover one insulating strip sparingly, with no excess cement on the wax paper. If you've maintained the proper clearances on the wood mandrel, the insulating strip should move freely under the wire. Slide the strip back and forth,

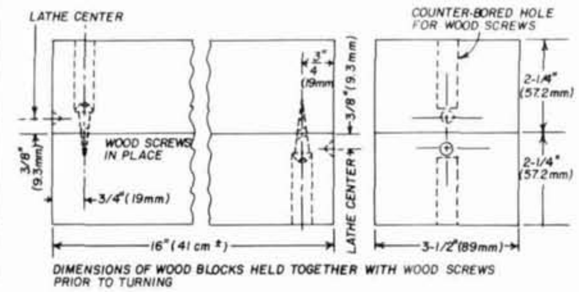

fig. 3. Wood blocks before turning. Offset turning centers are necessary to obtain a tapered split.

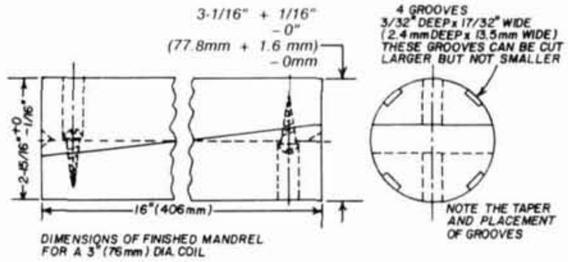

fig. 4. After the lathe turning operation, the mandrel is round and slightly tapered.

distributing the cement evenly between the wire and strip. Let it set for 5 minutes. Cement the other strips at 5-minute intervals. When cementing is complete, set the project aside overnight to allow the cement to harden completely.

removing the mandrel

Remove all wood screws anchoring the wire and holding the mandrel together. Place the mandrel vertically, larger end down, on the edge of a table. (The table should support the mandrel only up to the edge of the split.) Hit the smaller diameter split end with a block of wood. The mandrel will then slide apart easily. You now have a finished coil.

the end product

If you feel the finished coil needs more support, another layer of epoxy cement can be applied to each strip. I cement another strip on the coil for mounting purposes; this also makes a structurally stronger coil. In addition to strength and stability, this home-built coil offers high *Q* dissipating very little power even at the kilowatt power level. I have used coils built by this method in my trapped dipoles, antenna tuner, and final amplifier, with great success.

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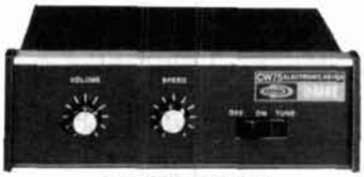

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improving amplifier ALC circuits: part 1

Grid current derived ALC helps upgrade AB2 amplifier performance

Part One of this article examines current ALC techniques and illustrates methods of improvement. Part Two details several modifications (including ALC) for input matching and tube protection in the compact MLA-2500 amplifier. **Editor**

Although modern exciters contain adequate ALC circuits, modern AB_2 amplifiers lack truly automatic practical circuits. In this article, several approaches to amplifier-developed ALC are examined and a practical circuit is developed, using a grid current derived sample. This circuit is used in a Dentron MLA-2500 to protect the 8875 tubes from overdrive and grid destruction. Adaptability to other tube types is also discussed.

One of the most important assets of a modern exciter is an ALC circuit that prevents overdrive of the exciter's final and intermediate stage amplifiers. Controlling the drive — or load — helps preserve spectrum space as well as the exciter's output devices.

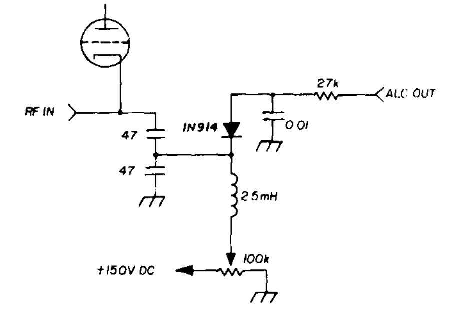

fig. 1. Typical HF amplifier ALC circuit.

Few, if any, modern exciters lack ALC. Forward power, reflected power, final amplifier current, frequency and other parameters are used to set a power output level at which the exciter can operate without distortion or destruction. It is also true that few -- if any — modern linear amplifiers have a satisfactory ALC circuit to prevent overdrive from occurring. This is so even though it is as important to control drive to an external amplifier as it is to control the drive to an exciter's final stage.

The term ALC is derived from early Collins nomenclature: *A*utomatic *L*oad *C*ontrol. Many amplifiers include a circuit such as that shown in **fig. 1**. This circuit is clearly not automatic, but is based solely on RF input voltage. Such circuits offer protection from overdrive only when adjusted for each set of operating conditions on each band; they also offer no amplifier tube protection. Two important exceptions to the rule are amplifiers that do protect themselves from overdrive and consequent destruction when connected to the exciter's ALC: the Collins 30S-1 and the E.T.O. Alpha 77.

30S-1 ALC circuit

An example of true ALC is the circuit used in the Collins 30S-1 amplifier (**fig. 2**). The 30S-1 is an AB_1 amplifier; any grid current automatically indicates an overdrive condition. A 10K:10K transformer provides DC isolation between the ALC and grid circuits. In SSB service, an AC voltage is developed across the primary and secondary of the ALC transformer proportional to the grid current that flows at the audio frequency (rate) of the incoming signal. A substantial amount of control voltage is available for small values of grid current by using a voltage doubler circuit to rectify the AC voltage present across the secondary of the transformer. Sensing grid current variations is an effective way of preventing overdrive and distor-

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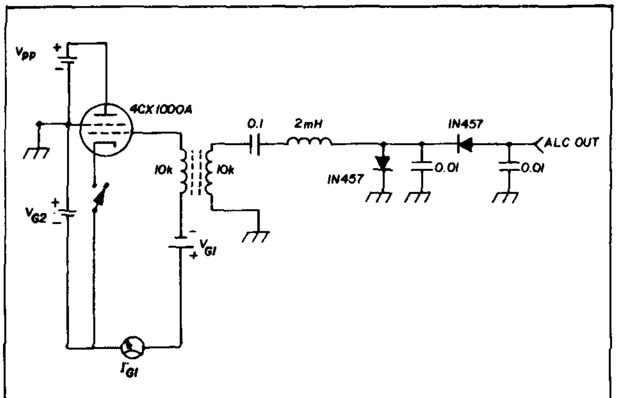

fig. 2. AB_1 ALC circuit used in the Collins 30S-1.

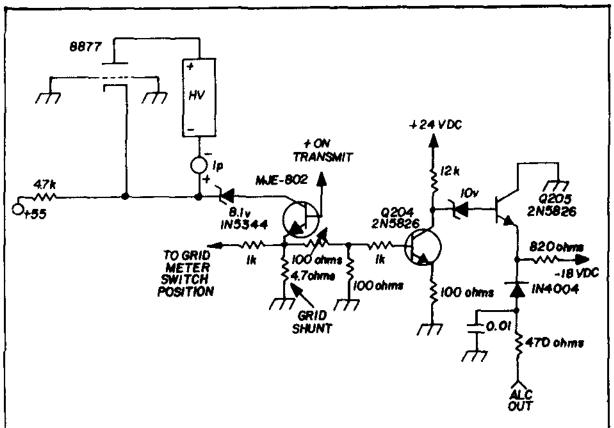

fig. 3. AB_2 grid-current-derived ALC circuit used in the E.T.O. Alpha 77 amplifier.

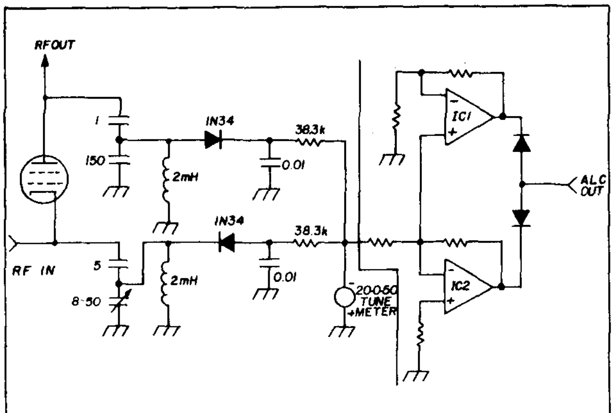

fig. 4. Comparator-type ALC circuit derived from the Collins 30S-1 tuning and loading comparator circuit.

tion in this amplifier. The particular sensitivity of the circuit is achieved by the 10 kilohm impedance of the grid transformer. This high impedance in series with the grid can cause problems if the ALC voltage is not returned to the ALC buss in the exciter. Anyone who has ever heard a 30S-1 being used without the ALC interconnected can testify to the extraordinary bandwidth that results from even minimum overdrive when the grid voltage is subject to dynamic instability.

The 30S-1 circuit is not adaptable to most modern amplifiers in Amateur use. The most common circuits use zero-bias tubes operated in Class AB_2. Significant values of grid current are necessary and normal. But there is an important analogy: just as the onset of grid current signals an overdrive condition in an AB_1 amplifier, certain fixed amounts of grid current can signal overdrive or dangerous drive levels in an AB_2 amplifier. It is quite possible to destroy a grid by applying drive without plate voltage being present. As the price of tubes soars, protective circuitry based on grid current seems a necessary adjunct for tube preservation alone even without consideration of performance.

E.T.O.* uses this type of circuit. The Alpha 77 is a modern AB_2 amplifier that has an ALC circuit designed to positively limit the 8877 grid current to 150-200 milliamperes (see **fig. 3**). Grid current is sensed, amplified, and inverted by the Q204, Q205 circuitry. In operation the negative ALC output voltage serves to limit the grid current to a preset, nondestructive limit even under conditions of mistuning, or worse, no plate voltage. In normal operation 150 milliamperes of grid current represents the upper limit of the tube's linear range.

modifying an older ALC circuit

The MLA-2500 amplifier ALC circuit shown in **fig. 1** is representative of the majority of ALC circuits used in other amplifiers. The lack of protection for the grids of the 8875 tubes offers an opportunity to adapt a circuit that protects against overdrive and potential tube destruction. An added incentive is the fact that it costs as much to replace the final tubes in an MLA-2500 as to buy a used amplifier.

The first circuit I experimented with was based on the tuning and loading circuit of the 30S-1. **Fig. 4** shows the comparator circuit which samples both input and output RF voltages to detect nonlinearity resulting from *any* cause. The use of DC amplifiers to generate a negative going ALC voltage when the comparator output voltage departs from its null seemed initially to be a satisfactory solution. In practice it failed. The impedance is fairly high and stray capacitance and inductance effects were different on each band. In addition, the circuit required correction to provide protection when the mode of operation was changed from SSB to CW which increased circuit complexity substantially. Disabling the circuit was also necessary in order to initially tune up. I soon abandoned this approach.

*Ehrhorn Technological Operations, Canon City, Colorado.

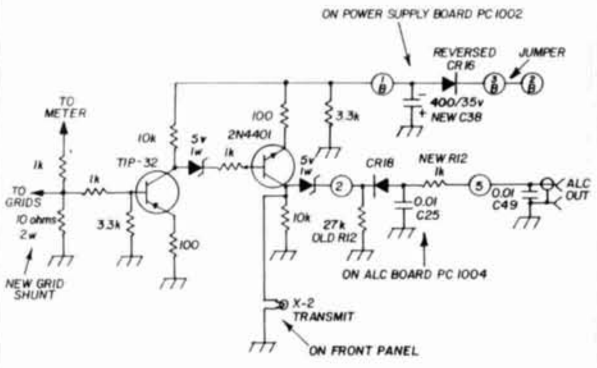

fig. 5. Final circuit as installed in Dentron MLA-2500.

a working MLA-2500 ALC circuit

Fig. 5 shows the final circuit that was developed for the MLA-2500. It operates solely through the sensing and control of grid current. I had observed nonlinearity in several different sets of tubes at more than 55-60 mA of grid current. After reviewing the tube specification sheets it soon became apparent that I could prevent overdrive and tube destruction by simply limiting exciter drive to 60 mA grid current under all conditions. The key to the circuit was a simple change in the value of the grid shunt. The new value was chosen to develop 0.6 VDC at 60 mA grid current, i.e., 10 ohms. A series multiplier resistor had to be added to the metering line. By using a 1-kilohm meter multiplier, full scale grid current was changed from 1 ampere to 100 mA. I modified the existing MLA-2500 ALC and power supply boards taking advantage of existing parts and wiring. **Fig. 6** shows the construction technique used for the remaining components added. **Fig. 7** shows the actual installation in the MLA-2500. The open area beneath the meter/function switches offered enough space to mount the component strips. After installing the ALC circuit and conecting it to the exciter, the grid current could not be driven past 60 mA. Combined with the visual warning of the front panel-mounted transmit lamp, X-2, and the increased sensitivity of the grid current meter the circuit offers positive protection. Now, if the supply voltage is accidentally left in the CW position I no longer see the high grid current that previously occurred. It is also now practically impossible to overdrive the amplifier in the SSB mode. Loading the amplifier too lightly results in excess grid current which reduces the drive and prevents flat-topping; the load is automatically controlled. It is truly an ALC circuit.

adapting to other amplifiers

Other tube circuits operating in AB_2 can also benefit from the addition of this circuit. 3-500, 813, and 811 users can all probably point to some finite value of grid current in their amplifiers which represents an overdrive condition: for example, my 3CV1500A7 (3CX1000A) begins to distort above 325 mA. The circuit is adapted to other amplifiers by simply choosing a value of grid shunt so that the desired maximum grid current develops 0.6 VDC. The circuit I developed is useful where the grid voltage sample is negative; the E.T.O. circuit could be used where the sample is positive. In either case the addition of a grid-current-derived ALC circuit represents the addition of an extremely useful operating adjunct. By using multiple isolation transistors, as shown in **fig. 8**, other parameters can be used to limit exciter drive. I have not found such circuits necessary with the 8875s, however. (A more extensive set of construction notes

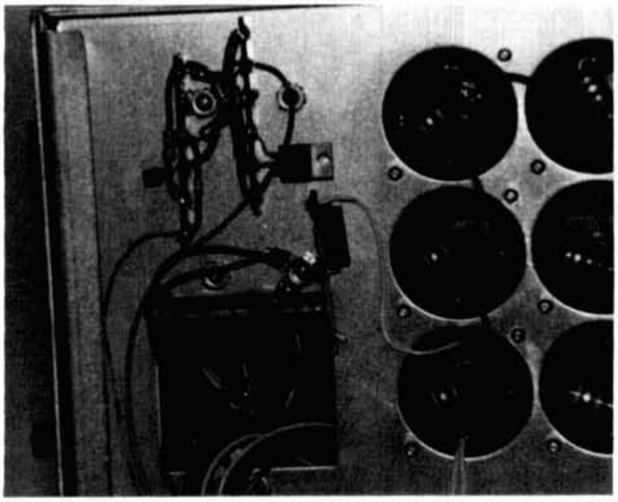

fig. 6. Terminal strip construction technique used for grid-current-derived ALC circuit in MLA-2500.

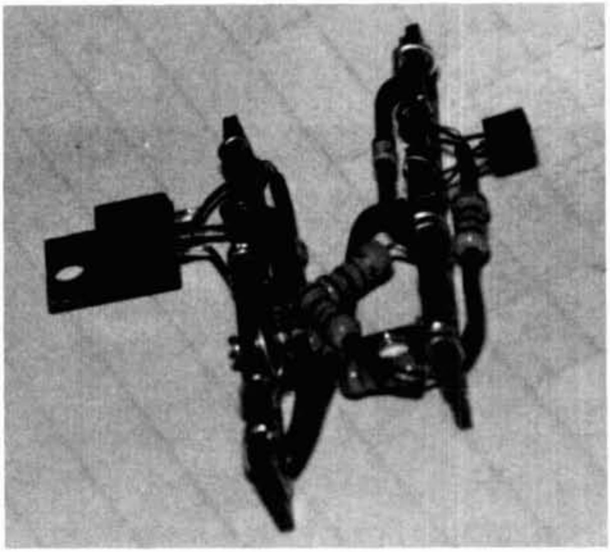

fig. 7. Final installation of ALC circuit in MLA-2500.

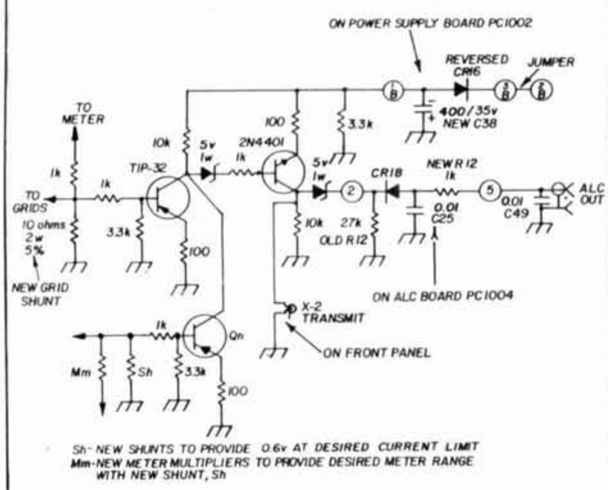

fig. 8. The ALC circuit can also be used to protect other circuit elements, e.g., plate current.

and an input matching circuit follows in Part Two of this article. — **Editor.**)

acknowledgement

I wish to thank Tom Kneadle, W8EII, for the photography, and Rodger Miller, KC8DA, for the use of his amplifier.

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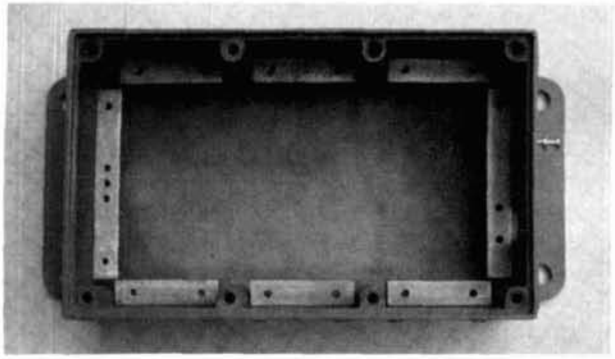

fig. 1. Interior view of box built for a wideband RF amplifier. (See *ham radio*, March 1984, pages 12-28.)

build a better box

How to modify pre-built enclosures for RF-tight design

Sometimes it seems that packaging a project is more difficult than building the actual project itself. In packaging a complete project, building the right box is critical, because if the packaging is not done well, the device inside may not work properly.

Commercially available die-cast boxes — you know, the ones that seem to be just about perfect for many things, but are never quite right for anything — appear, at first glance, to be ideal for small RF enclosures. There is no convenient way to mount *anything* in these. If you try to mount your neat, low noise, wideband amplifier in one of these boxes with a few standoffs to the bottom, you quickly find that your mounted amplifier has become an oscillator and now generates a considerable amount of output with no input.

If pre-manufactured boxes are to be used successfully for RF enclosures, particularly above several hundred megahertz, they must be modified first, with a solid, well defined grounding configuration to tightly couple the box to the circuit ground. The mechanical assembly described and illustrated in this article, though not particularly simple, provides an excellent packaging configuration for small RF projects through L-band. Its fabrication should be well within the capability of most Amateurs (no machine shop is required) and result in a much more successful and professional-looking project than any collection of coffee cans, PC board pieces and shim stock, however skillfully assembled.

Fig. 1 shows what your finished project should look like using this method.

drilling patterns

I used a Pomona 2901 diecast box for this article, but similar products can be adapted with equal success. The overall assembly is shown in **fig. 2**. From that you can see the relative mounting positions of the eight mounting blocks and RF connectors. The details of the box modifications are shown in **fig. 3**. All holes must be positioned with reasonable accuracy. The best way to accomplish this manually is with a precision steel rule calibrated in tenths or hundreths of an inch. This should be available from almost any hardware store or machine tool supply store. Because the diecast boxes vary somewhat in size, the holes in **fig. 3** are dimensioned from the side center lines. Experience has shown that dimensioning from one end can lead to problems with fitting parts. Before drilling, be sure to centerpunch all holes to prevent the drill from "walking."

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A number of different filters may be used. If you use other than the one listed, be sure to drill and tap the filter mounting hole to fit your particular filter.

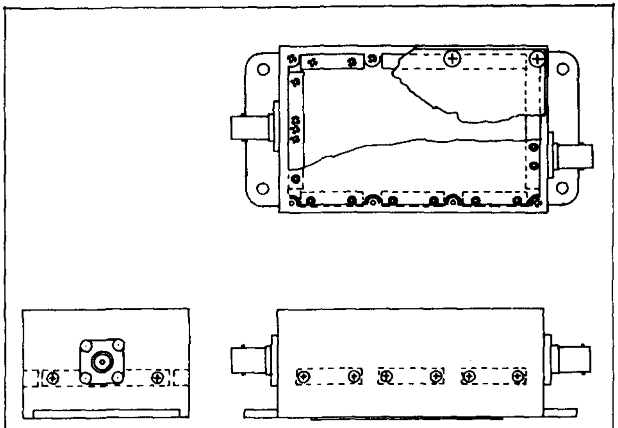

fig. 2. Assembly drawing of RF enclosure.

Don't try to use solder-in filters; the box alloy is very difficult to solder. The various screw-mounted filters are your best choice. You'll also notice that one RF connector is centered and the other offset in the corresponding ends. This is a convenient layout, but be creative and mount the connectors where best suited to your project.

treating the surface

The paint must be removed from the inside of the box where the mounting blocks are to be installed. The paint in these boxes is tenacious; the easiest method of removal is with a small sandblaster. But if you don't have a sandblaster in your work room the next best thing is sandpaper. A little work with about 120 grit wet-or-dry should do the trick. Use plenty of water to keep the paper from loading. (If you use regular sandpaper, don't use water — you'll end up with a handful of wet sand and soggy paper.)

An unpainted box such as the Pomona 2906 can also be used, but then you'll have to prepare the sur-

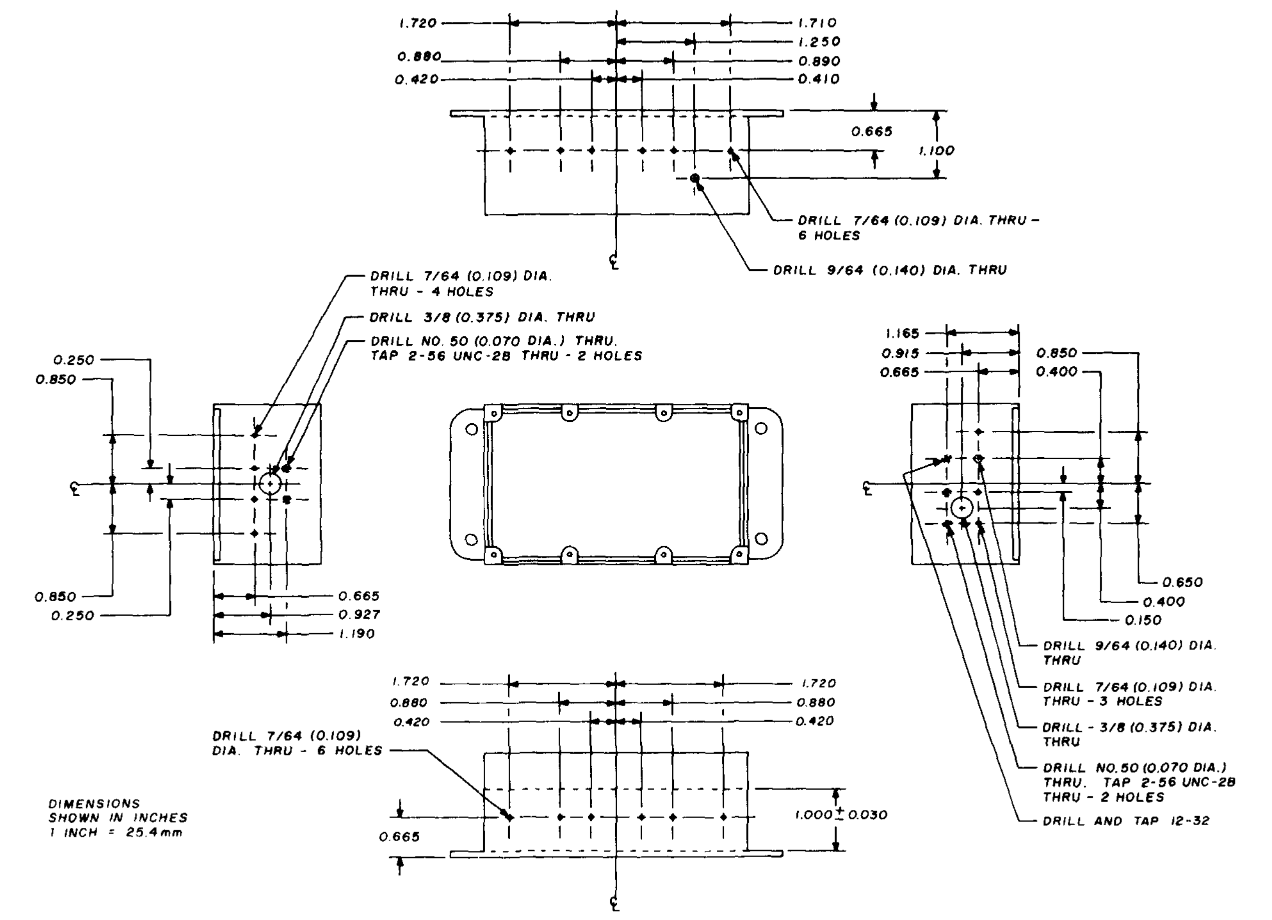

fig. 3. RF enclosure drilling pattern.

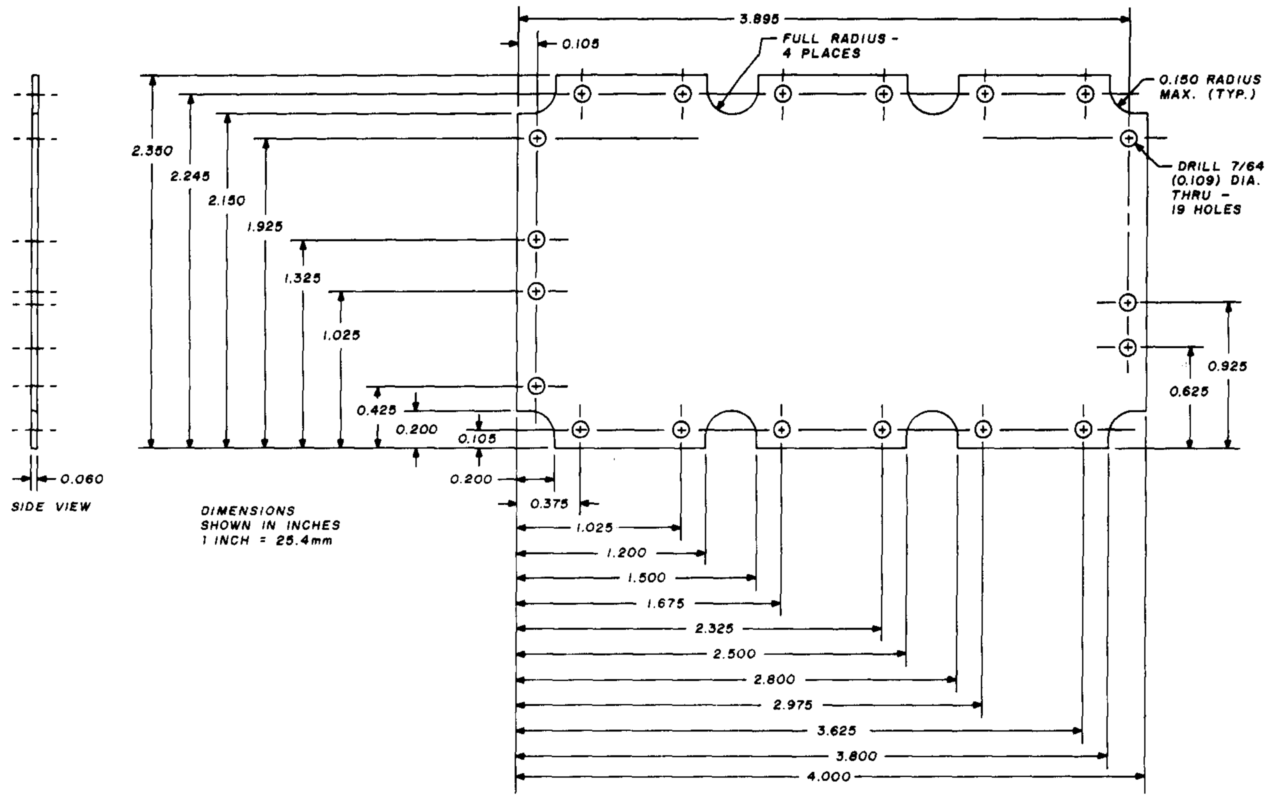

fig. 4. Board outline drawing indicates hole and cutout patterns.

face and paint the finished unit for an attractive "professional" look. This can be tricky; the bare cast box requires considerable effort if you're determined to produce a visually appealing product. All things considered, I think the painted box — with interior paint removed — is the easier to use.

interior details

Once you have all the holes drilled in the box and the paint is removed, you have to make all those little pieces that fit inside the box behind the holes. This is a tedious task, but with a little care and patience, good results can be expected. The details of the six side blocks and the two end blocks are shown in **fig. 5**. The 2-56 tapped holes are quite small, so you must be very careful when drilling and tapping — particularly in tapping. Use plenty of oil for both drilling and tapping, and be sure to back the tap out often to prevent jamming.

component assembly

After all the interior pieces are completed, the box is ready for assembly. For a little more professional appearance, use flat washers with all the screws, but be sure to mount the filter *without* a washer. On some filters, the thread is long enough to accept a nut on the inside of the box to lock the filter in place. You may have a problem purchasing the ground terminal specified in small quantities; if a suitable terminal cannot be found, a 3/4-inch, 4-40 screw and nut may be used. Place the nut about half way up the screw, drive the screw into the ground terminal location about 1/4 inch, and tighten the nut. Use a plated brass or steel screw to make soldering easier.

The finished box is now ready to have something put in it. What you install is up to you, but be sure your board is tailored to fit the box and mounting blocks. An outline drawing of the cutout and mounting details of the board is shown in **fig. 4**. This should help you in getting a board cut to fit the box. Be careful not to run any wiring or conductors within about 5/16 inch of the board edges, since that's where the mounting blocks attach.

This versatile packaging technique adapts easily to other boxes. When carefully done, it results in a professional-looking enclosure providing the strong electrical bond between the board ground plane and the box in critical RF circuits. I've used this assembly

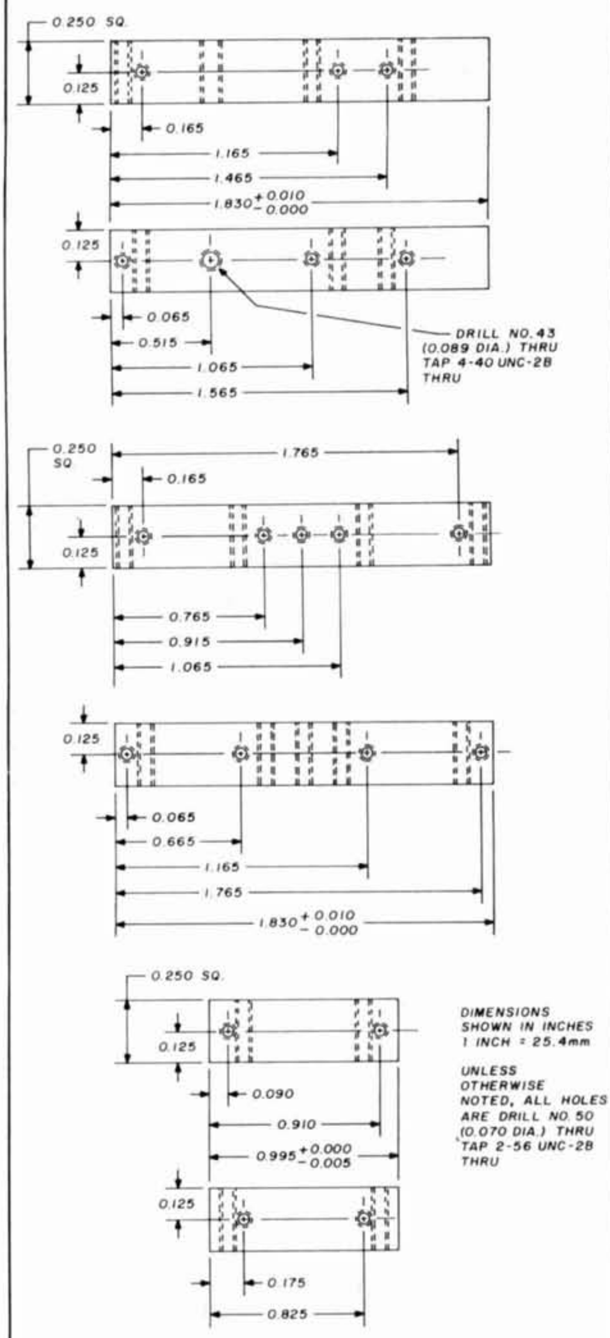

fig. 5. Side mounting block drilling details.

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(See "Publisher's Log," April, 1984, page 6, for details.)

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LS30	.28	LS242	.90
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LS74	.40	LS251	.50
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LS132	.50	LS299	1.60
LS133	.49	LS366	.45
LS138	.60	LS367	.50
LS139	.60	LS368	.40
LS151	.50	LS373	1.25
LS153	.50	LS374	1.35
LS154	1.75	LS375	1.19
LS155	.50	LS377	1.49
LS156	.55	LS378	.85
LS157	.60	LS390	1.19
LS161	.60	LS393	1.19
LS162	.65	LS399	1.25
LS163	.50		

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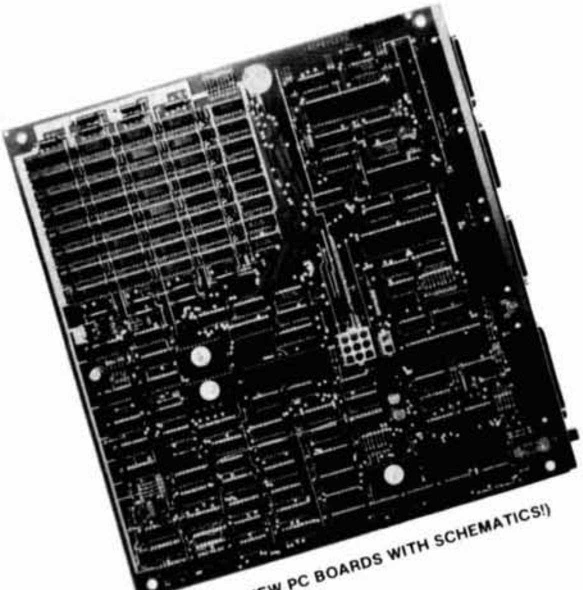

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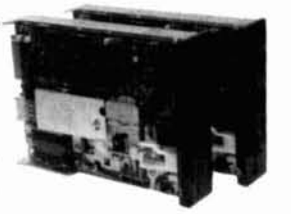

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cooling semiconductors
part 2: blowers and fans

Heatsinks aren't the only way to dissipate excess heat

This article has been adapted, with permission, from *IC Voltage Regulator Sourcebook with Experiments*, by Vaughn D. Martin, published by TAB Books, Inc., and available from Ham Radio's Bookstore, Greenville, New Hampshire 03048 ($14 postpaid).

In Part One of this series we discussed the design and use of heatsinks in cooling electronic equipment. In this part, we'll examine the several other means by which excess heat can be prevented, monitored, and dissipated.

While heat sinks are without doubt the most familiar means of moving heat away from electronic equipment, they can be of limited use if the ambient temperature itself is high, or if the area surrounding the unit remains warm because heat is not evacuated quickly enough. If, for example, a power supply were enclosed in a poorly ventilated cabinet, a heat sink would be of little or no use; in such a situation, a fan or blower would be more effective.

While similar to heat sinks in principle, fans and blowers are significantly different in application and design. Fans (see **fig. 1**) generally employ propeller-like blades to move large volumes of low-pressure air. Blowers, on the other hand, usually consist of a revolving wheel that displaces air; they are therefore more efficient while operating near their maximum (non-moving) pressure (see **fig. 2**).

In cooling a poorly ventilated cabinet, pressurization of the enclosure by pumping filtered air *in* is vastly preferable to drawing air *out* because air pulled into the cabinet may contain particulate matter whose presence, over time, can compound the problem of temperature control by collecting in cabinet openings, such as those between panels or around doors, and blocking the exit of air.

Of the four methods of cooling electronic equipment housed in cabinets — forced-convection filtered air, air-to-air heat exchangers, air-to-water heat exchangers, and specially packaged air conditioning units — only the first (see **fig. 3**) is appropriate for Amateur Radio applications.

forced-air cooling

In designing the forced-convection filtered air-cooling of the interior of an equipment cabinet, five design guidelines should be followed: first, there should be no constrictions; the cross-sectional area of the air current should be at least as large as the intake. Second, the exhaust area must be located *downstream* from the heat-producing elements. Third, baffles work best when used to channel a small volume of air across an exceedingly hot component at a high velocity. Fourth, ducts may be used to maintain a more even cooling effect throughout the cabinet. If maintenance of an even temperature from the top to bottom of the cabinet is important, ducts should be located along the sides of the cabinet.

Finally, because blowers and especially fans can cause vibration, it's important that neoprene vibration isolators or similar devices be built into the fan if this is a concern. If you decide to use a fan, using the following two formulas will enable you to determine the required fan size:

$$\text{volume of air at inlet} = \frac{3.17 \times power \times 1.25}{T\,(°F)}$$

$$= \frac{1.76 \times power \times 1.25}{T\,(°C)}$$

By Vaughn D. Martin, 114 Lost Meadows, Cibolo, Texas 78108

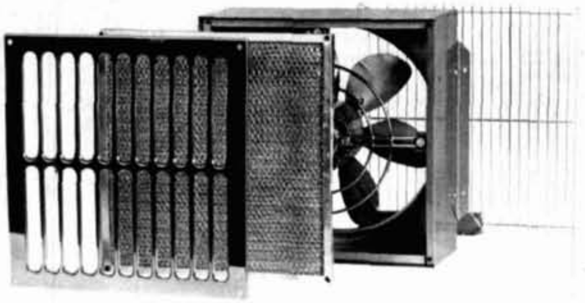

fig. 1. A typical fan used for ventilation purposes. (Photo courtesy McLean Engineering, Inc.)

The power to be dissipated is expressed in watts; the temperature is the average temperature rise within the cabinet, expressed in the first equation as degrees Fahrenheit and in the second equation as degrees Celsius. These two formulas as well as the nomograph shown in **fig. 4** have a built-in safety factor of 25 percent (note the 1.25 for 125 percent). If only a quick approximation is required, the nomograph may be used.

Let's work through a typical design example, assuming we are designing for a typical cabinet and using both the formula and the nomograph. Let's strike a line through the nomograph and see how close it comes to the exact calculated value.

Assume we have exactly 200 watts of power to be dissipated and can accept only a 10°F rise in temperature within the cabinet. The first equation for degrees Fahrenheit yields $[(3.17)(200 \text{ watts})(1.25)]/10 = 79.25$ *cubic feet per minute*. Note in **fig. 4** that the nomograph indicates approximately 80 cubic feet per minute — very close to 79.25, the value derived by actual calculation.

thermoelectric devices

In addition to forced air venting, thermoelectric devices such as Peltier and Thomson-Joule devices may be used to pull heat away from a specific small area in the cabinet or a critical semiconductor that must remain cool.

Four basic physical phenomena are associated with thermoelectric devices:

- The *Seebeck effect* is the EMF that exists when two dissimilar conductors are connected and have their junctions maintained at different temperatures. This is the basis of thermocouples.
- The *Thomson effect* is the heating or cooling effect that takes place in a homogeneous conductor when an electric current passes in the direction of the temperature gradient.
- The *Joule effect* occurs when an electric current passes through a conductor (which is isothermal or maintains the same temperature throughout) and generates heat — this is called "Joule heat."
- The *Peltier effect*, named in honor of Jean C.A. Peltier, who in 1834 discovered that the passing of electric current through the junction of two dissimilar materials causes a cooling effect when passed in one direction and a heating effect when the direction of current flow is reversed.

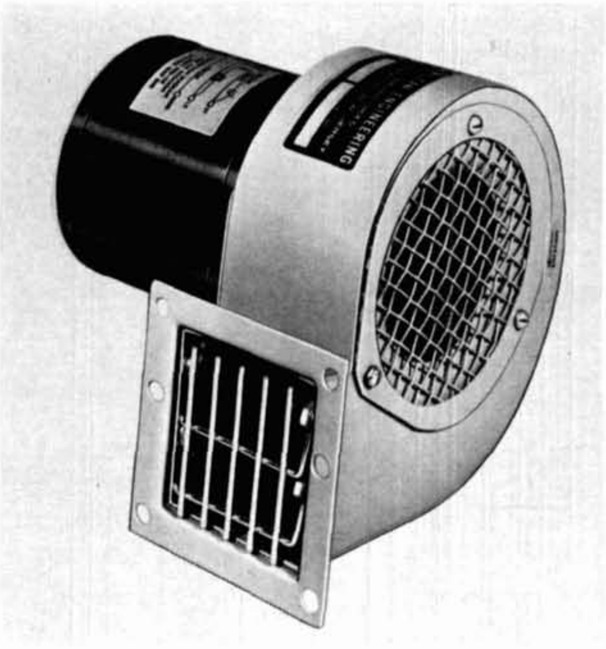

fig. 2. A typical blower along with a housing for blowers. (Photo courtesy McLean Engineering, Inc.)

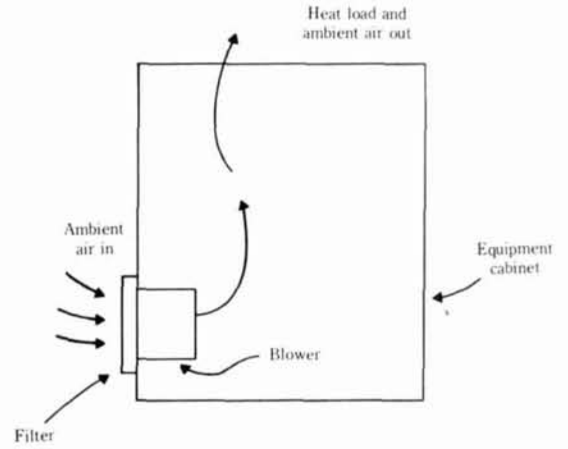

fig. 3. An illustration depicting forced-convention filtered air cooling. This technique uses ambient air to cool electronic control equipment. Incoming air is filtered before being blown throughout the equipment cabinet.

The Seebeck, Peltier, and Thomson effects are all

reversible phenomena. The Peltier effect is the one most useful in power supply design because of its ability to literally draw heat away from a semiconductor, although the Thomson effect also has some limited applications in these areas and will be discussed shortly.

Peltier cooling devices (**fig. 5**) may be attached directly to surfaces of heat-producing semiconductors. The effect of heat being drawn away in proportion to the current passing through the cooling device is what makes this device so effective, if somewhat expensive; a device large enough to handle a TO-3 power transistor is priced at about $15.00.

Another interesting thermoelectric device is the Joule-Thomson cooler, as shown in **fig. 6**. Described by its manufacturer as a "micro-miniature refrigerator," it cools a wide range of IR (infrared) and millimeter wave detectors down to 77°K, or Kelvin, which is the temperature of liquid nitrogen (N_2). Zero degrees Kelvin is *absolute zero* (where all molecular motion stops); this is equal to −273.15°C or −459.67°F. (One degree Kelvin equals in magnitude one degree Celsius, so to convert Kelvin to Celsius, just subtract 273.15 degrees from it. So *77°K = 77 − 273.15 = −196.15°C or −321.07°F.*)

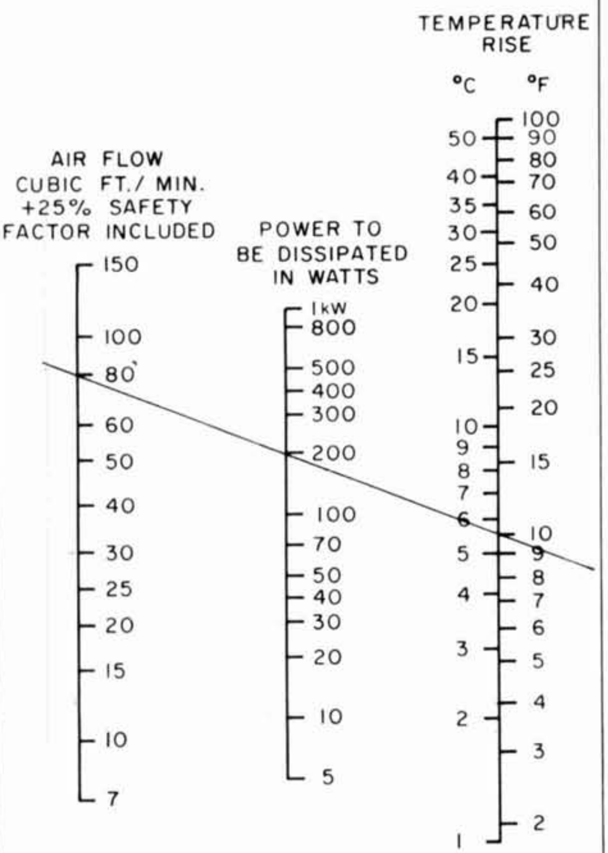

fig. 4. A nomogram for determining air flow requirements.

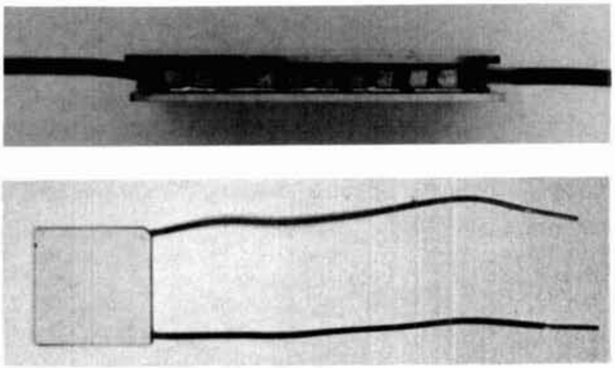

fig. 5. A Peltier cooling device (2 views).

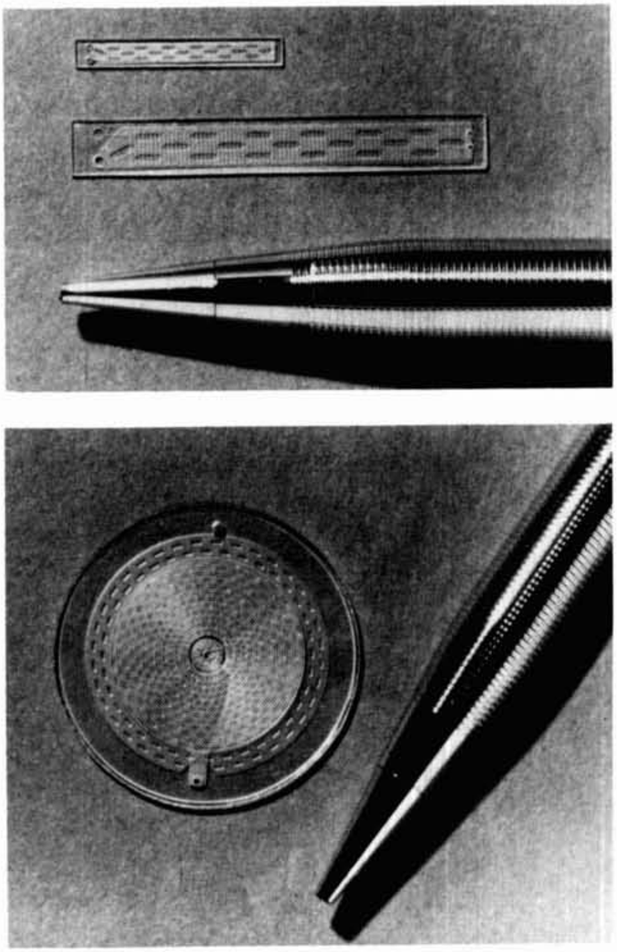

fig. 6. A Joule-Thompson cooler. (Photo courtesy MMR, Inc.)

These 1.5 cm (0.6 inch) in diameter devices can cool some detectors to 80°K (−193.15°C) in just one second.

piezoelectric fan

Another interesting cooling device is the piezoelectrically driven fan designed for PC board use. Manufactured by Piezo Electric Products,* this device (**fig. 7**)

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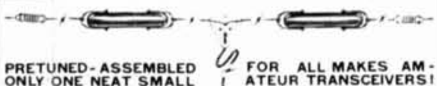

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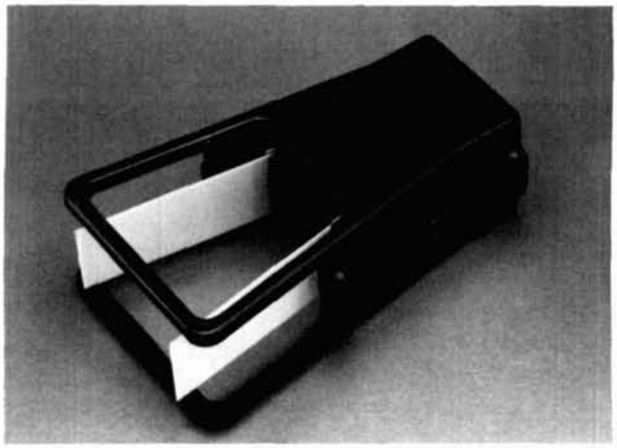

fig. 7. A piezoelectric fan. (Photo courtesy Piezo Electric Products, Inc.)

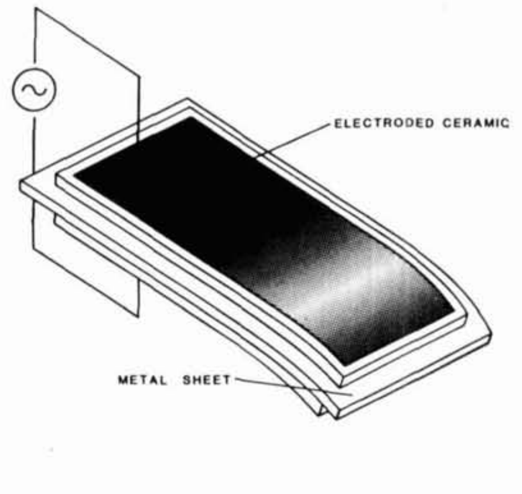

fig. 8. An illustration of the principle behind the piezoelectric fan.

is available in either 50 or 60 Hz at 120 or 240 VAC. Used for spot cooling, it consumes about 1/15 of the power of a fan, *yet accomplishes the same cooling effect*. Its reliability is very high because of flexible metal strap blades laminated to thin-sheet piezoceramic elements. The mechanical vibrations that result when an AC voltage is applied across the piezoelectric element in the bender assembly cause the attached plastic blades to flap. This principle is illustrated in **fig. 8**. The highly "focused" air streams are responsible for the unit's exceptional efficiency; the fan moves 20 cubic feet/minute of air while using just 0.36 watts.

the heat pipe

In size, heat pipes range from very small — about the size of a pipe cleaner (**fig. 9**) — to very large, as in furnace linings and factory smokestacks. The heat pipe's claim to fame is its unique ability to equally and uniformly distribute heat and thus equalize the differences between the hottest and coolest objects (usually ICs and ambient air, respectively). The smallest heat pipes fit nicely beneath and between the two adjacent rows of IC pins.

Heat pipes are metallic, sealed, self-contained units (**fig. 10**) with a thin outer wall or shell of copper which surrounds an internal wick saturated with a working fluid. As one end of the heat pipe (the evaporator end) is heated, the fluid within vaporizes and travels to the other end (the condenser end). As the vapor condenses, heat is given off and the vaporized liquid condenses and travels back, via capillary action, to the evaporator end. The end result is an efficient self-contained heat exchange system with the following advantages:

• The ability to transfer over 1000 times more heat than a copper rod of the same size and weight.

• Virtually absolutely uniform heat transfer and distribution throughout the heat pipe with less than 0.1 de-

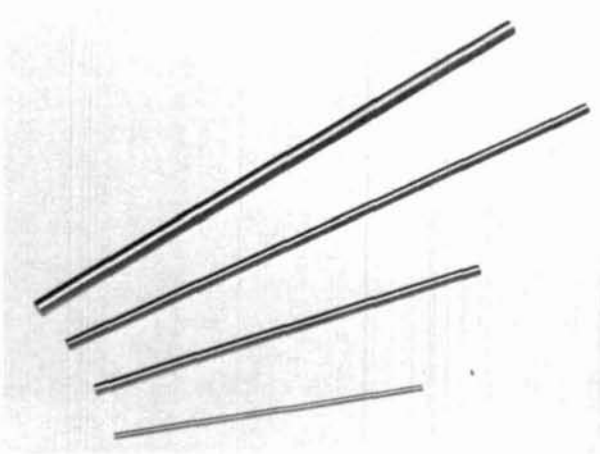

fig. 9. Typical small heat pipes. (Photo courtesy Noren Products, Inc.)

gree C drop or heat gradient from one end of the pipe to the other.

• Lightweight and compact.

• No moving parts, no maintenance or external power required.

• No noise — either electrical or audible.

• Capability of being fused to an existing heat sink (**fig. 11**).

If, for example, you had an LED display composed of a row of adjacent DIPs, and very poor or no ventilation, as in **fig. 12**, you wouldn't be able to use a slip-on DIP heat sink such as the one shown in **fig. 13**; slipping this heat sink over the DIP displays would obscure the front of the display, rendering it useless. In

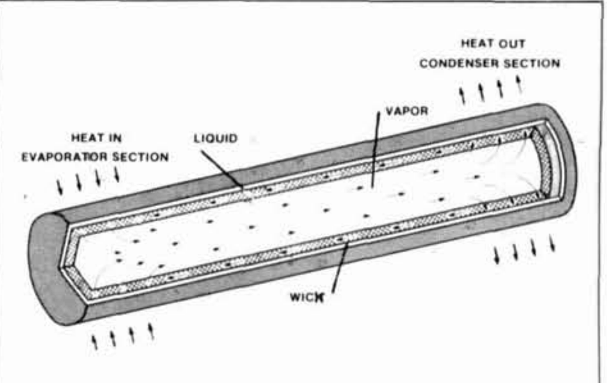

fig. 10. An illustration of the heat pipe's operating principle.

applications such as this, a heat pipe is ideal. When it's necessary to vent heat away *after* it has been transferred and evenly distributed, a radiator, as shown in **fig. 14**, may be attached to the heat pipe.

monitoring temperature

After heat sinks, heat pipes, and either a fan and/or a Peltier or Thomson-Joule device are added, the temperature should be within acceptable limits, and temperature monitoring should begin. A number of companies manufacture a crayon-like pen that can be used to apply a heat-sensitive substance to the surface of a semiconductor whose temperature is to be monitored (**fig. 15**). There are also TO-3, TO-66, and DIP stick-on temperature indicators (**fig. 16**) and other heat-sensitive products such as paints and tablets (**fig. 17**) that change colors in direct relation to the temperature they monitor; as the temperature changes, so does the color of the temperature indicator. These indicators are available in two types. The more traditional throwaway types change color as temperature rises, but if the temperature falls again, cannot change back to a color corresponding to this lower temperature. This unfortunate "ratchet" effect can be avoided by use of an LCD temperature indicator. Instead of the more traditional nematic crystals, these indicators use cholesteric crystals — produced in the cholesterol in lambs wool and cuttlefish[1] — and cost about four dollars each, feature as many as seven colors, and have 5-degree C temperature increments as standard. There are larger indicators based on the same principle that can cover whole power supplies or entire printed circuit boards.

protection devices

In order for overheating to be controlled, it must first be sensed. The visual methods just described (shown in **fig. 15** through **17**) are one form of indicator; however, in unattended applications, electrical parameters, as well as heat, must be sensed and controlled. In a typical power supply, there is a fuse at the transformer, but other protection can be provided for individual component parts within the system.

A PTC (positive temperature coefficient) thermistor can help. These devices are very inexpensive — about $1 — and are two-lead devices that sense ambient heat by having the body or encapsulating cover experience heating, causing its resistance to rise by an order of magnitude (a factor of ten) for each 10 degree C rise in temperature above its trip point. This trip point is different per unit and can be specified, but a typical trip point is about 100 degrees C. Once this elevated

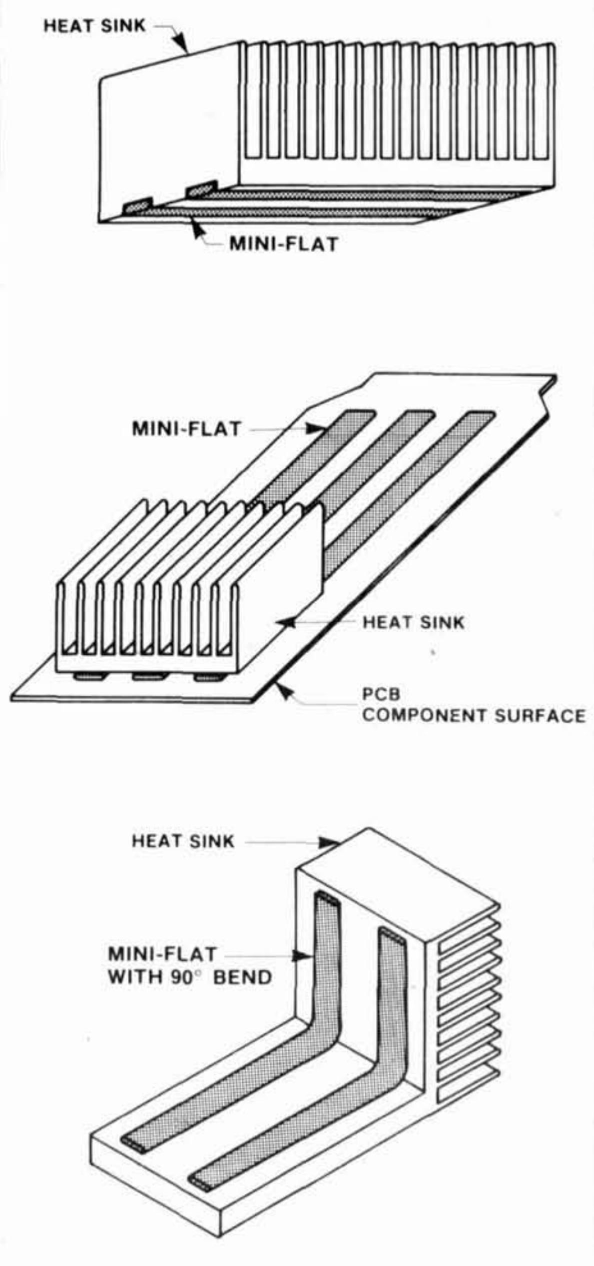

fig. 11. Various schemes of fusing heat pipes into existing heat sinks to increase their effectiveness.

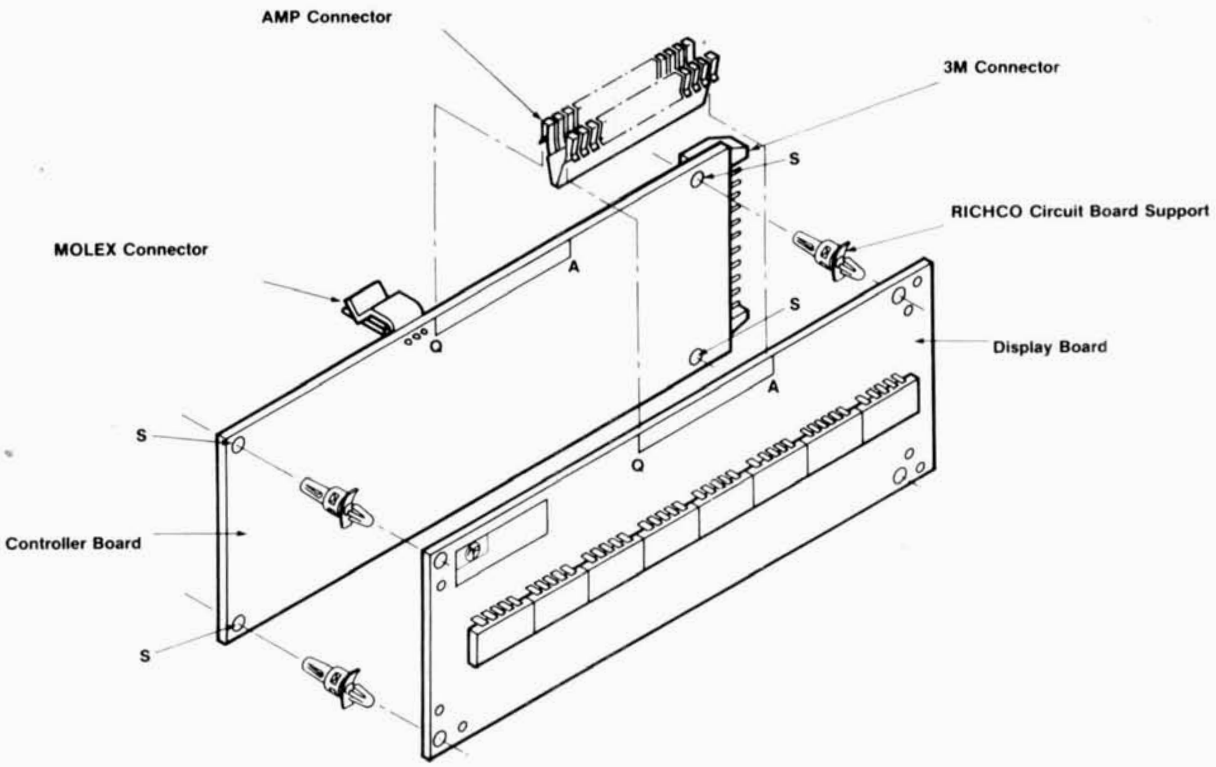

fig. 12. An ideal candidate for a heat pipe application, a poorly vented LED display.

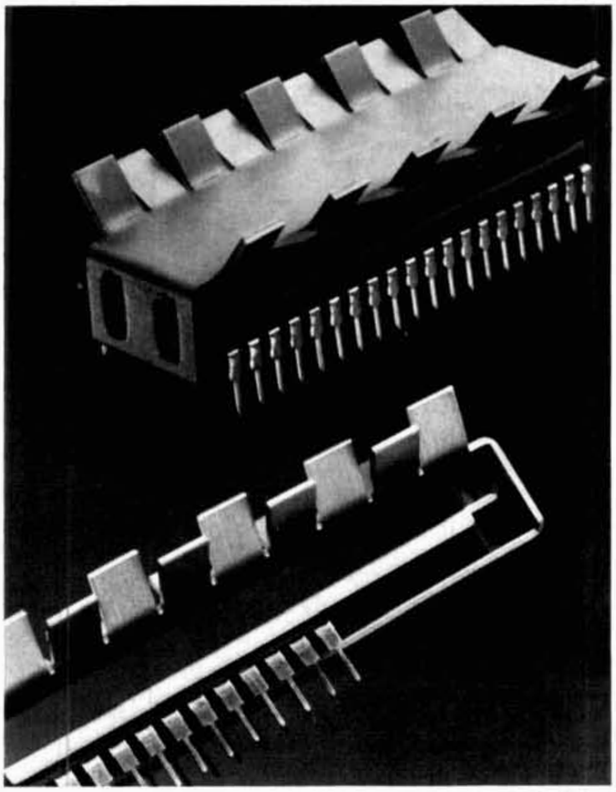

fig. 13. A DIP slip-on heat sink, unfortunately not useful in an application such as with the display in *fig. 12*. (Photo courtesy Aavid Engineering, Inc.)

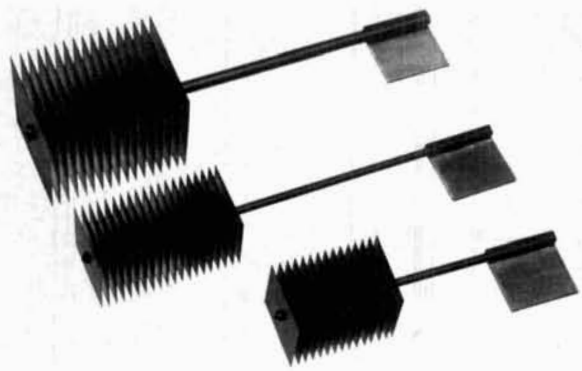

fig. 14. A "radiator" attached to a heat pipe for more effective heat radiation. (Photo courtesy Noren Products, Inc.)

fig. 15. Heat sensitive crayons used to visually detect temperature changes. (Photo courtesy Tempil Division, Big Three Industries, Inc.)

temperature is reached, though, automatic reset by merely removing power to the PTC thermistor is not possible. An actual cooling of the PTC thermistor to below its trip temperature must first occur before re-

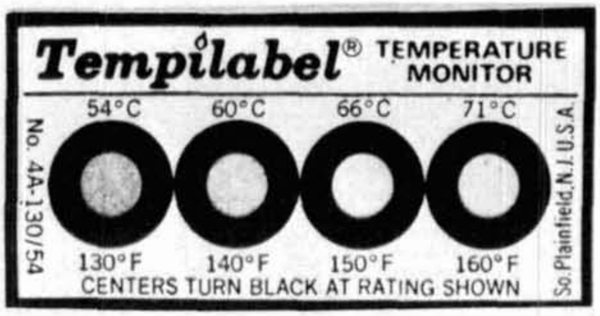

fig. 16. Heat sensitive sticky backed peel-off temperature indicators.

fig. 17. A whole product line of visual temperature indicators. (Photo courtesy Omega Engineering, Inc.)

setting is possible. The internal heating effect of the thermistor itself is inadequate to cause it to reach the trip temperature. This allows internal heating to have only a very small effect on the resistance of this heat sensitive resistor. It also allows the surface that is producing heat, usually flush with the PTC thermistor, to control the device's resistance. **Fig. 18** is a graph showing how this internal heating effect is minimized by a PTC.

summary

Though useful for the applications intended, heat sinks are not the only means of dissipating heat, especially within an equipment cabinet. Blowers and

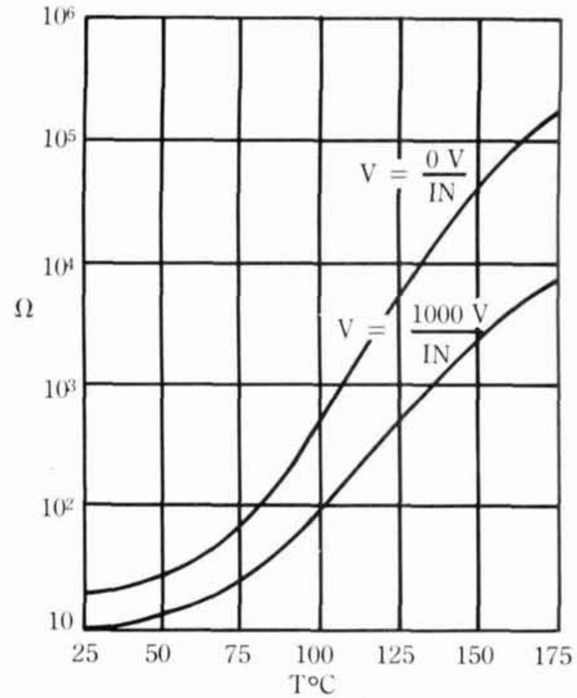

fig. 18. A graph showing how a PTC (positive temperature coefficient thermistor) can overcome the effects of internal device heat generation. This graph demonstrates the sensitivity of resistance of PTC material to applied voltage.

fans can be selected and sized to maintain specified temperature rises for a given power dissipation requirement. On a smaller scale, thermoelectric devices exhibiting the Seebeck, Thomson, Joule, or Peltier effect can be used to cool individual semiconductors. Heat pipes are also very effective in uniformly transferring heat from one location to another. The effectiveness of these devices can be determined by using temperature indicators in the form of stick-ons or paints. Overheating protection devices that generate voltages in a feedback loop can be used to reduce the original cause of heat buildup.

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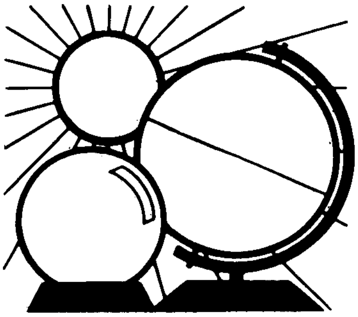

DX FORECASTER

Garth Stonehocker, KØRYW

summer noise

Summertime DX really isn't too bad on the higher frequency bands, 6-30 meters. Between sporadic-E short-skip openings near noontime and the bands staying open longer, enough DX fun is still available to keep us happy all day and well into the evening. The bands hardest hit by summertime problems are 80 and 160 meters of the lower-frequency bands. Their problem is summer thunderstorm noise — QRN.

Thunderstorm noise propagated from the equatorial regions increases the overall average noise level of the lower-frequency HF bands. At any given moment, 3600 storms are in progress around the world. That's a lot of QRN! Some, of course, are inevitably nearby.

Air-mass thunderstorms, which form only over land, build up from the hot summer sun's heating the ground and the air above it. They form in the afternoon if the humidity is above 50 percent, and last into the night before cooling off enough to dissipate. Unlike spring and fall frontal passage thunderstorms, which simply pass by your QTH, air-mass thunderstorms stay around for days until they release their moisture in the form of rain. During the evening DXing hours, the air-mass thunderstorm QRN more or less limits the usefulness of these band's signals to local ragchewing, and rule out weak-signal DX.

So how do you get some DXing in on these bands? Most operators switch operating hours, giving up evenings in favor of the pre-dawn hours of early morning. By this time, the thunderstorms have dissipated locally and are dissipating on paths to the west. This is a cool, comfortable time of the day to be up and around. Good luck, early bird!

last-minute forecast

August is the last full month of summertime DX conditions, characterized mainly by sporadic-E short skip and longer daylight for high-frequency band DX operating. These higher frequencies are forecast to be best during the first two weeks of the month because of an expected high solar flux. The lower frequency bands, 30-160 meters, should improve during the last two weeks of the month because of lower noise and lower absorption of the signal's energy. This trend will become even more apparent next month.

The moon's perigee will occur on the 27th, with a full moon on the 11th. The Perseids meteor shower occurs from the 10th to 14th, with its maximum on the 11th and 12th, with better than fifty meteors per hour. This is an excellent shower.

band-by-band summary

Six-meter paths will open for a half hour to a couple of hours on some days around local noon. Sporadic-E propagation will make this short-skip path possible out to nearly 1200 miles (2000 km) per hop.

Ten, fifteen, twenty, and thirty meters will support DX propagation from most areas of the world during daylight and into the evening with long-skip out to 2000 miles (3500 km) per hop. Sporadic-E short skip will also be available on many days for several hours near local noon. The direction of propagation will follow the sun across the sky: morning to the east, south at midday, and toward the west in the evening. Daylight is still long, providing many hours of good DXing.

Thirty, forty, eighty, and one-sixty meters are the nighttime DXer's bands. On many nights 30 and 40 meters will be the only usable bands because of thunderstorm QRN. Try the pre-dawn hours for less QRN. The direction of propagation follows the darkness path across the sky: evening to the east, south around midnight, and toward the west in the pre-dawn hours. Distances will decrease to 1000 miles (1600 km) for skip on these bands. Sporadic-E openings will be most frequently observed around sunrise and sunset. These may be the only signals getting through the noise in the evening.

ham radio

AUGUST

WESTERN USA

	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000	GMT
AUGUST	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	PDT
ASIA FAR EAST	20	20	20	20	30*	30*	30*	30*	30*	30*	_20_	_20_	_20_	_20_	_20_	20	20	20	20	20	20	20	20	20	N
EUROPE	20	20	20	20	20	20	20	20	20	20	30	30	30	_30_	_30_	_30_	_20_	_20_	20	20	20	20	20	20	NE
S. AFRICA	15	15	10	10	10	10	15	15	15	15	15	_20_	_20_	_20_	_20_	_20_	_20_	20	20	20	20	20	20*	15	E
S. AMERICA	15	15	15	15	15	20	20	20	20	20	20	20	_20_	_20_	_20_	_15_	15	15	10	10	10	10	10	10	SE
ANTARCTICA	15	20*	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	_30_	_30_	_30_	20	20	20	20	20	15	15	S
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MID USA

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EUROPE	20	20	20	20	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	_30_	_20_	20	20	20	20	20	20	NE
S. AFRICA	15	15	10	10	10	10	15	15	15	15	15	_20_	_20_	_20_	_20_	_20_	_20_	20	20	20	20	20	20*	15	E
S. AMERICA	15	15	10	10	10	10	10	15	15	15	15	_20_	_20_	_20_	_20_	_20_	20	20	20	20	20	20	15	15	SE
ANTARCTICA	15	20	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	_30_	_30_	_30_	20	20	20	20	20	20	15	S
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EASTERN USA

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ANTARCTICA	20	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	_30_	_30_	30	30	30	20	20	20	20	20	20	S
NEW ZEALAND	10	10	10	15*	15	15	15	15	_20_	_20_	_20_	_20_	_20_	_20_	20	20	20	15	15	15	15*	10	10	10	SW
OCEANIA AUSTRALIA	15	15	15	15	15	20	20	20	_20_	_20_	_20_	_20_	_20_	_20_	_20_	15	15	15	10	10	10	10	10	10	W
JAPAN	20	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	_30_	_30_	_20_	_20_	_20_	_20_	20	20	20	20	20	20	NW

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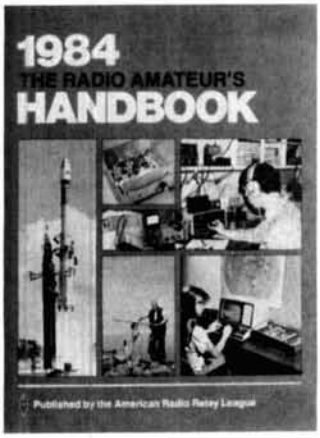

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MRF453A	60W	15.00	33.00
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MRF455	60W	12.00	27.00
MRF455A	60W	12.00	27.00
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MRF238	30W	12.00	—
MRF239	30W	15.00	—
MRF240	40W	16.00	—
MRF245	80W	25.00	59.00
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MRF648	60W	29.50	69.00
SD1416	80W	29.50	—
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2N4427	1W	1.25	—
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2N5946	10W	12.00	—
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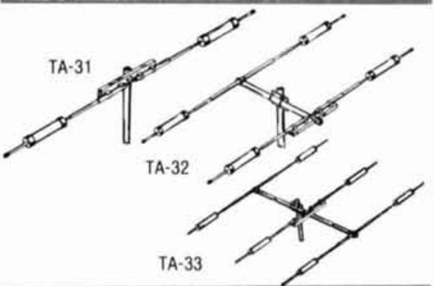

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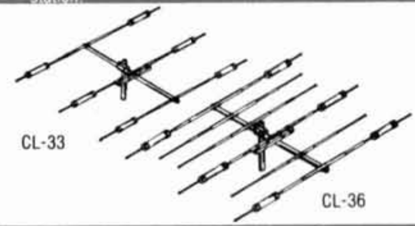

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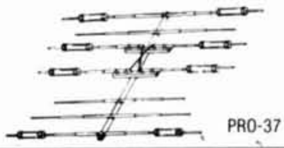

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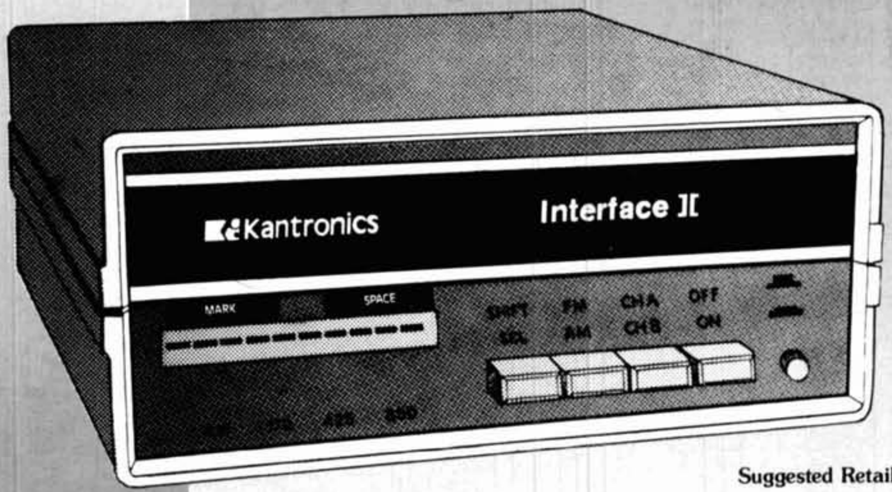

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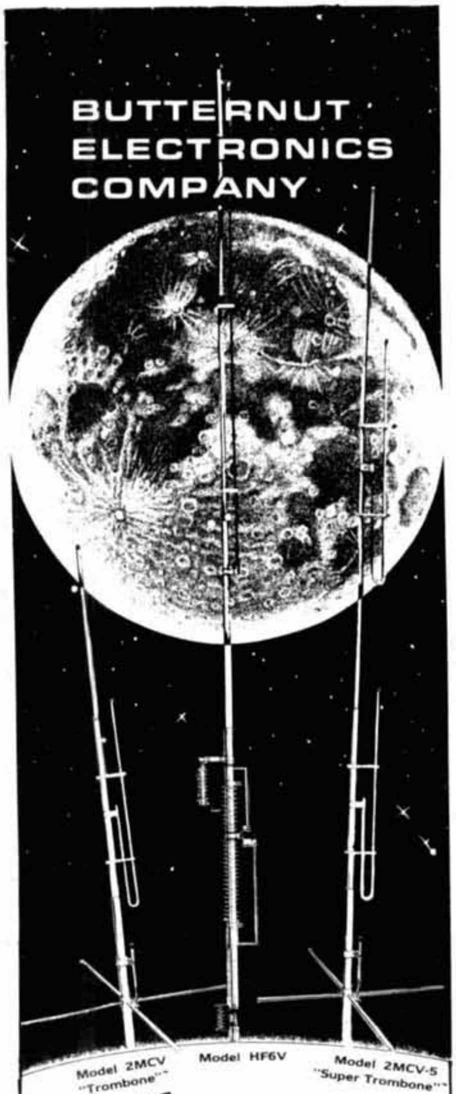

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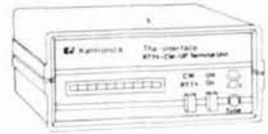

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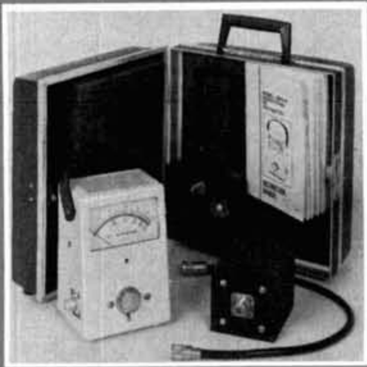

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fundamentals of grayline propagation

Signals don't always follow "normal" paths

The decline of the sunspot cycle has been accompanied by a corresponding decrease in DX opportunities on the higher frequency bands. Ten meters is becoming very sporadic in nature, as F-layer path openings continue to decrease in both number and duration. Within a few years, at the bottom of the solar cycle, the only activity remaining on 10 meters will be via sporadic-E propagation. The 15-meter band is not much better; as 10 meters goes downhill, so goes 15: this band will also continue to decline, offering fewer and poorer openings of much shorter duration.

As the levels of solar flux continue to drop, there will be an increasing number of days when the only (high HF band) activity will be found on 20 meters. Even this band won't offer the same quality openings of several years past. During many of the years to come, it will be a strictly daylight DX band with only scattered openings to various parts of the world.

With the knowledge that much of the DX has migrated to 40 and 80 meters, and believing that high power is required on these bands, many Amateurs feel that there's no place left for the "barefoot" DXer. After all, even though the low power operator can compensate for the lack of a kilowatt with a good beam and tower combination on the higher frequency bands, how many of us have the money and/or acreage for beams or phased arrays on 80 or 40 meters? Today, many low power operators will attempt to work DX on these bands only during contests, believing that their signals will never be heard at any other time.

try grayline

Is there really no place left for the "barefoot" DXer? Of course not: nature has provided us with a mode of propagation on these low bands that will allow DX operation without the use of maximum power or costly low-band directive arrays. This type of propagation — called "grayline" or "shadow edge" propagation — takes place along that line dividing the daylight and darkness hemispheres of the planet, functions on both 80 and 40 meters, and offers outstanding conditions during all phases of the sunspot cycle. What's more, it's at its *best* during the years of low solar activity!

The line that divides the region of the Earth in daylight from the nighttime side is called the *terminator*. The terminator is not a distinct division, but instead a gray, "twilight" band approximately 1000 miles in width and stretching completely around the Earth. The time at any point along this band will be that of local sunrise or local sunset.

As shown in **fig. 1**, the position of the terminator changes as the position of the Earth changes with respect to the Sun. (This familiar phenomenon causes the change in seasons of the year and is due entirely to the tilt of the Earth's rotational axis. Since this axis is not perpendicular to the plane of the ecliptic, but rather tilted 23 degrees, 27 minutes, the terminator swings back and forth through an arc of just under 47 degrees during the course of a year. The northerly and southerly limits of this motion are delineated by the Antarctic and Arctic circles, respectively.)

The absorptive and refractive characteristics of the ionosphere are directly related to the angle of solar radiation. Normally, the higher this angle (the more nearly the Sun is to vertical), the more enhanced these characteristics become. Conversely, at very low angles of radiation, the absorption characteristics change much more quickly than do the refractive characteris-

By Bradley Wells, KR7L, 5053 37th Avenue, S.W., Seattle, Washington 98126

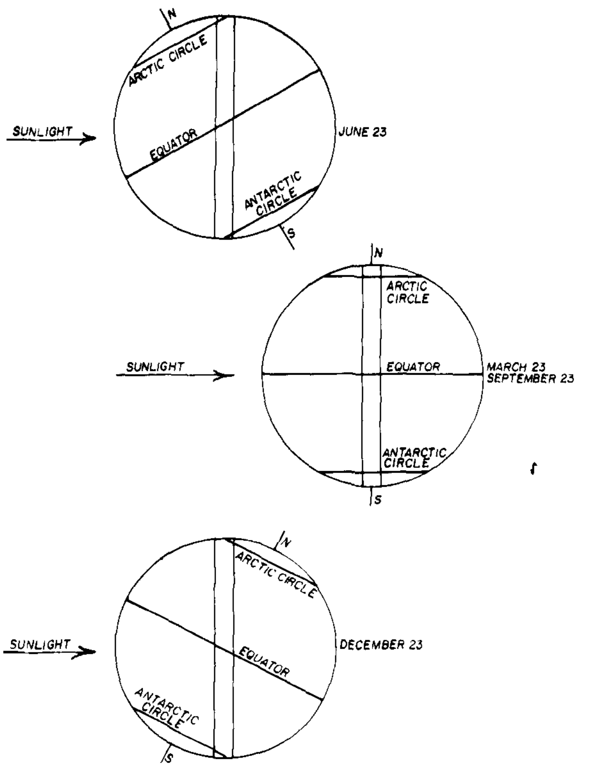

fig. 1. Motion of the terminator with the changing seasons.

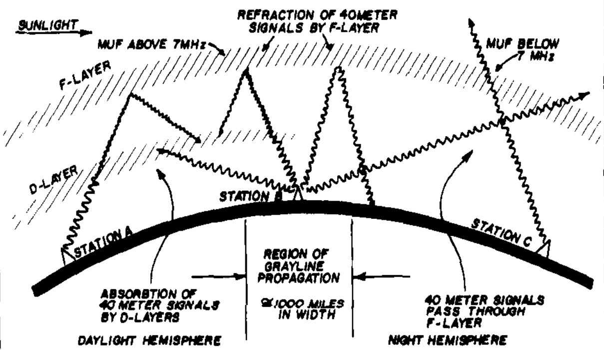

fig. 2. The mechanics of grayline propagation viewed at right angles to the Earth's terminator.

tics. Thus, the ionosphere in the twilight regions of Earth is in a state of flux and rapidly changing conditions prevail.

Because of the rapidly shifting properties of the ionosphere within this region, propagation of certain frequencies along the terminator is extremely efficient. **Fig. 2** represents a cross-sectional view of the terminator and the ionosphere in and around this region. Within the daylight hemisphere, both the D-layer and F-layer are near their peak levels of ionization. High levels of ionization cause the D-layer to become an effective absorber of radio frequency energy within the frequency range of 300 kHz to approximately 10 MHz. While the F-layer is capable of refracting radio signals within this range of frequencies, the high levels of absorption within the D-layer prevent these signals from reaching the F-layer. This explains why the 160, 80, and 40-meter bands are essentially nighttime bands except for local or regional communications.

visualizing grayline

To visualize how grayline propagation works, examine station "A" in **fig. 2**. Located in the daylight hemisphere, its 40-meter signal is severely attenuated as it passes through the D-layer. That signal which remains is refracted by the F-layer, only to be further attenuated as it passes through the D-layer on its return path. Some RF energy will, in fact, reach the surface, but it will be well below the threshold of detectability in Amateur receivers. The only way to avoid this dilemma would be to increase power to levels well above those allowed in the Amateur service or to increase integration time of receiver detection systems well beyond that which is required for either CW or SSB.

Station "C," in **fig. 2**, suffers from the opposite problem. The D-layer is nonexistent due to the lack of solar radiation, but because of changes in the F-layer, the MUF (Maximum Usable Frequency) has dropped below 7 MHz. As a consequence, the 40-meter signal radiated by station "C" penetrates the ionosphere and is lost.

Now look at station "B," located in the terminator region on the Earth's surface. Signals radiated toward the daylight region are as severely attenuated as those of station "A," while the signals radiated toward the nighttime region pass through the ionosphere, as are those of station "C." It would seem that station "B" is in no more a favored position than those other two stations. **Fig. 3** illustrates what would happen in actual operation. Signals radiated parallel to the terminator are propagated for long distances with little attenuation.

Because the terminator, shown in **fig. 3**, extends completely around the Earth, it is possible to work into any area of the world within this region. This situation is most noticeable on 80 and 40 meters and, to a lesser degree, on 20, 30, and 160 meters. Since these low-band signals suffer little attenuation on this path, long distance communications are possible with low power levels and ordinary non-directional antennas, such as dipoles and verticals.

There are, unfortunately, some areas of the world you'll never be able to work using grayline; this is because any two selected areas on the surface of the Earth do not necessarily share a common terminator. If the Earth's rotational axis were tilted 45 degrees from the plane of the ecliptic, then, at some time or other

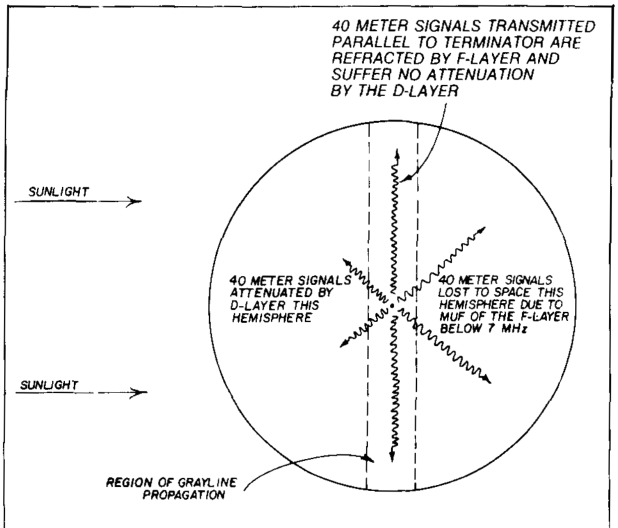

fig. 3. Radio wave propagation along the terminator.

during the year, your QTH would be on the terminator with every other spot on the Earth's surface. In addition, the position of the terminator and hence the path of grayline propagation is not stationary, but instead moves with the changing seasons because of the yearly movement of the Earth's rotational axis with respect to the Sun.

Two other factors enter into grayline DXing. Remember that local time will vary all along the length of the terminator. Since most Amateurs are more active in the local afternoon and early evening, rather than at dawn, time your operating to coincide with that time when *they* are most active. Thus, to work hams on the other side of the world with this mode, the best time would be between 30 minutes before to 30 minutes after your local sunrise. In addition, remember that the position of the terminator at sunrise is not the same as its position at sunset, local time.

Figs. 4, 5, and **6** show the positions of the terminator at various times throughout the year. Notice that the only time the sunrise and sunset paths coincide is twice a year, during the spring and fall equinoxes. *The information shown in these three charts is valid only for a station located in the Pacific Northwest and will be different for stations located elsewhere.** It is apparent that a station in Seattle could work half of Africa, Europe, much of Asia, parts of South America, and much of the South Pacific during the course of a year using grayline propagation on 80 and 40 meters.

determining grayline paths

There are several methods used to determine grayline paths for your location. The easiest, but most cumbersome, involves the use of a globe and a piece of thin cardboard. *Any* globe will do, even the type sold as piggybanks in the local five-and-dime. Cut a circular hole in the center of the cardboard just big enough to allow it to slip over the globe. It can then be positioned on the globe to represent the grayline path during any particular day of the year. This method can also be used to determine the grayline path for

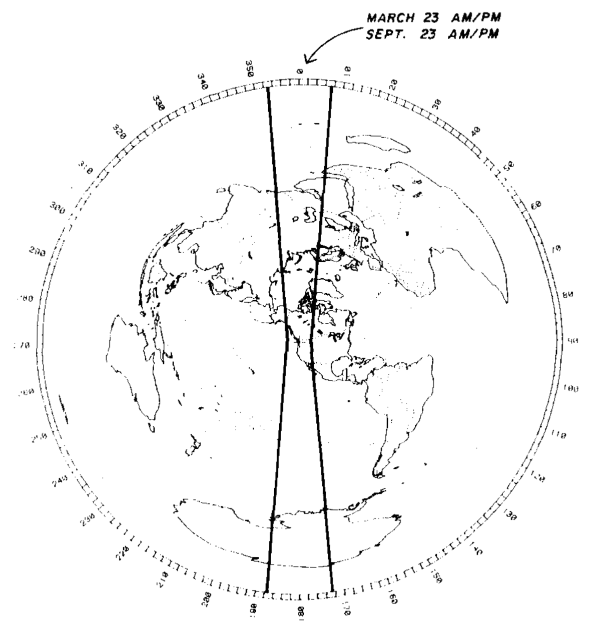

fig. 4. Grayline paths during the equinoxes. (Azimuthal-equidistant maps prepared by Bill Johnston, N5KR.)

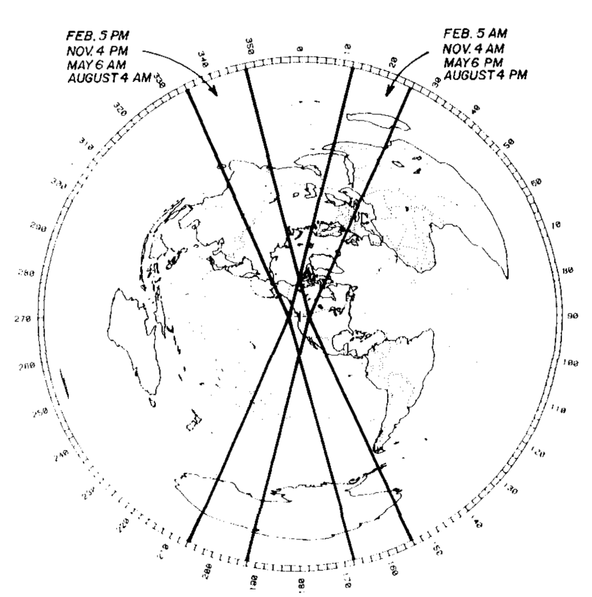

fig. 5. Grayline paths during several non-equinox periods. (Azimuthal-equidistant maps prepared by Bill Johnston, N5KR.)

*Custom-made azimuthal-equidistant (great circle) maps centered on your own location are available from Bill Johnston, N5KR, 1808 Pomona Drive, Las Cruces, New Mexico 88001.

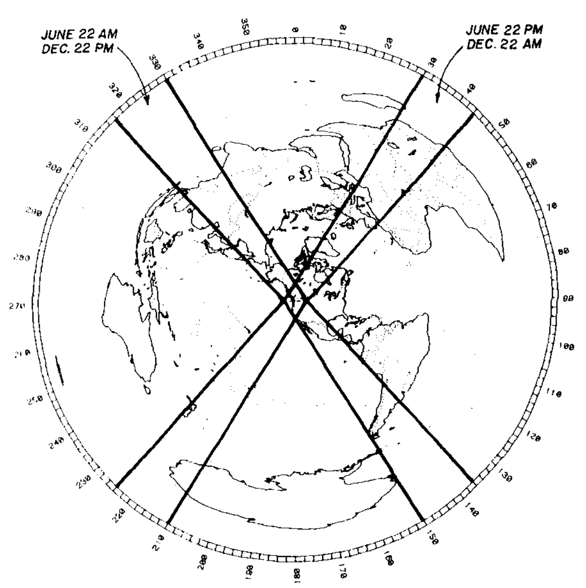

fig. 6. Grayline paths during the longest and shortest days of the year. (Azimuthal-equidistant maps prepared by *Bill* Johnston, N5KR.)

selected times during the year and plot the results on a map as was done in **figs. 4**, **5**, and **6**. (These base maps are available through a number of sources, most of which advertise in the various Amateur magazines.) By taking the time to devise three sets of maps, the approximate grayline path for any day of the year can be quickly and easily determined.

Perhaps the most convenient method of figuring grayline paths is through the use of "The DX Edge," slide rule-type device with a map of the world printed on one side and equipped with a series of overlays representing the grayline paths for each month of the year.* By sliding the appropriate overlay back and forth along the map, the path of the terminator across the Earth's surface is easily determined.

Regardless of the method used, figuring and using grayline propagation paths will enhance your ability to work low-band DX. Of course, the old adage "The higher the antenna, the better" is still true. But the fact that you don't have a directional antenna array or a 2000 watt amplifier is no excuse for not snagging the rare ones. Patience, perserverance, and a knowledge of grayline propagation will catch all the 80 and 40-meter DX you can handle, and you won't have to stay up until two o'clock in the morning to do it.

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ham radio

**DX Edge* is available from Ham Radio's Bookstore, Greenville, New Hampshire 03048 ($16.95 plus $1.50 postage and handling).

DXing by computer

Program determines grayline, distance/azimuth, and MUF/FOT

You're an avid contester who needs an elusive KX6 multiplier on 10 and 15 meters during the VK/ZL contest in October; when should you spend time looking for this rare prefix? Or perhaps you don't care too much about DXing, but are interested in talking with a friend in Pakistan; which band and at what time should you expect propagation to be at its best? Or maybe you've heard about grayline propagation, but don't know how to tell what countries are on the grayline or when to try to make contact with them. What's the beam heading to South Africa? How far is the long path distance? If you do make contact with your friend in Australia, how good will the band conditions be? Should you use CW or SSB? It's questions such as these that suggest that the only way to manage the variety and volume of information available to Amateurs is by computer.

The user-friendly program described in this article consolidates the best features of many programs already on the market. It makes available, for the first time, a means of accurately determining the sunrise and sunset grayline for any location on the earth and for any desired day during a year.

A summary of the program's features is shown below, and a short discussion of the outputs follows. In addition, several examples of how to use the program are demonstrated by answering some of the questions raised at the beginning of the article.

User inputs (data entered) include the date, base location, the name of any of 433 target locations (countries, states, or provinces), DX location (target), 10.7 cm solar flux, geomagnetic A factor, and the grayline desired and its width.

Printed program outputs include the grayline output and screen output. Computer inputs include the following:

Base sunrise/sunset times. This is normally the user's operating location sunrise/sunset times given in UTC, or more popularly, GMT. The algorithm used to calculate the sunrise and sunset times has been extensively compared to world and nautical almanacs *and no error greater than 1 minute has been found.*

Target sunrise/sunset times. If the target selected is a single point — that is, one specific location — the output will give only the target average sunrise/sunset time. If you have chosen a country for your target location, and the country is large enough to have significantly different sunrise/sunset times, then the output will include a *minimum and maximum* sunrise and sunset time. This output can be used to determine the coincident darkness and daylight between you and the desired target. In general, look for 10 and 15-meter openings during daylight coincidences (except in years of very high sunspot activity). Look for openings on

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40, 80, and 160 meters during darkness coincidences. *Twenty meters is normally open most days and nearly through the night to some areas of the world.*

Long/short path output. The program computes the long path and short path great circle distance in nautical miles *(1 nautical mile = 1.15 statute miles = 1.85 kilometers)* and also computes the long and short path compass beam headings between the user's operating location and the desired target location.

Sunspot number/quality factor. The program determines the sunspot number based on the 10.7 cm solar flux. The quality factor comes from the August, 1982, issue of *ham radio* and is an empirical means of describing the quality of a QSO, with 0 being poor and 9 being very good.[1]

MUF/FOT. The MUF or Maximum Usable Frequency is a definite boundary that the HF user cannot overcome with power, antenna, or other mechanical means. The MUF is the range of frequencies that can be used before radio waves penetrate the F layer and not return to earth. *Because of minimum signal absorption at this frequency, the MUF gives the greatest signal strength at the receiving point for a given transmitted power.* Fifty percent of the month the highest propagated frequency achieves this value — MUF. Ninety percent of the month, the highest propagated frequency will achieve the value known as FOT (Frequency of Optimum Transmission). FOT is also included in the program and uses the same algorithm as was used to do MUF. This section of the program makes use of information provided by Robert Rose, K6GKU, on MINIMUF.[2]

Grayline. Observation has shown that enhanced conditions for working DX often occur at sunrise and sunset. This is particularly true when both the base location and the desired target location are undergoing sunrise or sunset at the same time. This section of the program provides an easy means of determining who else in the world is experiencing sunrise or sunset at the same time that you are. The grayline is the great circle path that describes the line drawn on the earth that separates the half that is in daylight from the half in darkness. The width of the grayline is a variable that is determined by the user; for most applications, a time window of ± ½ hour is sufficient to determine which countries can be found. This corresponds to a grayline width of 15 degrees.

The two questions that are answered by this part of the program are first, for any day, when will my sunrise/sunset occur? And second, what will be the bearing of the grayline, and what targets will lie along it?

table 1. Program output display showing information and format available.

```
[1] JAN 1                                    PATH
          LAT    LONG                  SHORT    LONG
[2] BASE  00:00  000:00        DIST      0      21600
[3] TGT   00:00  000:00        HEAD      0        180

          SUNRISE    SUNSET
BASE       05:59      18:07     [4]   GEO-MAG 0
TGT-AVE    05:59      18:07     [4]   10.7 cm 64
TGT-MIN                               SUNSPOT 0
TGT-MAX                               Q-FACT 4.1

[5] MAXIMUM USABLE FREQUENCY (FOT [6])
00        05          10          15          20
01        06          11          16          21
02        07          12          17          22
03        08          13          18          23
04        09          14          19          24
________________________________________________
ENTER 1-6, (G)-LINE, (P)RINT
```

As you can see from the list above, the number of inputs needed is really very small and readily available from just a few sources. Using any world atlas, the latitude and longitude of the base location — this is *where you are* — can be determined. Again, using the world atlas, any specific target location — this is *where you want to go* — can be obtained. The data base of 433 unique radio locations stored in the program eliminates the need to know or look up the latitude or longitude of a specific country; all you need to know is the name of the country. The 10.7 cm solar flux and the geomagnetic A index can be obtained from WWV. Listen to any of the assigned frequencies you are able to receive, (2.5, 5, 10, 15 and 20 MHz) at 18 minutes past the hour or use the hotline telephone number (303-497-3235). The program uses the 10.7 cm flux to calculate the sunspot number, and the geomagnetic *A* index to determine the quality factor. The two final items that the program needs are the date for which you wish to calculate the program outputs, and the width of the grayline.

using the program

After the program is loaded, the monitor will display information similar to that shown in **table 1**. Three distinct sections are seen on the screen and in **table 1**: data, coordinates, distances and headings; sunrise, sunset, and the geophysical information; and MUF and FOT. The numbers in brackets indicate where the user must input data to the program. All input routines are user-friendly and have built-in error detection to prevent data that is out of range: for example, February 31 or a 10.7 cm solar flux of 0 (minimum solar

table 2. Kansas to Marshall Island path parameters.

OCT 15

	LAT	LONG		PATH SHORT	PATH LONG
BASE	37:00	100:00	DIST	4802	16798
			HEAD	275	95

TARGET NAME: MARSHALL ISLANDS
TARGET PREFIX: KX

	SUNRISE	SUNSET	
BASE	12:46	00:06	GEO-MAG 8.0
TGT-AVE	18:08	06:04	10.7 cm 133.0
TGT-MIN	18:08	06:04	SUNSPOT 86
TGT-MAX	18:08	06:04	Q-FACT 4.9

MAXIMUM USABLE FREQUENCY

0	30.9	5	16.8	10	13.1	15	14.4	20	29.0
1	28.6	6	15.7	11	12.7	16	13.7	21	31.1
2	25.0	7	14.9	12	12.4	17	17.6	22	32.6
3	19.5	8	14.1	13	12.2	18	22.7	23	32.4
4	18.0	9	13.6	14	15.1	19	26.3	24	30.9

FREQUENCY OF OPTIMUM TRANSMISSION

0	26.2	5	14.2	10	11.1	15	12.2	20	24.7
1	24.3	6	13.4	11	10.8	16	11.7	21	26.4
2	21.3	7	12.6	12	10.6	17	14.9	22	27.7
3	16.6	8	12.0	13	10.4	18	19.3	23	27.5
4	15.3	9	11.5	14	12.8	19	22.4	24	26.2

table 3. Kansas to Pakistan path parameters.

APR 15

	LAT	LONG		PATH SHORT	PATH LONG
BASE	37:00	100:00	DIST	6723	14877
			HEAD	11	191

TARGET NAME: PAKISTAN
TARGET PREFIX: AP

	SUNRISE	SUNSET	
BASE	12:08	01:13	GEO-MAG 8.0
TGT-AVE	01:03	13:55	10.7 cm 133.0
TGT-MIN	00:25	13:28	SUNSPOT 86
TGT-MAX	01:33	14:22	Q-FACT 4.9

MAXIMUM USABLE FREQUENCY

0	9.0	5	8.9	10	10.2	15	14.9	20	9.1
1	12.3	6	8.3	11	13.1	16	13.0	21	8.5
2	13.5	7	7.9	12	14.6	17	11.7	22	8.0
3	10.9	8	7.5	13	15.7	18	10.7	23	7.6
4	9.6	9	7.2	14	16.1	19	9.9	24	9.0

FREQUENCY OF OPTIMUM TRANSMISSION

0	7.7	5	7.6	10	8.6	15	12.6	20	7.8
1	10.5	6	7.1	11	11.1	16	11.1	21	7.3
2	11.4	7	6.7	12	12.4	17	9.9	22	6.8
3	9.3	8	6.4	13	13.4	18	9.1	23	6.5
4	8.1	9	6.1	14	13.7	19	8.4	24	7.7

flux is 63.75). The ability to perform a screen dump to get hard copy is also available, and that format will be used to answer some of the questions raised at the beginning of the article.

Kansas to Marshall Islands

Suppose you're a top Kansas contester who needs that KX6 prefix on 10 and 15 meters for the VK/ZL contest during the middle of October. You've determined that the geomagnetic *A* index is presently 8 and the 10.7 cm flux is 133. When do you look for that rare one? Once the coordinates, date, country, and the geophysical information have been entered, the computer will give the information shown in **table 2**.

The first thing to note is that the great circle distance is less than 6000 miles. Since this is within the 250 to 6000 mile range in which the MUF algorithm is most accurate, you can feel fairly comfortable about using the MUF/FOT data. By examining the MUF, you can see that the best time to start looking for a 15-meter path is approximately 1800 GMT, which corresponds to the KX6 sunrise. Looking for the KX6 on 10 meters, you should wait about two hours, according to the MUF. Because the FOT shows that 10 meters might not be too dependable, spending more time on 15 meters could prove more fruitful; you would probably look for KX6 on 15 first. If you got him, you'd then look for him on 10.

Kansas to Pakistan

Once you've received the greatest number of points ever accumulated in the VK/ZL contest, you decide that it would be good to talk to your friend in Pakistan. Assuming that the 10.7 cm flux and the *A* index have not changed, you have all the information you need to use the program. After inputting the needed data, the computer calculates the information shown in **table 3**.

Using **table 3**, the first thing you'll note is that the great circle distance is greater than 6000 miles, so you'll use the MUF and FOT data with caution. You'll see with some surprise that there is an overlap between your sunrise and sunset in Pakistan. Knowing that the best chance for a long path contact is when your sunset occurs slightly before sunrise in Pakistan, you see that you have a 20-minute window (01:13 - 01:33) for a possible try at that time. There are two peaks in the MUF; you're going to try them both to maximize your chances of hooking up with your friend. You'll also try 30 meters between 0100 and 0300 GMT and try 20 meters between 1200 and 1500 GMT.

Texas grayline determination

What grayline locations are available to a station in Texas during sunrise? Once you've entered your base coordinates and the date, the computer will provide the data listed in **table 4**.

table 4. Grayline countries available to Texas at sunrise on November 15. Base latitude is 030:00. The longitude is 097:00. Sunrise is at 12:52, and sunset is at 23:33. The grayline headings are 201 and 021. For a grayline width of 16.00 degrees, these are the "gray" countries.

COUNTRY	PREFIX	SS/SR	DISTANCE	HEADING
AFGANISTAN	YA	SS	14694	195
ALABAMA	W5-AL	SR	553	75
ÅLAND ISLAND	OH0	SS	17021	207
ARKANSAS	W5-AR	SR	383	37
ASIATIC R.S.F.S.R.	UA9-0	SS	16289	162
AZERBAIJAN	UD6	SS	15430	207
CASEY STATION	VK0	SS	13175	17
CHAGOS ISLANDS	VQ9	SS	12291	204
CLIPPERTON ISLAND	FO8	SR	1433	216
COLORADO	W0-CO	SR	699	323
DENMARK	OZ	SS	17179	214
DUMONT D'URAVILLE STATION	FB8Y	SS	13792	25
EASTER ISLAND	CE0A	SR	3492	193
ESTONIA	UR2	SS	16842	206
EUROPEAN R.S.F.S.R.	UA2	SS	15906	206
FINLAND	OH	SS	17060	203
FLORIDA	W4-FL	SR	744	96
GEORGIA	W4-GA	SR	688	72
GEORGIA (USSR)	UF6	SS	15666	209
GREENLAND	OX-XP	SR	3107	19
ICELAND	TF	SR	3495	29
ILLINOIS	W9-IL	SR	717	31
INDIA	VU	SS	13981	178
INDIANA	W9-IN	SR	797	38
IOWA	W0-IA	SR	732	10
IRAN	EP	SS	14930	206
JAN MAYEN	JX	SS	17912	202
KANSAS	W0-KS	SR	490	349
KARELO-FINNISH REPUBLIC	UN1	SS	16955	199
KAZAKH	UL7	SS	15500	191
KENTUCKY	W4-KY	SR	720	51
LABRADOR	VO2	SR	2077	36
LACCADIVE ISLANDS	VU7	SS	13262	194
LATVIA	UQ2	SS	16797	208
LENINGRADSKAYA STATION	UA1	SS	14253	24
LOUISIANA	W5-LA	SR	215	73
MALDIVE ISLANDS	8Q-VS9	SS	13035	197
MANITOBA	VE4	SR	1440	1
MARKET REEF	OJ0	SS	17034	206
McMURDO	KC4	SS	14369	14
MEXICO	XE	SR	604	208
MICHIGAN	W8-MI	SR	990	29
MINNESOTA	W0-MN	SR	915	9
MISSISSIPPI	W5-MS	SR	428	72
MISSOURI	W0-MO	SR	514	20
NEBRASKA	W0-NE	SR	671	350
NEW MEXICO	W5-NM	SR	517	300
NEW YORK	W2-NY	SR	1329	48
NORTH CAROLINA	W4-NC	SR	987	64
NORTH DAKOTA	W0-ND	SR	1033	352
NORTHWEST TERRITORIES	VE8	SR	2255	353
NORWAY	LA	SS	17379	209
OHIO	W8-OH	SR	911	45
OKLAHOMA	W5-OK	SR	243	351
OMAN	A4X	SS	14155	210
ONTARIO	VE3	SR	1273	23
PAKISTAN	AP	SS	14502	195
PENNSYLVANIA	W3-PA	SR	1154	50
QUEBEC	VE2	SR	1666	31
SCOTT STATION	ZL5	SS	14369	14
SOUTH DAKOTA	W0-SD	SR	856	350
SVALBARD	JW	SS	18119	194
SWEDEN	SK	SS	17166	207
TADZHIK	UJ8	SS	14938	190
TENNESSEE	W4-TN	SR	647	53
TEXAS	W5-TX	SR	184	312
TURKOMAN	UH8	SS	15180	201
UKRAINE	UB5	SS	16268	211
UNITED ARAB EMIRATES	A6X	SS	14393	211
UZBEK	UI8	SS	15364	203
VIRGINIA	W4-VA	SR	927	55
WHITE R.S.S.R.	UC2	SS	16546	210
WISCONSIN	W9-WI	SR	907	20

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ROCKWELL/COLLINS KWM-380
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Nye-MB5 3 Kilowatt Tuner
SANTEC ST-222/UP ST-142/UP ST-442/UP HT-7
Computer Interfaces stocked: MFJ-1224
AEA CP-1, Kantronics
Big Ham Clock/Ham Tags
TET ANTENNA SYSTEMS
Repeaters Stocked.
Yaesu FTR-2410, Wilson
ICOM IC-RP 3010 (440 MHz)
ICOM IC-RP 1210 (1.2 GHz) Spectrum
MFJ Models 900, 940B, 941C, & 941D
HAM MasterTapes— Beta or VHS Tapes
DIGITAL FREQUENCY COUNTER
Trionyx Model TR-1000 0-600 MHz
Digimax Model D-510 50 Hz-1GHz
MICROLOG-AIR I in stock
KANTRONICS Interface II, software
Complete Butternut Antenna Inventory In Stock!
MURCH Model UT2000B
ROBOT 450C-800C-1200C Color Mod Kits
ONV Safety belts-in stock
EIMAC 3-500Z 572B, 6JS6C 12BY7A & 4-400A
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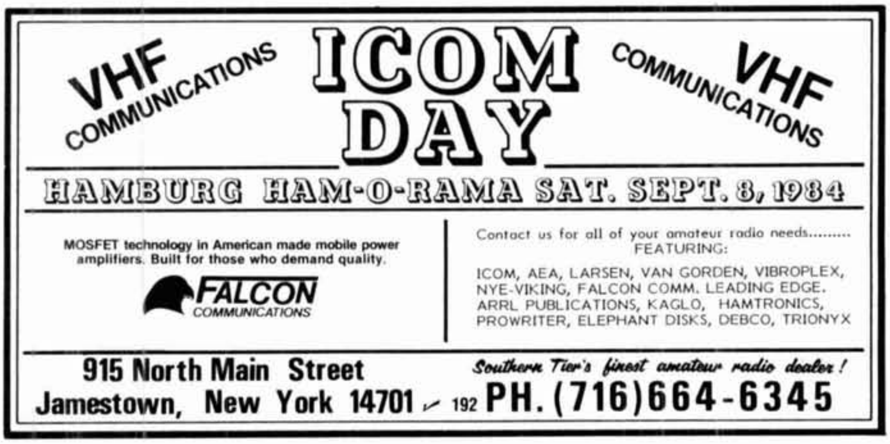

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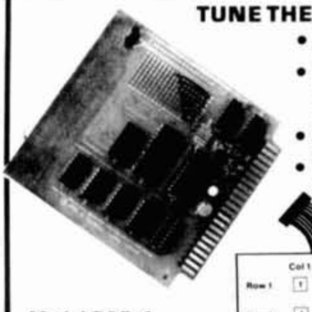

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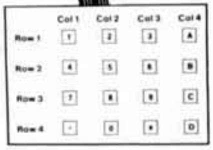

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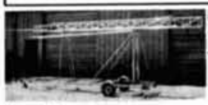

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table 5. List of long path countries from Texas at sunrise on November 15. (These countries meet the additional criterion that Texas sunrise occurs after their sunset.)

AFGHANISTAN
EUROPEAN R.S.F.S.R.
FINLAND
IRAN
KARELO-FINNISH REPUBLIC
KAZAKH
NORWAY
PAKISTAN
SWEDEN
TURKOMAN
UZBEK

Assume that you're interested in working only long path this morning. If you know that the best chance for a long path QSO occurs between the distant station's sunset and your sunrise, use the program to determine which of the countries listed in **table 4** meet that condition. These countries are listed in **table 5.** The value given in the HEADING column is the long path direction to the particular country. The program gives long path when the sunrise or sunset of the distant QTH is opposite yours.

do it yourself?

This program is available for purchase in two versions (one with the grayline feature, DX1, and one without the grayline feature, DX2), each configured for any 64k Apple with a disk drive and 16K expander (a printer is optional; if you have one, be sure to plug it into slot No. 1). Purchase information, as well as information describing computer services available to owners of computers other than the Apple, is provided at the end of this article.

It took the two of us *nine months* to develop and debug this program. But if you'd like to try writing your own, here's what you'll need to know. Almost all the information any DX or SWL operator needs for effective operation is available in standard sources and can be written into a single program. You'll need a variety of resources — a thorough understanding of programming *your* computer — but it can be done.

Basic sources of data include a DX country list and for each country given, the appropriate coordinates; you'll also need a MUF summary, beam headings, Great Circle Distances, Sunrise and Sunset times, and a list of grayline countries. The grayline list can be generated using a variety of techniques, including calculation from sunrise/sunset times and longitude[3] or a slide rule-like product, *DX Edge*;* what makes this program unique is not the data itself, but how it is assembled and made useful.

developing the data base

From the beginning it was clear that the program would have to have a world data base that was always in memory. This would allow the other sections of the program using the data base to run at a higher speed, and eliminate the need for disk access, which would slow the program down. The program would also have to be done in a language that would allow the source code to be compiled; we chose Pascal, which allowed a structured approach to be followed and made "modular code development" possible. By using Pascal, we could write, debug, and compile each module separately. The program would also have to integrate the various data in such a way that would allow the program to be easy to use — i.e., "user friendly." It would have to "fit" into a 64k Apple.†

The most challenging part of designing this program was the development of the grayline feature; this is the area we'll discuss here in the greatest depth. The other sections of the program will be summarized, with the sources or the equations used to develop them shown in appendix A.

Using the equations shown in appendix A, you can write your own version of the program. *The version of the program shown in the examples in this article has been copyrighted*; however, all pertinent information is shown here for the benefit of *ham radio's* readers who wish to experiment with developing their own programs.

Our final world data base consists of 433 countries, states, and provinces, as well as prefixes and an average of three points per country for doing the grayline determination. A complete 15-page listing of the world data base will be provided for a 8½ × 11 SASE and $3.00 to help defray the cost of photocopying. (Send requests directly to author.)

The final program consists of 1600 lines of code or about 26 sheets of paper requiring 61,440 bytes of storage before compilation. After the data is compiled, an additional 21,504 bytes are needed for storage. Again, note that a large portion of this program is designed to produce "friendly" input and output routines; this results in a great deal of software "overhead."

The data base required 71,440 bytes of disk storage — more than our machine's memory could accommodate. By applying a "compaction scheme," we were able to reduce the number of bytes required to 19,456.

determining grayline

The grayline is the Great Circle path that defines or

*DX Edge is available from Ham Radio's Bookstore, Greenville, New Hampshire 03048 ($16.95 plus $1.50 postage and handling).

†A 16k extender card must be added for the version of the program reproduced here and the purchased program as well. The cost of a 16k card is approximately $25.00.

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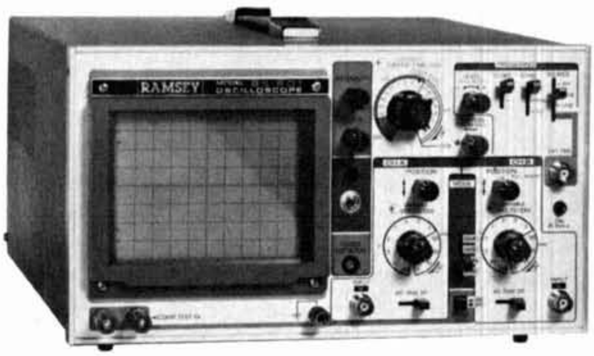

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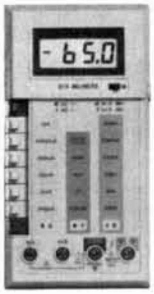

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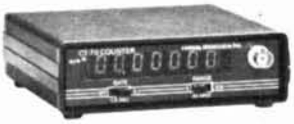

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separates the regions of the world that are in daylight and darkness. Each location on the globe has two graylines each day; one at sunrise and the other at sunset. In order to accurately determine the grayline, an accurate equation for sunrise is necessary. Part of the sunrise/sunset equation is the declination of the sun; the equation that describes sunrise time and sunset time and declination of the sun are shown in appendix A.

In order to determine whether or not a particular country is on the grayline, a comparison must first be made between the sunrise/sunset of the desired location and the desired country. But which coordinates should be used to describe the location of a country? Consider, for example, the USSR. This country has several different radio prefixes within it and spans thousands of miles. It's obvious, then, that any "average" of the latitude and longitude would be grossly incorrect in describing the USSR. If the country selected were Andorra, then this means of describing the country would be fully acceptable. So what's the best way to describe each country? Each country must be described (i.e., digitized with a sufficient number of points) in such a manner that during the year all minimum and maximum sunrise/sunset points will have been obtained.

By trial and error, the following approach has been successful in limiting the total number of data points necessary to describe each country.

In the rough outline drawing of the state of California (**fig. 1**), the extreme points of the state are emphasized. These are the points that were assumed to be the minimum number necessary to describe California as far as differences in sunrise and sunset time are concerned.

All of the points on the outline of the state were programmed into the sunrise and sunset equations shown in the appendix along with intermediate points to confirm that they were, in fact, sufficient to describe a "radio country." This approach was determined to be valid. (While the simple drawing shown in **fig. 1** is far less complex than a sketch of the USSR — with its many prefixes — would be, for example, it should be easy to imagine what the final "radio country" sketch of such a vast area would look like.)

This approach was used for every country in the *DX Callbook*, for each one of the United States, for all provinces of Canada, and for any new country that could be found at the time the program was developed. Once the world data base was developed, a second data base was extracted from it and used to calculate beam headings and Great Circle distances. This second data base is essentially the average of all the given points that describe each country. In **fig. 1**, point E represents the average.

Readers who want to generate their own data base

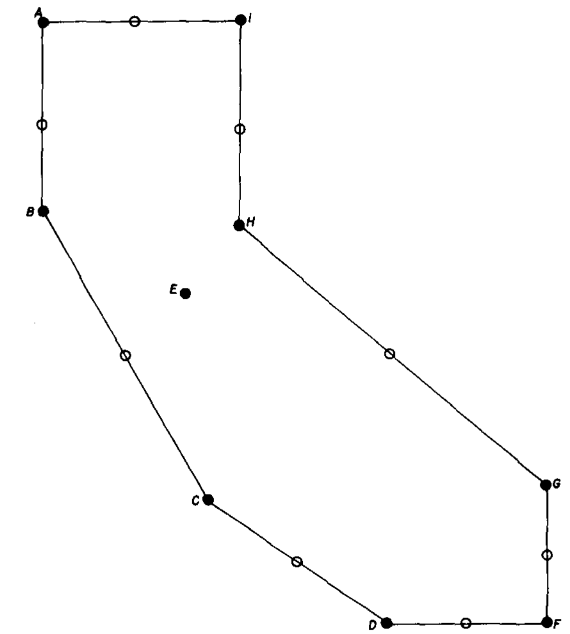

fig. 1. Calculation of sunrise and sunset times begins with a rough sketch of area to be identified.

can produce the best result if they use a computer that automatically digitizes each country and then computes sunrise and sunset times throughout the year.

using the data base

If the sunset or sunrise time is accurately known for your location, then it's easy to determine the countries that lie on the grayline. Calculate the sunrise and sunset times for each of the points of a particular country. Since the time that the grayline occurs is identical for all the points along it, compare each of the calculated times in the countries of interest to the time at your base location. If the difference in time is within the range of time desired — typically ± 1/2 hour, or if the base sunrise/sunset lies between the minimum and maximum rise/set times, then that particular country is on the grayline.

When printing out the grayline, the subroutines for heading and distance are also used as an aid in determining long and short path propagation. The beam heading for grayline can be determined by first using the equation of time rewritten to solve for longitude. The latitude used is arbitrarily chosen to be the target latitude + or − 25 degrees. Once the longitude is found, the equation for beam heading is employed by using your base location and the arbitrarily chosen latitude and computed longitude. This will then be the grayline heading. To output long path distance, just subtract the short-path distance computed by the equation in appendix A from 21600. The final item of interest that can be extracted from the data base is *whether the country that is on the grayline is going through sunrise or sunset.* Keep track of which time equation was used to match your base location time — sunrise or sunset — and make note of which one it was when printing out your listing. A brief excerpt from the program manual will show why this information is important to you:

Daylight overlap. Compare your sunrise with the target sunset(s). The time span between could be good for daylight openings.

Daylight openings. Try 10 or 15 meters, except when the sunspot number is high.

Darkness overlap. Compare your sunset with the target sunrise(s). The time span could be good for darkness openings.

Darkness openings. Try 30, 40, 80, 160 meters.

Long-path openings. Base sunset occurs *before* target sunrise; base sunrise occurs *after* target sunset; use long-path heading.

Grayline openings. Eastern paths: look *before* sunrise; western paths: look *after* your sunrise; use grayline heading.

conclusion

With the writing of this program, we have attempted to combine a variety of aids for the Novice or experienced operator that will free up his or her schedule for more time on the air. For the first time, an accurate computerized grayline that leaves no doubt as to what country lies on the grayline and what time to operate is available. (This program will *not* help predict those cases in which what appears to be grayline propagation is occurring, but is one hour too early.) Propagation modes are varied and many; this program serves as a predictive tool to the ham operator and SWLer alike in providing assistance for some, but not all, modes of propagation.

acknowledgement

We would like to acknowledge the patience that both our wives exhibited while we developed and tried to perfect this program. Many thanks also to Vern, K6VXY, for his unflagging love of CW that gave us the idea and inspiration for this program.

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1. Garth Stonehocker, KØRYW, "DX Forecaster," *ham radio*, August, 1982, page 80.
2. Robert Rose, K6GKU, "MINIMUF: A Simplified MUF-prediction Program for Microcomputers," *QST*, December, 1982, page 36.
3. D. Hoppe, K6UA, P. Dalton, W6NLZ, and F. Capossela, K6SSS, "The Grayline Method of DXing," *CQ*, September, 1975, page 27.
4. G.P. Stancey, G3MCK, "An Easy Method for Determining Grayline Bearings," *Radio Communication*, July, 1981, page 623.

appendix

Use the following equations to determine base and target sunrise/sunset times, long/short path output, MUF/FOT, and gray-line. Note that some equations include additional code; be sure to include these codes to prevent "crashing" when implementing this program on your computer.

Date-dependent constants. This little do-loop determines the day number of the present date: for example, January 1 is Day Number 1; December 31 is Day Number 365.

```
monum='303232332323'
FOR I  = 1 TO (MONTH - 1) DO
DAYNUM = DAYNUM + ORD(MONUM[I]) - 20;
DAYNUM = DAYNUM + DAY;
```

Sunrise/sunset constants.

```
pi = 3.14159265
pj = pi / 180
pk = 180 / pi
```

(*Lat* signifies latitude; *Lon* indicates longitude. Both are expressed in radians.)

```
DAYCONST = 0.017202 * (DAYNUM - 1.5)

EQ_OF_T = (-1.842 * SIN(DAYCONST-0.05952)
      -2.482 * SIN(2*DAYCONST+0.3557) - 0.079 * SIN(3*DAYCONST+0.2967)
      -0.055 * SIN(4*DAYCONST+0.6981) - 0.003 * SIN(5*DAYCONST+0.7156))
      / 15

DECL = PJ * (0.379 - 23.267 * COS(DAYCONST+0.1793)
      -0.381 * COS(2*DAYCONST+0.1292) - 0.171 * COS(3*DAYCONST+0.5184)
      -0.008 * COS(4*DAYCONST+0.4538) - 0.003 * COS(5*DAYCONST+1.658))

temp = 12 - eq_of_t + long * pk / 15
temp1 = arccos((-0.01454 - sin(lat) * sin(decl)) /
   (cos(lat) * cos(decl))) * pk / 15;

sunrise = temp - temp1
sunset = temp + temp1
```

Answer is in decimal hours.

Conversion of 10.7 cm flux and the quality factor.

```
sunspot number = (-0.728 + sqrt(0.728*0.728 - 4 * (63.75 - flux) * 0.00089))
/ 0.00178;

qual   := 1.0857 * ln(flux) * (1.0 - 0.2625 * cos(8.642E-3 * daynum) *
cos(8.642E-3 * daynum)) * exp(-0.01 * gflux) + 0.82;
```

g flux indicates geomagnetic flux or A factor; **flux** signifies the 10.7 cm flux as reported by WWV.

Great Circle distance/beam headings. (Distance expressed in radians*; heading from Lat 1, Lon 1 to Lat 2, Lon 2. Check for poles.)

```
IF LAT1 > 1.5533 THEN LAT1 = 1.5533
IF LAT1 < -1.5533 THEN LAT1 = -1.5533

IF LAT2 > 1.5533 THEN LAT2 = 1.5533
IF LAT2 < -1.5533 THEN LAT2 = -1.5533
```

*To convert distance to nautical miles, multiply by 60 * pk.

Check for diametrically opposed locations.

```
IF (ABS(LON1 - LON2) > 3.124139) AND
((-1.0 * ROUND(LAT1*120)) = (ROUND(LAT2 *120)))

THEN LON2 = LON2 + 0.01745
```

Check for equal longitudes.

```
IF ROUND(LON1 * 120) = ROUND(LON2 * 120) THEN DISTANCE = ABS(LAT1 - LAT2)
IF LAT1 > LAT2 THEN HEADING = PI ELSE HEADING = 0.0



DISTANCE = ARCCOS(SIN(LAT1) * SIN(LAT2) +
           COS(LAT1) * COS(LAT2) * COS(LON2 - LON1))

HEADING  = ARCCOS((SIN(LAT2) - SIN(LAT1) * COS(DISTANCE)) /
           (SIN(DISTANCE) * COS(LAT1)))
```

Check to see if heading needs to be reversed.

```
IF SIN(LON2 - LON1) > 0.0 THEN HEADING = 2 * PI - HEADING
```

For information on how to order a copy of the program, or to obtain other DX computer services if you don't own an Apple, contact Van Brollini, NS6N, 5861 Bridle Way, San Jose, California 95123 (SASE appreciated).

ham radio

✓ 138

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1412 1412G	144	160	30	199 239
2210 2210G	220	130	10	225 265
2212 2212G	220	130	30	199 239
4410 4410G	440	100	10	225 265
4412 4412G	440	100	30	199 239

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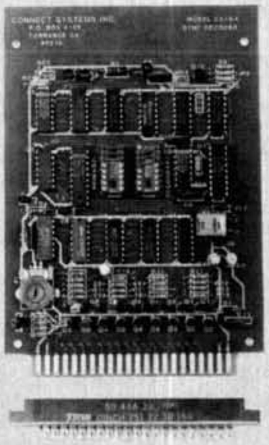

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2114L-3	1024 x 4 (300ns) (LP)	1.30
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TMS2716	2048 x 8 (450ns)	7.90
TMS2532	4096 x 8 (450ns) (5v)	5.90
2732	4096 x 8 (450ns) (5v)	4.45
2732-250	4096 x 8 (250ns) (5v)	8.45
2732-200	4096 x 8 (200ns) (5V)	11.45
2764	8192 x 8 (450ns) (5v)	6.45
2764-250	8192 x 8 (250ns) (5v)	7.45
2764-200	8192 x 1 (200ns) (5v)	16.45
TMS2564	8192 x 8 (450ns) (5v)	14.45
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27128	16384 x 8 Call	24.45

5v = Single 5 Volt Supply

74LS00

74LS00	.23	74LS173	.68
74LS01	.24	74LS174	.54
74LS02	.24	74LS175	.54
74LS03	.24	74LS181	2.10
74LS04	.23	74LS189	8.90
74LS05	.24	74LS190	.88
74LS08	.27	74LS191	.88
74LS09	.28	74LS192	.78
74LS10	.24	74LS193	.78
74LS11	.34	74LS194	.68
74LS12	.34	74LS195	.68
74LS13	.44	74LS196	.78
74LS14	.58	74LS197	.78
74LS15	.34	74LS221	.88
74LS20	.24	74LS240	.94
74LS21	.28	74LS241	.98
74LS22	.24	74LS242	.98
74LS26	.28	74LS243	.98
74LS27	.28	74LS244	1.25
74LS28	.34	74LS245	1.45
74LS30	.24	74LS247	.74
74LS32	.28	74LS248	.98
74LS33	.54	74LS249	.98
74LS37	.34	74LS251	.58
74LS38	.34	74LS253	.58
74LS40	.24	74LS257	.58
74LS42	.48	74LS258	.58
74LS47	.74	74LS259	2.70
74LS48	.74	74LS260	.58
74LS49	.74	74LS266	.54
74LS51	.24	74LS273	1.45
74LS54	.28	74LS275	3.30
74LS55	.28	74LS279	.48
74LS63	1.20	74LS280	1.95
74LS73	.38	74LS283	.68
74LS74	.34	74LS290	.88
74LS75	.38	74LS293	.88
74LS76	.38	74LS295	.98
74LS78	.48	74LS298	.88
74LS83	.59	74LS299	1.70
74LS85	.68	74LS323	3.45
74LS86	.38	74LS324	1.70
74LS90	.54	74LS352	1.25
74LS91	.88	74LS353	1.25
74LS92	.54	74LS363	1.30
74LS93	.54	74LS364	1.90
74LS95	.74	74LS365	.48
74LS96	.88	74LS366	.48
74LS107	.38	74LS367	.44
74LS109	.38	74LS368	.44
74LS112	.38	74LS373	1.35
74LS113	.38	74LS374	1.35
74LS114	.38	74LS377	1.35
74LS122	.44	74LS378	1.13
74LS123	.78	74LS379	1.30
74LS124	2.85	74LS385	1.85
74LS125	.48	74LS386	.44
74LS126	.48	74LS390	1.15
74LS132	.58	74LS393	1.15
74LS133	.58	74LS395	1.15
74LS136	.38	74LS399	1.45
74LS137	.98	74LS424	2.90
74LS138	.54	74LS447	.36
74LS139	.54	74LS490	1.90
74LS145	1.15	74LS624	3.95
74LS147	2.45	74LS640	2.15
74LS148	1.30	74LS645	2.15
74LS151	.54	74LS668	1.65
74LS153	.54	74LS669	1.85
74LS154	1.85	74LS670	1.45
74LS155	.68	74LS674	9.60
74LS156	.68	74LS682	3.15
74LS157	.64	74LS683	3.15
74LS158	.58	74LS684	3.15
74LS160	.68	74LS685	3.15
74LS161	.64	74LS688	2.35
74LS162	.68	74LS689	3.15
74LS163	.64	74LS783	23.95
74LS164	.68	81LS95	1.45
74LS165	.94	81LS96	1.45
74LS166	1.90	81LS97	1.45
74LS168	1.70	81LS98	1.45
74LS169	1.70	25LS2521	2.75
74LS170	1.45	25LS2569	4.20

7400

7400	.18	7482	.94	74172	5.90
7401	.18	7483	.49	74173	.74
7402	.18	7485	.58	74174	.88
7403	.18	7486	.34	74175	1.75
7404	.18	7489	2.10	74176	.88
7405	.24	7490	.34	74177	.74
7406	.28	7491	.39	74178	1.10
7407	.28	7492	.49	74179	1.70
7408	.23	7493	.34	74180	.74
7409	.18	7494	.64	74181	2.20
7410	.18	7495	.54	74182	.74
7411	.24	7496	.69	74184	1.95
7412	.29	7497	2.70	74185	1.95
7413	.34	74100	1.70	74190	1.10
7414	.48	74107	.29	74191	1.10
7416	.24	74109	.44	74192	.78
7417	.24	74110	.44	74193	.78
7420	.18	74111	.54	74194	.84
7421	.34	74116	1.50	74195	.84
7422	.34	74120	1.15	74196	.78
7423	.28	74121	.28	74197	.74
7425	.28	74122	.44	74198	1.34
7426	.28	74123	.48	74199	1.34
7427	.28	74125	.44	74221	1.34
7428	.44	74126	1.44	74246	1.34
7430	.18	74128	.54	74247	1.24
7432	.28	74132	.44	74248	1.80
7433	.44	74136	.49	74249	1.90
7437	.28	74141	.64	74251	.74
7438	.28	74142	2.90	74259	2.20
7440	.18	74143	2.90	74265	1.30
7442	.48	74145	.59	74273	1.90
7443	.64	74147	1.75	74276	1.20
7444	.68	74148	1.75	74279	.74
7445	.68	74150	1.30	74283	1.95
7446	.68	74151	.54	74284	3.70
7447	.68	74152	.64	74285	3.70
7448	.68	74153	.54	74290	.94
7450	.18	74154	1.20	74293	.74
7451	.22	74155	.74	74298	.84
7453	.22	74156	.64	74351	2.20
7454	.22	74157	.54	74365	.64
7460	.22	74159	1.60	74366	.64
7470	.34	74160	.84	74367	.64
7472	.28	74161	.68	74368	.64
7473	.33	74162	.84	74376	2.15
7474	.32	74163	.68	74390	1.70
7475	.44	74164	.84	74393	1.30
7476	.34	74165	.84	74425	3.10
7480	.58	74166	.95	74426	.84
7481	1.05	74167	2.90	74490	2.50
		74170	1.60		

6500

1 Mhz

6502 .... 4.90
6504 .... 6.90
6505 .... 8.90
6507 .... 9.90
6520 .... 4.30
6522 .... 6.90
6532 .... 9.90
6545 .... 21.50
6551 .... 10.85

2 Mhz

6502A 6.90
6522A 9.90
6532A 10.95
6545A 26.95
6551A 10.95

3 Mhz

6502B 9.90

6800

68000 ...... 58.95
6800 .... 3.90
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6809E 18.95
6809 .... 10.95
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6860 .... 9.90
6862 .... 10.95
6875 .... 6.90
6880 .... 2.20
6883 .... 21.95
68047 ...... 23.95
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1 Mhz

68B00 .... 9.95
68B02 ...... 21.25
68B09E 28.95
68B09 ...... 28.95
68B10 .... 6.90
68B21 .... 6.90
68B45 ...... 18.95
68B50 .... 5.90

74S00

74S00	.31	74S163	1.90
74S02	.34	74S168	3.90
74S03	.34	74S169	3.90
74S04	.34	74S174	.94
74S05	.34	74S175	.94
74S08	.34	74S181	3.90
74S09	.39	74S182	2.90
74S10	.34	74S188	1.90
74S11	.34	74S189	6.90
74S15	.34	74S194	1.44
74S20	.34	74S195	1.44
74S22	.34	74S196	1.44
74S30	.34	74S197	1.44
74S32	.39	74S201	6.90
74S37	.87	74S225	7.90
74S38	.84	74S240	2.15
74S40	.34	74S241	2.15
74S51	.34	74S244	2.15
74S64	.39	74S251	.94
74S65	.39	74S253	.94
74S74	.49	74S257	.94
74S85	1.94	74S258	.94
74S86	.49	74S260	.78
74S212	.49	74S274	19.90
74S113	.49	74S275	19.90
74S114	.54	74S280	1.90
74S124	2.70	74S287	1.85
74S132	1.20	74S288	1.85
74S133	.44	74S289	6.84
74S134	.49	74S301	6.90
74S135	.88	74S373	2.40
74S138	.84	74S374	2.40
74S139	.84	74S381	7.90
74S140	.54	74S387	1.90
74S151	.94	74S412	2.93
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8200

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8203 ..... 38.95
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8216 ...... 1.70
8224 ...... 2.20
8226 ...... 1.75
8228 ...... 3.45
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6.0 MHZ

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8T97	.88	DS8836	.98

ham radio TECHNIQUES

Bill Orr W6SAI

As of this writing (mid-June) it looks as if the FCC is slowly moving toward the possible release of additional frequencies for Amateur Radio, as authorized by the 1979 World Administrative Radio Conference. A good guess is that the so-called 24-MHz band may be released on Special Temporary Authority in the near future.

Interest in the new bands has received a boost because of the ARRL Antenna Design Competition, announced this past spring.[1] The goal of the contest is to provide new antenna designs that can be constructed at home and will cover as many of the WARC-79 bands as possible. The two entry categories include a five-band design that will cover all Amateur bands between 14 and 30 MHz and a six-band design that adds the 10-MHz band. (Details are listed in **table 1**; a "design frequency" indicating the midpoint of each band is also listed.)

the "multiband" antenna

The problem of designing a single antenna that covers the frequency range of 14 to 30 MHz (or 10 to 30 MHz, as the case may be) is an *interesting* one. No doubt many fascinating antenna designs will surface during the next few months. One basic choice that must be made is whether the antenna designed will be a wideband type that covers the entire frequency span, or a type that functions only over the bands in question. Let's look at the wideband concept first.

For this discussion, a wideband antenna is defined as one that has relatively constant gain, polarization, and

table 1. Most antennas built for the design frequency specified will work well over the whole Amateur band. Two design frequencies are chosen for 10 meters, one for operation at the low frequency end of the band and one for operation at the high frequency end.

band (MHz)	design frequency (MHz)
10.100-10.150	10.12
14.000-14.350	14.17
18.068-18.168	18.11
21.000-21.450	21.22
24.890-24.990	24.94
28.000-29.700	28.60 (low)
	29.20 (high)

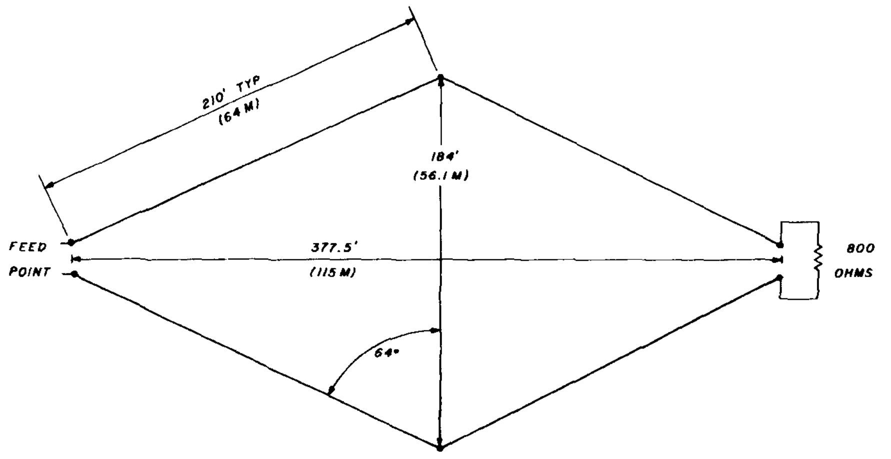

fig. 1. A terminated rhombic antenna for the frequency range of 14 to 30 MHz. Antenna is terminated with a noninductive resistor capable of dissipating about half the transmitter average power output. (Design taken from *The ARRL Antenna Book*, 14th Edition, Chapter 7, fig. 16.)

mpedance characteristics over the ɔperating range.

One of the earliest wideband gain ɜntennas is the terminated rhombic[2] ;hown in **fig. 1**. This antenna works ᴧell over a 2-to-1 frequency range, ɔrovides good front-to-back ratio and ;an exhibit as high as 14 dB gain over ɿ dipole, providing the leg-length of :he array is long enough. The front-to-ɔack ratio is achieved by choice of leg ength and the use of a terminating re-;istor, at the far end of the array, ᴧhich absorbs reflected power. Be-;ause the feedpoint resistance is about '50 to 800 ohms, an impedance match-ng transformer is required to match he antenna illustrated in **fig. 1** to a ;0-ohm transmission line.

Other varieties of traveling-wave an-ennas, such as the terminated V-an-enna, exist, but their main disadvan-age is their large size and the corre-;ponding amount of real estate they equire.

he log-periodic array

Two relatively new types of wide-ɿand antennas, the equiangular anten-ıa and the log-periodic antenna, are nore practical for Amateur service.

The equiangular antenna evolved 'om the observation that the proper-es of an antenna (impedance and pat-ɜrn) are determined by its shape and imensions with respect to operating ᴧavelength. When the antenna is caled, its properties are independent f frequency, provided its form is spec-ied only by angles and not by any par-cular dimension. A two-arm equian-ular spiral antenna, shown in **fig. 2**, ; an example of this design.

This antenna is a variation of the di-ole, where the two halves have been ᴧisted into a pair of equiangular arms. he antenna is fed by a balanced line t the center point. High frequency utoff is determined by antenna con-guration near the feedpoint; low fre-uency cutoff is determined by the uter circumference of the spiral, in-icated by the dashed line. Feedpoint ɛsistance of the antenna is quite high, ɘing of the order of 120 to 180 ohms, ɘpending upon antenna size and de-

fig. 2. The two-arm equiangular dipole antenna is fed with a balanced line at F-F. The feedpoint impedance is relatively independent of frequency over operating range. Low frequency operating limit is defined by the circumference of antenna, indicated by the dashed line. (Drawing adapted from Jasik[2].)

sign. Frequency spans as great as 10-to-1 have been achieved in practice with this antenna type.

A second wideband antenna design, with which most Amateurs are familiar, is the log-periodic antenna (**fig. 3**).* The geometry of this antenna design is chosen so that the electrical properties repeat periodically with the logarithm of frequency. The basic trapezoidal-tooth log periodic structure is shown in the illustration.

The design can be further simplified if the structure is replaced by dipole elements (**fig. 4**). This log-periodic dipole antenna is a popular design for TV and FM receiving antennas, and versions of this antenna are often used by Amateurs on the VHF bands. The frequency limits of this antenna are those at which the outer elements are about one-half wavelength long.

The dipoles are fed at the center from a parallel wire transmission line in such fashion that successive dipoles have 180-degree phase reversal between them. A broadband structure is formed, with most of the radiation coming from the section containing elements approximately half a wavelength long at the operating frequency. Gain and bandwidth bear a definite relationship to the length and included angle of the antenna.

Unfortunately, at any given frequency in the operating passband, some of the elements in this array are inactive; the active element area moves along the structure as the frequency of operation is changed. At the lowest operating frequency, the longest elements have the most current in them and, as operating frequency is raised, the center elements become active and have the greatest current in them. At the upper frequency of operation, the shortest elements have the greatest current in them, with the longer elements relatively inactive. Thus a log-periodic dipole beam antenna must be considerably longer than a parasitic Yagi antenna of equivalent gain.

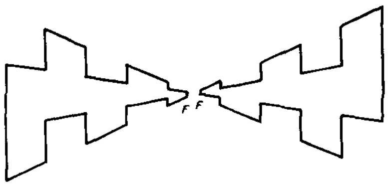

fig. 3. The geometry of the planar, log-periodic dipole antenna repeats periodically with the logarithm of the frequency.

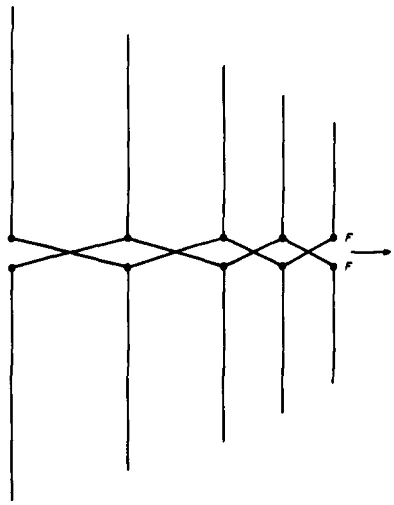

fig. 4. The log-periodic dipole array, in which linear elements replace the "teeth" of the antenna shown in *fig. 3*. This structure forms a beam antenna.

*Designed by KLM Electronics, Morgan Hill, California 95037.

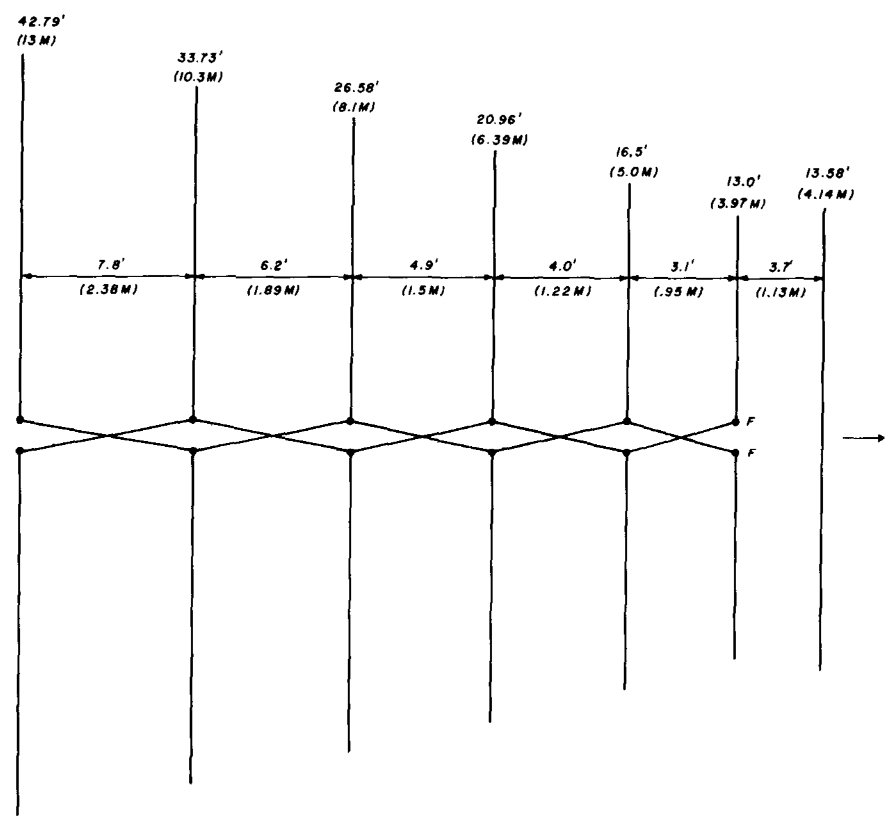

fig. 5. the KLM 13-30 LPY array covers 13-30 MHz with an average power gain of 5 dB over a dipole. The average front-to-back ratio is 15 dB. The array uses a single parasitic element.

the log-periodic Yagi

An interesting version of the log-periodic design is the log-periodic Yagi (LPY) antenna (**fig. 5**). This passband array provides higher gain per unit of length than the original designs, making use of a log-periodic dipole structure having the frequency characteristics of a bandpass filter. One or more parasitic elements are used to boost the gain of the log-periodic structure. Trimming the parasitics to specific frequencies can enhance the gain of the array at these frequencies at the expense of gain loss at other frequencies. Thus, an LPY antenna can be designed for maximum performance in closely adjacent Amateur bands (14, 18, 21, and 24 MHz, for example).

Other interesting wideband antennas exist but are not practical for use in the HF spectrum because of their size.

narrowband tuned antennas

The easiest way to get on one of the proposed new HF Amateur bands is to use a dipole cut to the midpoint of the band. A more useful antenna is a half-wave wire cut to the lowest band (for example, 10 MHz) and fed at the center with an open wire transmission line and an antenna tuner (**fig. 6**).

This is a very simple antenna and, when properly built and tuned, will cover all Amateur bands between 10 and 29.7 MHz. In fact, if the tuner is flexible enough, this antenna can also be used for the 40 and 80-meter bands, thus making a true "all-band" HF antenna.

At my station, I have an old Johnson Kilowatt "Matchbox" tuner that I picked up at a flea market. No longer made, this useful device will match almost anything at any frequency in the HF region. With this, or an equivalent tuner, the center-fed antenna dimen sions are not critical at all because th tuner makes up for variation in anten na and feeder length. If difficulty i experienced in loading up a particula combination of flat-top/feede lengths, adding or subtracting a foo or two of feeder length will usuall cure the problem.

parallel-connected dipoles

A simple multiband antenna used i the HF region consists of two or mor dipoles connected in parallel at th feedpoint. The ends of the dipoles ar separated a foot or two. This arrange ment works well when the bands ar harmonically related (7, 14, and 2 MHz, for example), but problems aris when the principle is applied to th new HF bands. Dipoles for 18 and 2 MHz, for example, when paralleled i this fashion do not seem to perfor properly. The 18-MHz dipole is una fected, but the 24-MHz dipole is con pletely detuned and will not perform all! Other combinations have not bee tried, to my knowledge, but perha one of *ham radio*'s readers will try di ferent combinations, such as 10 and MHz, or 14 and 24 MHz. I think th parallel-dipole approach has merit, b I haven't hit upon the lucky combin tion that works for the new bands

the multiband loop antenn

One interesting antenna that w cover five or six bands when used wi an open wire line and tuner is th quarter-wave loop antenna (**fig. 7** With each side cut to 24 feet 6 inch (7.47 meters), the loop will cover bands from 10 MHz up through meters. Most loops of this type a mounted in the vertical plane and f at the bottom to provide horizontal p larization. Some experimenters ha had luck with this loop mounted in t horizontal plane, about 30 to 40 fe above the ground. Horizontal polariz tion is still provided.

If operation is desired only on MHz and up, the sides of the loop c be reduced to 13 feet 9 inches (4 meters).

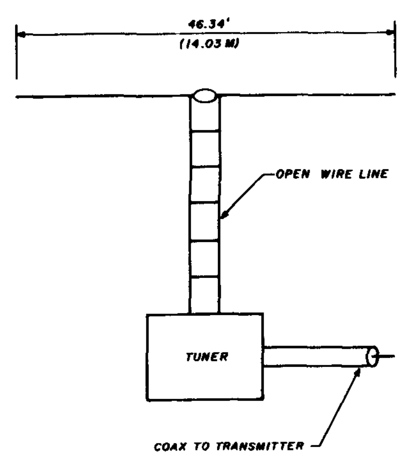

fig. 6. The 10 MHz dipole fed with random-length open wire line provides operation on all bands between 10 and 30 MHz if proper tuning unit is used.

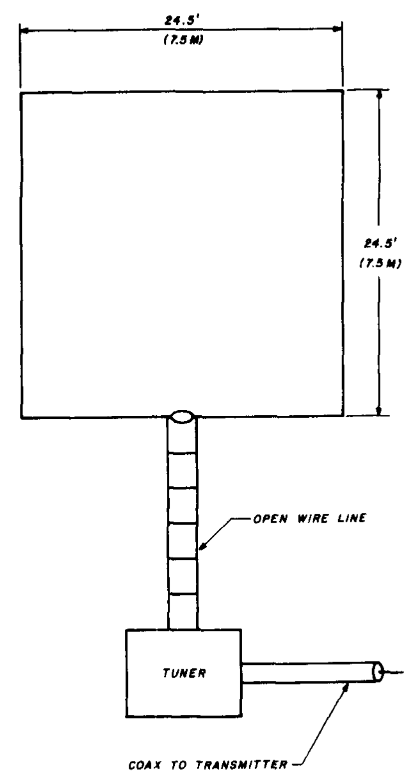

fig. 7. A simple quad-type loop antenna that will cover all bands from 30 through 6 meters. Open-wire line and antenna tuner provide balanced feed from a coaxial system.

the trap dipole

The trap dipole (**fig. 8**) makes use of the high impedance of a parallel resonant circuit to isolate or decouple unwanted tip portions of the antenna. The inner set of traps is placed in the element to isolate the center portion for operation on the highest frequency band (f_1). A second set of traps may be placed somewhat farther out along the element to isolate a longer portion, with the first set of traps becoming part of the antenna element at the lower operating frequency (f_2). Trap dipole antennas have been built with eight traps to allow operation on four Amateur bands. Trap design is straightforward, but determining the length of the tip sections, and the wire length between the traps is usually done on a cut-and-try basis.*

An approximate system for mathematically determining the length of the tip sections has been described in the Amateur literature.[3]

trap construction

Traps can be built either with discrete components (inductors and capacitors) or by using a length of coaxial line as a combined inductor and capacitor. Gary O'Neil, N3GO, described an interesting coaxial cable trap in *ham radio*, just a few years ago.[4] While his design provided somewhat better operational bandwidth than the conventional trap design, unfortunately, any form of trap made of coaxial cable is very difficult to accurately adjust to frequency because any variation in the spacing of the coiled cable can change the resonant frequency of the trap many hundreds of kilohertz. Trap construction and adjustment become quite a problem.

*An article on a computer-aided design for a trap antenna is scheduled for publication in October. — Editor

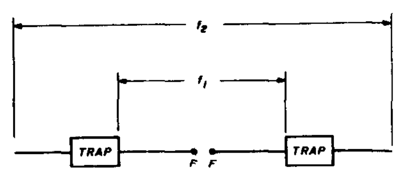

fig. 8. Trap dipole employs electrical "switches" to connect and disconnect antenna tips automatically for operation at frequencies f1 and f2.

The trap made up of a capacitor and a separate inductor is easier to adjust to frequency, which is usually chosen as the midpoint of the band. A fixed, high voltage capacitor is commonly used; one popular unit is a 25 pF, 5 kV ceramic type.* Frequency can be adjusted by pruning the parallel-connected coil. Many Amateurs use prewound, spaced air inductors mounted on four plastic strips. One type of coil, the "miniductor" manufactured by Barker & Williamson Co., is suitable for this purpose.†

Unfortunately a trap made up of an air coil and a ceramic capacitor must be protected from the weather. Water can damage the capacitor, and ultraviolet light from the sun can quickly ruin the plastic strips supporting the coil! Solving these problems is not an easy task, and any ideas supplied by the readers as to the design of a weatherproof trap assembly would be appreciated.

practical two-band dipole for 18 and 24 MHz

Here's a simple antenna you can build in anticipation of the happy day when the 18 and 24-MHz bands are made available to Radio Amateurs for general communication. Important antenna dimensions are shown in **fig. 9**. The traps are made of a coil-capacitor combination, as discussed previously, and mounted to a small ceramic insulator which serves to take the pull of the antenna.

Before the traps are installed, they must be frequency-checked with a dip oscillator and a calibrated receiver. Place the trap in an area free of nearby metallic objects and loosely couple the dip oscillator to it. When reso-

*The popular Centralab type 850 capacitors are no longer made by this company. I understand an equivalent type is manufactured by Jennings Radio Co., 970 McLaughlin Avenue, San Jose, California 95122, and also by High Energy Corp., Lower Valley Road, Parkesburgh, Pennsylvania 19365.

†Barker & Williamson Co., 10 Canal Street, Bristol, Pennsylvania 19007

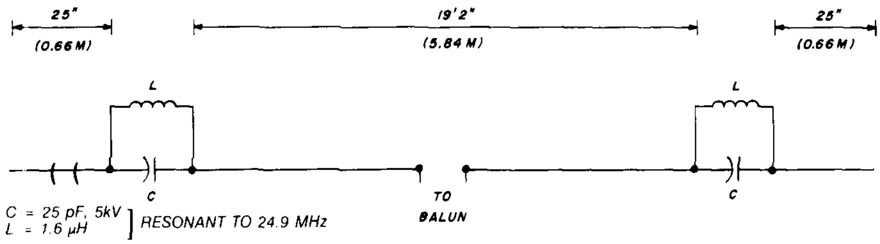

fig. 9. Trap dipole antenna for the 18 and 24 MHz bands. The trap is held in position by a 4-inch long ceramic insulator. The antenna is fed from a 1-to-1 balun and 50-ohm coaxial line.

nance is indicated, note the frequency of the oscillator on the nearby receiver. The traps should show resonance within ±100 kHz of 24.9 MHz. One end turn on each trap should be broken free of the coil bars so that it can be moved about to set the exact resonant point of the trap. You'll find that when you attach the trap across the supporting insulator, the resonant frequency will drop a bit because of the capacitance across the insulator. It's best to shoot for a resonant trap frequency about 24.9 MHz; the insulator capacitance will then place your trap "right on the nose." You can also run your checks after assembly — take your choice.

The length of the other tip sections is critical for proper operation on 18 MHz. Varying the tip length by as little as one inch per end will change the resonant frequency about 150 kHz. Since the band is only 100 kHz wide, this means tip dimensions are critical to about an inch to establish antenna resonance within the band.

The tip dimensions shown in **fig. 1** are quite accurate. If you want to frequency-check the whole antenna, suspend it in the air, in the clear, about six feet above the ground. Place a 1/2-turn inductor across the center insulator, and measure the 18 and 24 MHz frequencies of the complete antenna with a dip oscillator coupled to the inductor.

When I made my antenna I cut the tip sections about a foot longer than necessary and then folded them back and twisted the wires around the active antenna wire. That provided plenty of extra wire in case I had to lengthen the tip sections. Once I reached the correct length, I cut off the excess wire.

After some minor adjustments were made I found out that removing one inch at each end of the center dipole raised the resonant frequency of the antenna 100 kHz/inch at 24.9 MHz. (Since the length of the 24.9 MHz dipole affects the resonant frequency of the 18.1 MHz dipole, pruning the 24.9 MHz dipole must be done before the tip sections are adjusted.)

When the antenna was completely tuned, it was hauled up my tower and anchored at the 45-foot level, with the ends dropping down to the 25-foot level and tied to two nearby trees. SWR measurements revealed that the maximum figure on either range was under 1.3-to-1, with near-unity SWR at the design frequency on each band.

*Note: More information on multiband antennas and trap antennas can be found in the 22nd edition of **Radio Handbook**, available from Ham Radio's Bookstore, Greenville, NH 03048, at $21.95, postpaid.*

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3. "Trap Dipoles," *ARRL Antenna Handbook*, 14th Edition, 1982, American Radio Relay League, Newington, Connecticut, Chapters 8-4 and 10-5.
4. Gary E. O'Neil, N3GO, "Trapping the Mysteries of Trapped Antennas," *ham radio*, October, 1981, page 10.

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applied Yagi antenna design part 4: a 50-MHz Tilton/Greenblum design

Computer model analyzes, updates an atypical Yagi design

Of the four VHF/UHF bands discussed in this series, 50 MHz is the most difficult mechanically. Where the other bands' Yagis are able to employ welding rods for the driven and parasitic elements, 50 MHz requires tubing of at least 0.5 inches (1.27 cm) in diameter. Fortunately, long enough single lengths of tubing are available so the builder can avoid the additional calculations needed to compensate for telescopic elements.[1] While element mounting may require methods that have some effect on element lengths, these effects are known quantities, and of relatively minor consequence.[2]

Because the NBS 1.2 wavelength design is often the practical limit, long-boom Yagis are not common on 50 MHz. Larger Yagis would be difficult to impossible for most 50 MHz operators; stacking would present even *more* difficulties. In effect, 50 MHz presents the VHF operator many of the antenna problems normally associated with the HF bands.

selecting a 50 MHz design

Lawson demonstrated that the simple Yagi performed almost as well as any other antenna in the lengths feasible on 50 MHz.[3] Any significant improvement would have to be derived from an unequal spacing approach for the parasitic elements. Tilton presented one such design, and since its initial publication 27 years ago, it has become a standard of comparison, even being adopted by a commercial antenna manufacturer.[4] As is true of Tilton's other fine antennas, his six-element 50 MHz classic is based on the Greenblum design data.

Simply adding another director to Tilton's antenna for iteration purposes would result in a higher calculated gain and hopefully in a better overall pattern. But as is evident from examining Greenblum's data, there is a difference between an optimized seven-element Yagi and a six-element Yagi with an added element.

Tilton experimented with Greenblum Yagis of up to eleven elements. Of these Yagis, a seven-element 220 MHz design was published.[5] The design frequency appears to be 221.5 MHz, and a non-conductive boom is used. Scaling to the 50 MHz band is easily accomplished, permitting the iteration process to begin. A design frequency of 50.25 MHz was selected since a Yagi centered on this frequency can easily provide good performance across the weak signal area. **Table 1** presents spacing data for this Yagi; column two of that table contains the inter-element spacings that were calculated from those given for the 220-MHz design. The former Yagi's spacings were stated in inches and were converted to wavelengths at 221.5 MHz. These wavelengths were converted to the comparable number of inches at 50.25 MHz. For the builder's convenience, the 50.25 MHz spacings were rounded to the nearest 0.125 inch. Column three of **table 1** shows the cumulative addition of the spacings in column two, and column four is the restatement of column three in wavelengths at 50.25 MHz. All element diameters are 0.5 inches, as used in Tilton's classic. Some builders may want to use 0.75-inch tubing as is done in *The Radio Amateur's Handbook* for the NBS Yagi of this same boom length.[6]

table 1. The baselined 50.25 MHz Yagi with parasitic element lengths supplied during iteration and the driven element fixed at the non-reactive length of 112.545495 inches.

element name	element spacing (inches)	cumulative spacing (inches)	cumulative spacing (wavelengths)
reflector	0.000	0.000	0.0000
driven	44.000	44.000	0.1873
director 1	33.000	77.000	0.3278
director 2	37.500	114.500	0.4875
director 3	45.500	163.000	0.6940
director 4	57.250	220.250	0.9377
director 5	66.125	286.375	1.2192

iterating the 50-MHz Yagis

Reflector and director lengths were incremented in

By **Stanley Jaffin, WB3BGU**, 800 Stonington Road, Silver Spring, Maryland 20902

table 2. A comparison of optimized 50.25 MHz Yagis for each of six different director tapering approaches.

taper	optimized performance parameter	parasitic element length in inches reflector	director 1	gain (dBi)	F/B (dB)
0.000	gain	116.000	105.750	12.493	15.192
	F/B	115.500	103.000	12.066	49.580
0.125	gain	116.000	106.000	12.481	15.624
	F/B	115.750	103.250	12.066	50.774
0.250	gain	116.000	106.500	12.469	15.109
	F/B	115.750	103.500	12.063	59.342
0.500	gain	116.000	107.000	12.441	15.843
	F/B	116.000	104.000	12.057	52.097
1.000	gain	116.000	107.750	12.375	17.878
	F/B	117.000	104.250	11.884	60.431
1.500	gain	116.250	108.500	12.301	19.108
	F/B	117.500	104.750	11.769	42.259

table 3. Optimized gain iteration for a taper of 0.000 with a reflector length of 116.00 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
102.00	11.859	30.072
102.25	11.193	32.852
102.50	11.967	36.683
102.75	12.020	39.984
103.00	12.074	36.812
103.25	12.127	32.401
103.50	12.179	29.056
103.75	12.229	26.464
104.00	12.278	24.352
104.25	12.325	22.564
104.50	12.366	21.007
104.75	12.405	19.623
105.00	12.438	18.372
105.25	12.464	17.228
105.50	12.483	16.173
105.75	12.493	15.192
106.00	12.492	14.276
106.25	12.479	13.417
106.50	12.453	12.610
106.75	12.411	11.852
107.00	12.352	11.140
107.25	12.276	10.473
107.50	12.183	9.852
107.75	12.072	9.280
108.00	11.944	8.759
108.25	11.802	8.296
108.50	11.648	7.899
108.75	11.486	7.580
109.00	11.320	7.358
109.25	11.154	7.261
109.50	10.989	7.332
109.75	10.822	7.646
110.00	10.633	8.340

table 4. Optimized F/B iteration for a taper of 0.000 with a reflector length of 115.50 inches.

director 1 (inches)	gain (dBi)	F/B (dB)
102.00	11.856	27.029
102.25	11.909	29.117
102.50	11.961	32.046
102.75	12.014	36.815
103.00	12.066	49.580
103.25	12.118	41.466
103.50	12.169	33.637
103.75	12.218	29.414
104.00	12.266	26.457
104.25	12.312	24.152
104.50	12.354	22.247
104.75	12.393	20.612
105.00	12.427	19.172
105.25	12.454	17.881
105.50	12.475	16.708
105.75	12.486	15.631
106.00	12.488	14.634
106.25	12.478	13.707
106.50	12.454	12.841
106.75	12.416	12.032
107.00	12.362	11.275
107.25	12.290	10.570
107.50	12.201	9.915
107.75	12.093	9.312
108.00	11.969	8.764
108.25	11.829	8.277
108.50	11.676	7.859
108.75	11.513	7.522
109.00	11.344	7.285
109.25	11.172	7.175
109.50	10.998	7.236
109.75	10.818	7.542
110.00	10.613	8.231

0.25 inch steps, and element tapering was initially incremented in 0.5 inch steps. As a result of obtaining what appeared to be strange results for Greenblum Yagis, iterations were also made for tapers of 0.125 and 0.25 inch. All of these results are summarized in **table 2**. A zero taper clearly gives the highest calculated gain figures, even though Greenblum Yagis usually require some degree of parasitic element

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Crystal Controlled AFSK Modulator: A transceiver without FSK function can transmit in RTTY mode by utilizing the high stability crystal-controlled modulator controlled by the computer.
Photocoupler CW, FSK Keyer built-in: Very high voltage, high current photocoupler keyer is provided for CW, FSK keying.
Convenient ASCII Key Arrangement: The keyboard layout is ASCII arrangement with function keys. Automatic insertion of LTR/FIG code makes operation a breeze.
Battery Back-up Memory: Data in the battery back-up memory, covering 72 characters x 7 channels and 24 characters x 8 channels, is retained even when the external power source is removed. Messages can be recalled from a keyboard instruction and some particular channels can be read out continuously. You can write messages into any channel while receiving.
Large Capacity Display Memory: Covers up to 1,280 characters. Screen Format contains 40 characters x 16 lines x 2 pages.
Screen Display Type-Ahead Buffer Memory: A 160-character buffer memory is displayed on the lower part of the screen. The characters move to the left erasing one by one as soon as they are transmitted. Messages can be written during the receiving state for transmission with battery back-up memory or SEND function.
Function Display System: Each function (mode, channel number, speed, etc.) is displayed on the screen.
Printer Interface: Centronics Para Compatible interface enables easy connection of a low-cost dot printer for hard copy.
Wide Range of Transmitting and Receiving: Morse Code transmitting speed can be set from the keyboard at any rate between 5-100 WPM (every word per minute). AUTOTRACK on receive. For communication in Baudot and ASCII Codes, rate is variable by a keyboard instruction between 12-300 Baud when using RTTY Modem and between 12-600 Baud when using TTL level. The variable speed feature makes the unit ideal for amateur, business and commercial use.
Pre-load Function: The buffer memory can store the messages written from the keyboard instead of sending them immediately. The stored messages can be sent with a keyboard command.
"RUB-OUT" Function: You can correct mistakes while writing messages in the buffer memory. Misspellings can also be erased while the information is still in the buffer memory.
Automatic CR/LF: While transmitting, CR/LF automatically sent every 64, 72 or 80 characters.
WORD MODE operation: Characters can be transmitted by word groupings, not every character, from the buffer memory with keyboard instruction.
LINE MODE operation: Characters can be transmitted by line groupings from the buffer memory.
WORD-WRAP-AROUND operation: In receive mode, WORD-WRAP-AROUND prevents the last word of the line from splitting in two and makes the screen easily read.
"ECHO" Function: With a keyboard instruction, received data can be read and sent out at the same time. This function enables a cassette tape recorder to be used as a back-up memory, and a system can be created just like telex which uses paper tape.
Cursor Control Function: Full cursor control (up/down, left/right) is available from the keyboard. Test Message Function: "RY" and "QBF" test messages can be repeated with this function.
MARK-AND-BREAK (SPACE-AND-BREAK) System: Either mark or space tone can be used to copy RTTY.
Variable CW weights: For CW transmission, weights (ratio of dot to dash) can be changed within the limits of 1:3-1:6.
Audio Monitor Circuit: A built-in audio monitor circuit with an automatic transmit/receive switch enables checking of the transmitting and receiving state. In receive mode, it is possible to check the output of the mark filter, the space filter and AGC amplifier prior to the filters.
CW Practice Function: The unit reads data from the hand key and displays the characters on the screen. CW keying output circuit works according to the key operation.
CW Random Generator: Output of CW random signal can be used as CW reading practice. **Bargraph LED Meter for Tuning:** Tuning of CW and RTTY is very easy with the bargraph LED meter. In addition, provision has been made for attachment of an oscilloscope to aid tuning.
Built-in AC/DC: Power supply is switchable as required; 100-120 VAC; 220-240 VAC/ 50/60Hz + 13:8VDC.
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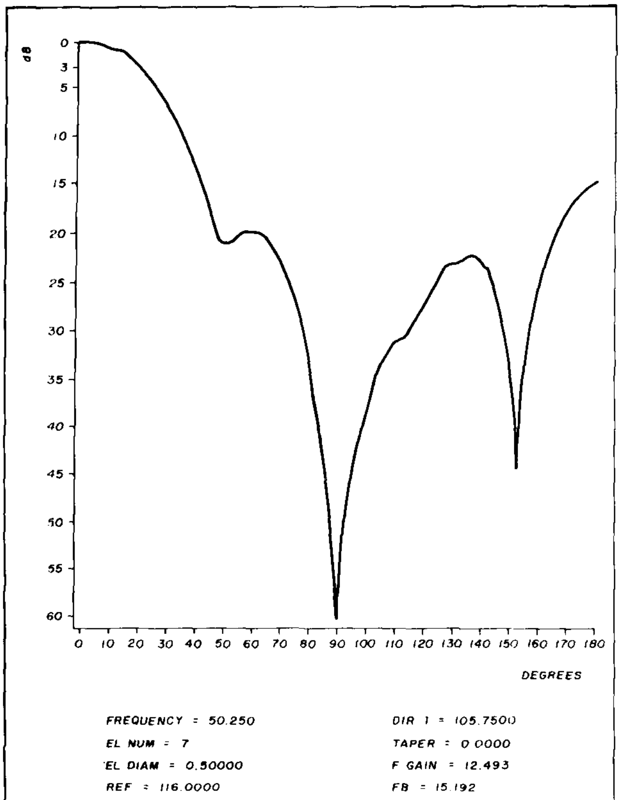


fig. 1. Zero taper gain optimized E-plane plot.

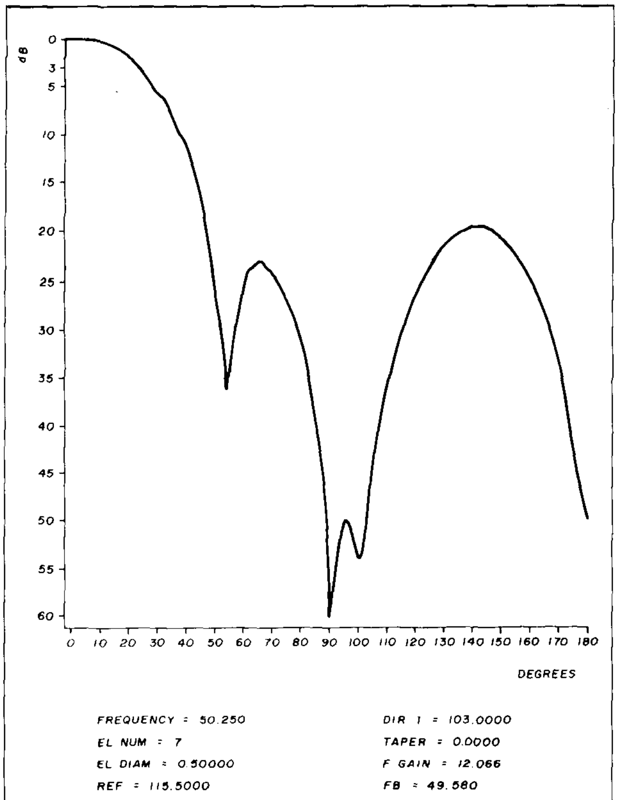


fig. 2. Zero taper F/B optimized E-plane plot.

table 5. Frequency response parameters for the gain optimized Yagi with a 0.000 taper.

frequency (MHz)	gain (dBi)	F/B (dB)
47.25	9.477	7.003
47.75	10.299	9.345
48.25	10.987	12.406
48.75	11.542	16.781
49.25	11.993	23.899
49.75	12.337	22.019
50.25	12.493	15.192
50.75	12.314	11.005
51.25	11.746	8.321
51.75	11.083	7.181
52.25	10.671	9.386
52.75	3.191	−0.549
53.25	−8.390	−14.057

table 6. Frequency response parameters for the F/B optimized Yagi with a 0.000 taper.

frequency (MHz)	gain (dBi)	F/B (dB)
47.25	8.775	5.016
47.75	9.672	6.858
48.25	10.431	9.105
48.75	11.014	11.874
49.25	11.449	15.540
49.75	11.787	21.460
50.25	12.066	49.580
50.75	12.282	21.748
51.25	12.378	15.236
51.75	12.247	11.331
52.25	11.816	8.631
52.75	11.204	6.984
53.25	10.835	7.071

tapering.[7] The zero taper F/B optimized Yagi, while not possessing the maximum calculated F/B, does have an outstanding F/B that is clearly representative of the F/B optimized Yagis.

Table 3 presents the iterations that identified the optimized gain of 12.493 dBi. **Table 4** presents the iterations that identified the optimized F/B of 49.580 dB. **Tables 5** and **6** present these antenna's respective frequency performance parameters, in 500 kHz increments across a 6 MHz bandwidth. The gain optimized antenna shows a clear peak at 50.25 MHz. The F/B optimized antenna also shows a peak in the optimized parameter at 50.25 MHz, almost to the point of being of the single frequency vectorial cancellation type of F/B. **Figs. 1** and **2** display these antennas' respective E-plane plots.

The comparison between these two Yagis serves to emphasize the superiority of the F/B antenna. This is the Yagi with the obviously more clearly defined main lobe and the reduced-amplitude minor lobes. With the

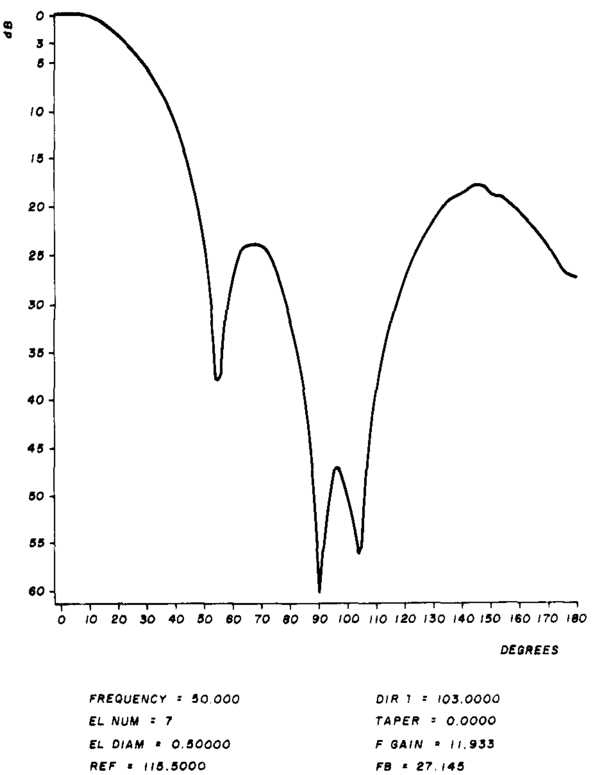


fig. 3. F/B optimized Yagi at 50.00 MHz.

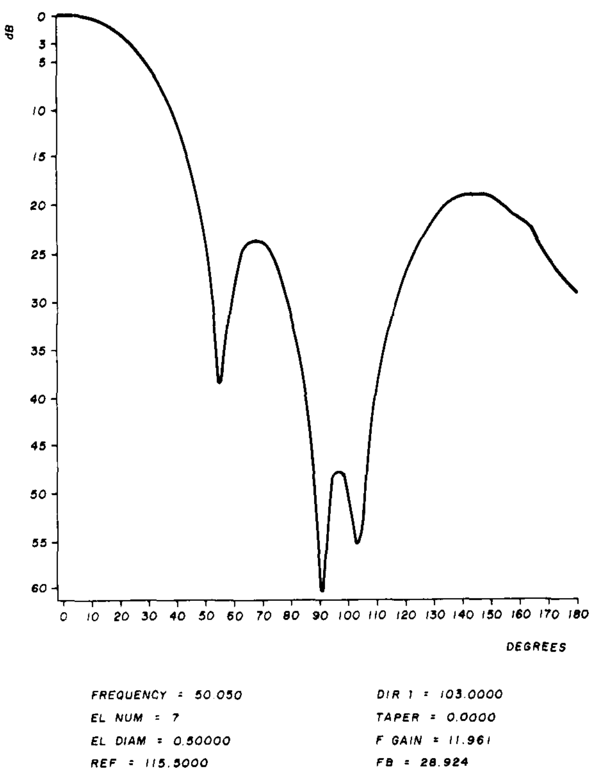


fig. 4. F/B optimized Yagi at 50.05 MHz.

exceptions of a slightly narrower main lobe and additional unwanted signal attenuation between 132 and 158 degrees, the gain optimized Yagi is a second choice. While unwanted signals are rarely an exact 180 degrees away from desired signals, a 15 dB F/B is more or less marginal for a Yagi of this length. However, the adequacy of this F/B ratio is really a function of band activity and operator preference.

A final question, addressing the bandwidth over which the F/B optimized antenna's F/B ratio and general pattern can be realized, remains. **Table 7** presents this Yagi's performance parameters as calculated from 50.0 MHz to 50.5 MHz, in 50 kHz increments. **Figs. 3** through **13** contain the E-plane plots that correspond to each 50 kHz increment, with that for 50.25 MHz being repeated for purposes of clarity. Over the frequency range of interest to weak signal operators, calculated F/B begins at 31.168 dB, peaks at 49.580 dB, and drops to 33.170 dB. Calculated gain begins at 11.988 dBi and rises to 12.139 dBi. These figures serve a second purpose, as they provide a study in the effects of slight variances in frequency response on the performance criteria on which a given Yagi was optimized. It is interesting to note the emergence of another minor lobe starting at 50.3 MHz.

A comparison with the NBS 1.2 wavelength Yagi proves the value of either of the optimized Tilton/Greenblum designs. While only 0.0192 wavelengths

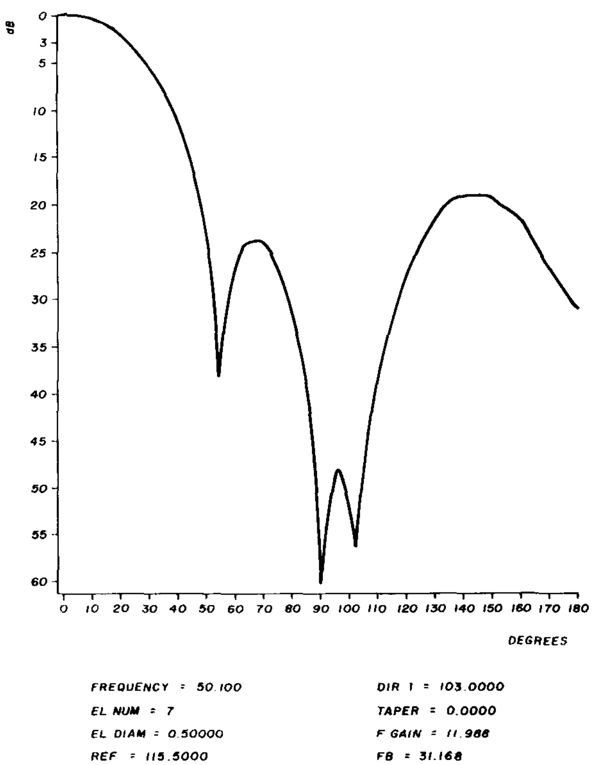
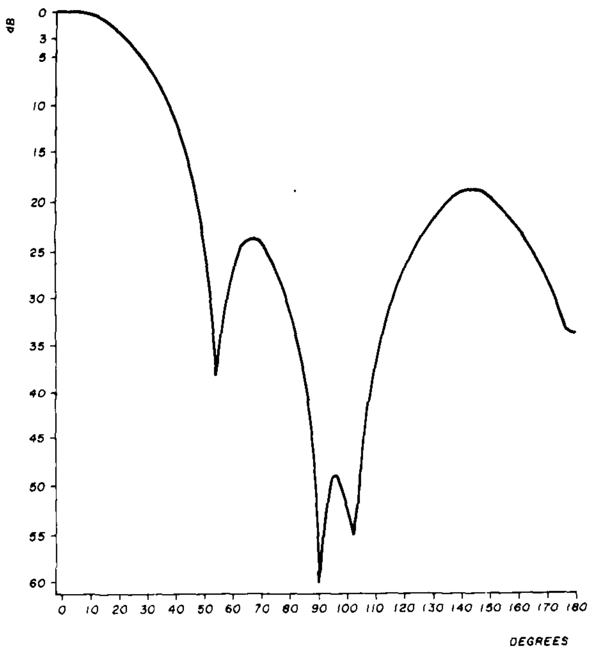


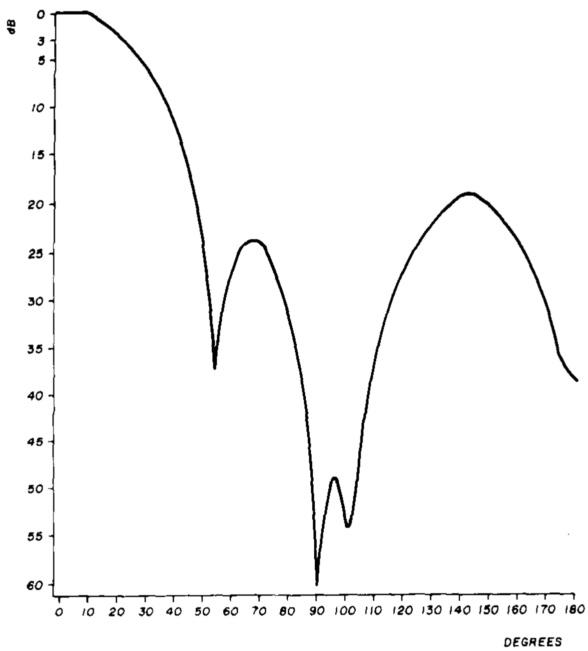
fig. 5. F/B optimized Yagi at 50.10 MHz.



FREQUENCY = 50.150
EL NUM = 7
EL DIAM = 0.50000
REF = 115.5000

DIR 1 = 103.0000
TAPER = 0.0000
F GAIN = 12.014
FB = 34.207

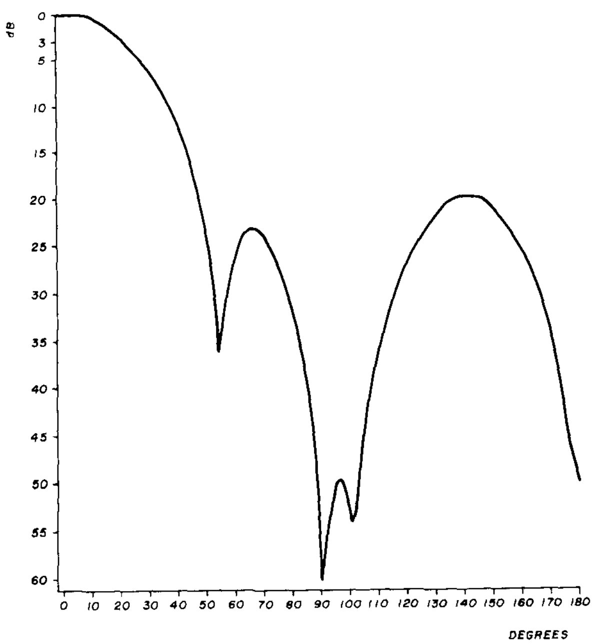
fig. 6. F/B optimized Yagi at 50.15 MHz.



FREQUENCY = 50.200
EL NUM = 7
EL DIAM = 0.50000
REF = 115.5000

DIR 1 = 103.0000
TAPER = 0.0000
F GAIN = 12.040
FB = 38.924

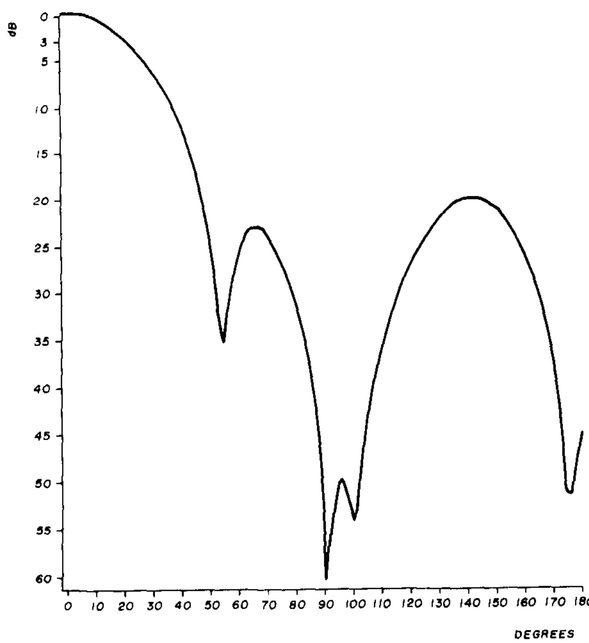
fig. 7. F/B optimized Yagi at 50.20 MHz.



FREQUENCY = 50.250
EL NUM = 7
EL DIAM = 0.50000
REF = 115.5000

DIR 1 = 103.0000
TAPER = 0.0000
F GAIN = 12.066
FB = 49.580

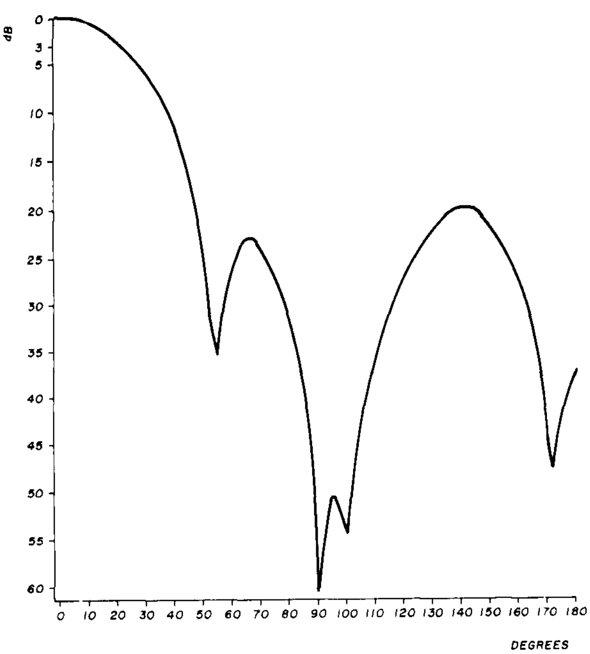
fig. 8. F/B optimized Yagi at 50.25 MHz.



FREQUENCY = 50.300
EL NUM = 7
EL DIAM = 0.50000
REF = 115.5000

DIR 1 = 103.0000
TAPER = 0.0000
F GAIN = 12.091
FB = 45.266

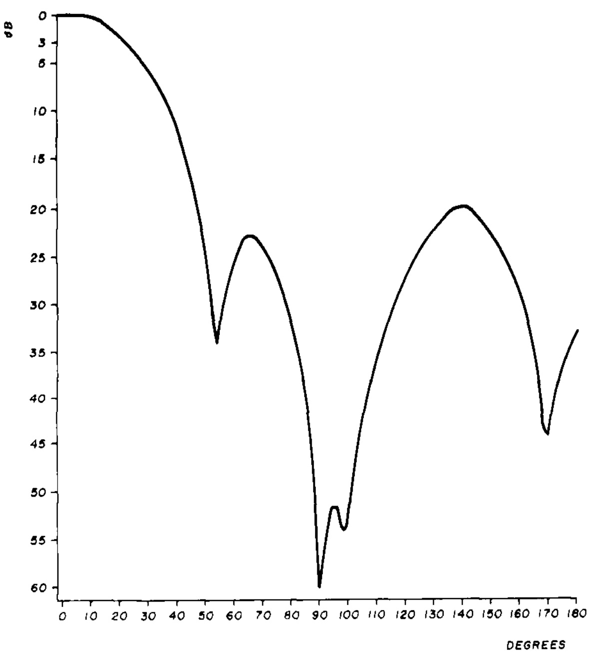
fig. 9. F/B optimized Yagi at 50.30 MHz.



FREQUENCY = 50.350
EL NUM = 7
EL DIAM = 0.50000
REF = 115.5000

DIR 1 = 103.0000
TAPER = 0.0000
F GAIN = 12.115
FB = 37.304

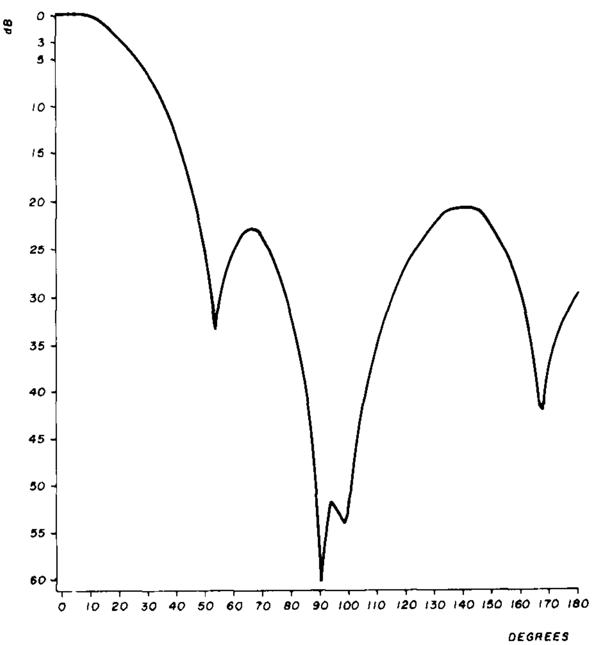
fig. 10. F/B optimized Yagi at 50.35 MHz.



FREQUENCY = 50.400
EL NUM = 7
EL DIAM = 0.50000
REF = 115.5000

DIR 1 = 103.0000
TAPER = 0.0000
F GAIN = 12.139
FB = 33.170

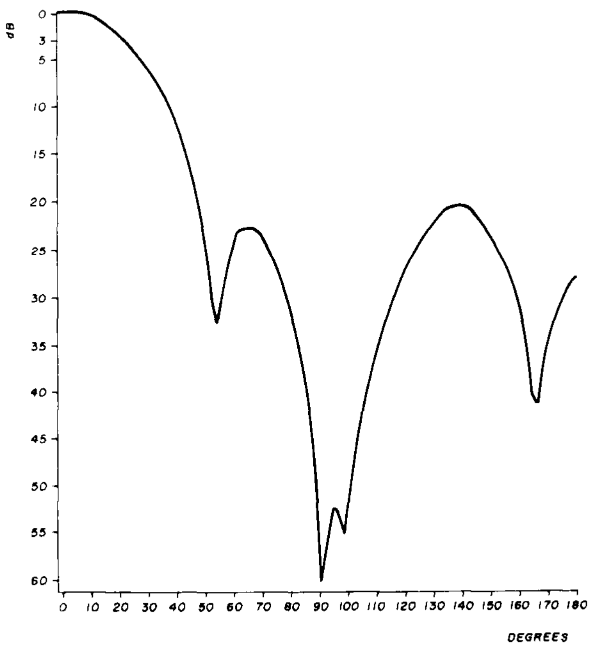
fig. 11. F/B optimized Yagi at 50.40 MHz.



FREQUENCY = 50.450
EL NUM = 7
EL DIAM = 0.50000
REF = 115.5000

DIR 1 = 103.0000
TAPER = 0.0000
F GAIN = 12.162
FB = 30.363

fig. 12. F/B optimized Yagi at 50.45 MHz.



FREQUENCY = 50.500
EL NUM = 7
EL DIAM = 0.50000
REF = 116.5000

DIR 1 = 103.0000
TAPER = 0.0000
F GAIN = 12.184
FB = 28.233

fig. 13. F/B optimized Yagi at 50.50 MHz.

table 7. Detailed performance parameters for the F/B optimized Yagi with a 0.000 taper.

frequency (MHz)	gain (dBi)	F/B (dB)
50.00	11.933	27.145
50.05	11.961	28.924
50.10	11.988	31.168
50.15	12.014	34.207
50.20	12.040	38.924
50.25	12.066	49.580
50.30	12.091	45.266
50.35	12.115	37.304
50.40	12.139	33.170
50.45	12.162	30.363
50.50	12.184	28.233

longer, these Yagis provide far more additional gain than this miniscule difference in boom length can explain. The model calculates 11.80 dBi gain for the NBS Yagi, as compared to 12.493 dBi for the gain optimized Tilton antenna, and 12.066 dBi for the F/B optimized Tilton antenna.[8] With approximately 19 dB of F/B, the NBS Yagi is superior to the gain optimized Tilton Yagi, but falls far short of the F/B optimized Tilton Yagi.[9] It should be noted that F/B was never a design criterion for any of the NBS Yagis. In conclusion it can be stated that as a result of the calculated performances of either of these two Tilton/Greenblum Yagis, either is preferable to the 1.2 wavelength NBS Yagi. The F/B optimized Yagi is the more preferable of the pair. The additional director on what is substantially the same boom length, provides a significant increase in performance.

Next month's installment addresses the general subject of Yagi performance optimization. In addition to discussing approaches taken by authors in the engineering literature, specific examples of techniques from the Amateur Radio literature will be modeled and iterated.

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Attention HFer's — Don't skip Joe's column this month. The principles he discusses apply to other frequency ranges as well. — **Editor**

VHF/UHF WORLD

Joe Reisert W1JR

the VHF/UHF primer: *an introduction to filters*

Filters seem to be one of the least understood subjects in Amateur Radio despite the fact that numerous articles have been written on the subject. Have you ever heard an Amateur say, "I have this great 2-meter filter with only a 1-MHz bandwidth" (while failing to note or be aware of the fact that the insertion loss of the filter is 3 dB) or worse, say "I have this 70-cm (432 MHz) filter with only 0.15 dB loss," forgetting to mention that the bandwidth of the filter is 100 MHz!

Although most Amateurs seem to understand the difference between the categories of filters, described later in this column, they seldom understand how filters work. Sometimes they fail to recognize the interrelationship between bandwidth, insertion loss, and out-of-band attenuation, and what the best design for an application may be or how one goes about designing and building a filter. Although space doesn't permit presentation of a detailed design compendium, some designs and guidance will be provided in this and future columns.

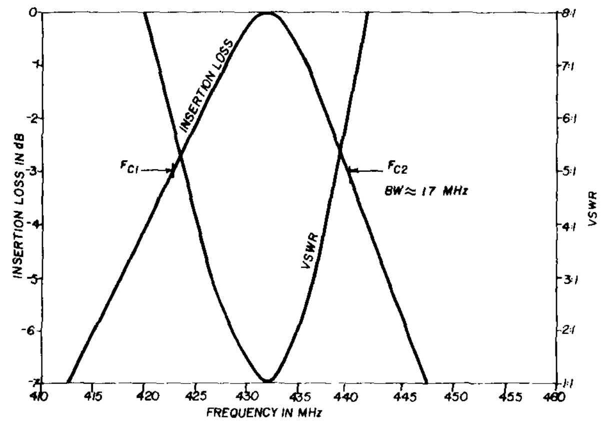

fig. 1. Insertion loss and VSWR of a 70-cm cavity filter.

filter basics

Filters can be classified according to two general types: absorptive and reflective, with absorptive filters the less common type. Absorptive filters accept all frequencies received. The desired frequency or frequencies are passed through to the output, while the undesired frequencies are directed to either a built-in or external load where they are dissipated. An example of an absorptive filter is the diplexer for terminating a double balanced mixer recommended in a previous column.[1] The better homebrew TVI lowpass filters are absorptive filters.[2] The advantage of this type of filter is that the source or transmitter always sees a good VSWR almost regardless of frequency, harmonics, etc.; its disadvantages lie in the fact that the filter is usually twice as complex and requires an extra termination.

The most common type of filter is the reflective type, which allows the desired signals to pass through from the input or source to the output, but reflects the undesired frequencies back to the source. A good analogy to this type of filter is the typical Amateur Radio antenna system. The resonant (or bandpass) frequency of the antenna has, if properly matched, a low

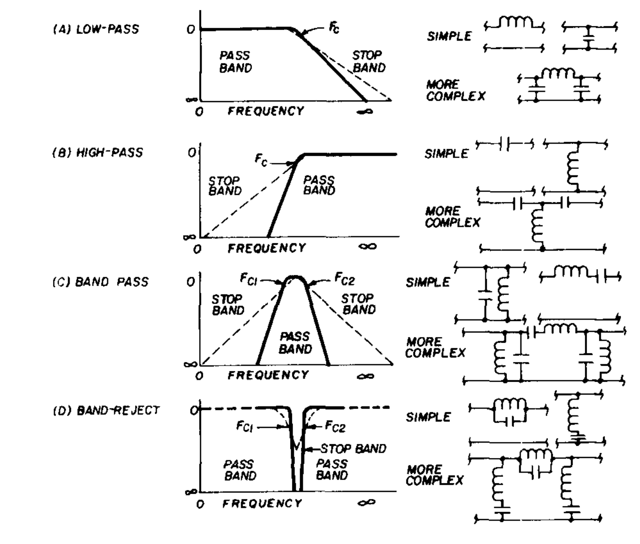

fig. 2. Basic categories of reflecting type filters in the frequency domain, illustrating typical simple and more complex circuits as well as frequency responses. Dotted responses represent simple filters, while solid lines indicate more complex filters.

VSWR, and radiates power into space. Frequencies off resonance are usually reflected back to the transmitter in the form of a high VSWR.

Fig. 1 illustrates this characteristic. A typical frequency versus input to output amplitude response and VSWR for a 70-cm reflective type bandpass filter is shown.[3] Note that the insertion loss, as expected, increases on either side of the center frequency, F_o. Note, too, that the VSWR rapidly increases on either side of F_o in a similar manner, and is approximately 6:1 at the half power or 3 dB down cutoff frequencies, F_{c1} and F_{c2}.

filter categories

Within each of the two filter types, absorptive and reflective, there are four basic categories: low-pass, high-pass, bandpass, and band reject or band stop. Each has a specific passband in which the insertion loss is low and a cutoff frequency (or frequencies) where the output is one half or 3 dB lower than the power in the desired passband. Sometimes filters consist of a combination of two or more of these categories. For instance, a low-pass and a high-pass filter may be connected in cascade to form a bandpass filter.

Low-pass filters have low loss up to the cutoff frequency and high insertion loss above this frequency (**fig. 2A**). They are most often used on the output of oscillators and transmitters to prevent harmonics from being radiated. (Typical low-pass filter schematics are also shown.) As the number of elements in the filter is increased, the passband insertion loss and the stop band attenuation increase. Also the passband insertion loss approaching cutoff is less as shown.

High-pass filters have high insertion loss below and low loss above the cutoff frequency (**fig. 2B**). They are most often used to prevent lower frequency transmitters from saturating the front end of a receiver. A common application involves using the filter on TV set inputs to prevent fundamental overload and on the input of an HF receiver to prevent overload from high power broadcast band transmitters. As the number of elements in the filter increases, the passband insertion loss and the stop band rejection increase, while the passband insertion loss approaching the cutoff frequency is less as shown in **fig. 2B**.

Bandpass filters have low insertion loss between two cutoff frequencies and high loss above and below the cutoff frequencies (**fig. 2C**). They are probably the most common form of filter used by VHF/UHF Radio Amateurs and can be considered as a combination of a low-pass and a high-pass filter. They are most often used as front-end filters to reject out-of-band signals that may overload a receiver. As the number of sections increases, the passband insertion loss and the stop band rejection increase, but the passband insertion loss is also less as you approach the cutoff frequency.

Band reject or band-stop filters have high insertion loss at a specific frequency or band of frequencies but low loss on all other frequencies (**fig. 2D**). They are used to eliminate discrete frequencies such as an IF image, a birdie, or local transmitter. For increased rejection, the number of sections must be increased.

filter parameters

The most important filter parameters are usually bandwidth and insertion loss. Secondary considerations are VSWR, passband ripple, out-of-band rejection, and shape factor. These parameters are all interrelated.

Insertion loss is especially important when a filter is at the input of a low-noise receiver because filter insertion loss at this location increases the noise figure by the same amount. If a filter follows a transmitter, the output power will be reduced by the amount of the insertion loss and if the filter is too lossy, it may break down or be destroyed when subjected to high power. Generally speaking, insertion loss increases if either the filter bandwidth is decreased, the number of sections in the filter is increased or the unloaded Q, Q_u, of the inductors is low (more on this later in this column).

Bandwidth is very important because it defines the operational frequency range over which signals will not be attenuated more than 3 dB. Bandwidth should never be any less than necessary, since narrow bandwidth usually goes hand-in-hand with higher passband insertion loss and more critical tuning.

VSWR is usually low at the center

frequency of a well designed and built reflective type bandpass filter and climbs abruptly near the cutoff frequency going toward infinity in the rejection band (**fig. 1**). VSWR will also be low in the passband of other categories of filters (to be discussed later in this article) but will increase abruptly as the cutoff frequency is approached. If a low VSWR is desired over a wide band, either the bandwidth of the filter must be increased or additional filter sections added.

Passband ripple is a function of the design parameters, the insertion loss and how well the filter is tuned and built. Remember that at each point where there is ripple, the input VSWR will increase or decrease accordingly. Ripple is associated with certain classes of filters as shall be discussed shortly.

Out-of-band rejection is a function of the design parameters, the bandwidth, the types of components used in the filter, construction, and alignment; but most importantly, it is primarily determined by the number of elements or tuned sections in the filter. If a low out-of-band rejection filter is used, it could mean overload to a low-noise receiver or harmonics radiation from a transmitter. Sometimes the bandwidth cannot be sufficiently reduced, and the number of sections in the filter must be increased to adequately attenuate out-of-band signals. As mentioned earlier, when the number of sections in the filter is increased, so is the insertion loss. Consequently, to increase out-of-band rejection, the filter complexity will usually increase.

Similarly, the shape factor of a filter is a direct function of the number of elements or tuned sections in a filter as well as the design parameters. VHF/UHF filters usually do not approach rectangular shape factors like IF filters because losses and the complexity of the filter would be difficult to work with at these frequencies. Hence, if good shape factor is required, the desired frequency range is usually converted to a lower frequency where insertion loss and components do not provide such a constraint.

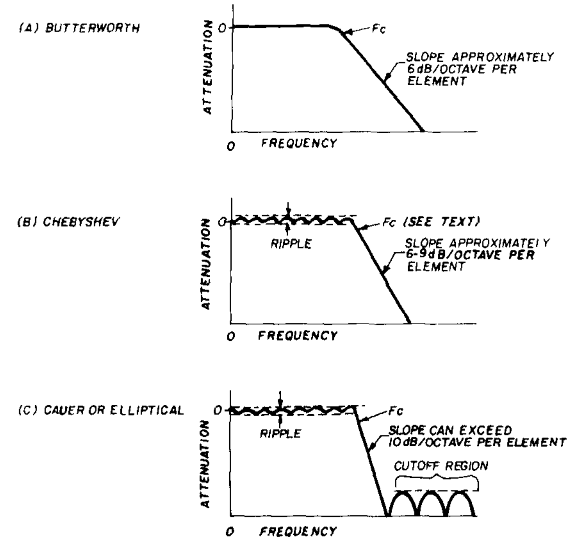

fig. 3. Typical amplitude and frequency responses of the different classes of low-pass filters.

filter classes

Frequency domain filters are the most commonly used "LC" filters. The three classes most often used are the Butterworth (or maximally flat), the Chebyshev, and the Cauer (or elliptical function). Each has specific characteristics defined by the design equations used to determine the component values and the tuning of the filter.

The most common filter, the Butterworth, or maximally flat filter, has been around for a long time. Its main advantages are that it has low insertion loss, low VSWR, a flat passband response and standard design tables are available.[4-7] Designs using normalized tables from these references are based on the 3 dB cutoff frequency. The disadvantage of the Butterworth filter is that its attenuation is only moderate out-of-band. A typical low-pass Butterworth filter response is shown in **fig. 3A**. Note that the attenuation in the stop band increases approximately 6 dB per octave (2 times the frequency) per filter element.

Chebyshev filters are a result of the development of modern filter theory. They are most often used when steeper stop band attenuation (than Butterworths can provide) is required. For example, the stop band attenuation for a properly designed Chebyshev filter may increase (depending on passband ripple selected) to approximately 9 dB per octave per element, up to 3 dB more than a Butterworth design. The principal drawback of a Chebyshev filter design is that it has ripples in the passband. The greater the desired attenuation out-of-band per number of elements in the filter, the more the ripple in band. As a point of interest, when the passband ripple goes to 0 dB, the design goes from Chebyshev to Butterworth. Design tables in references 4, 5, 6, and 7 are available. Beware, however; some authors specify the cutoff frequency as the 3 dB down bandwidth,[5] while others specify the cutoff frequency as the limit where the ripple bandwidth is constant.[6,7] A typical Chebyshev low-pass filter frequency response is shown in **fig. 3B**.

Cauer, or elliptical function filters, are also a result of the development of modern filter theory. Similar to the Chebyshev, they have resonant circuits that are used to produce notches in the stopband and are most often used when very steep attenuation is required just outside of the passband, particularly when you want to notch a specific frequency or frequencies. Other applications include designs that require only a finite amount of stop

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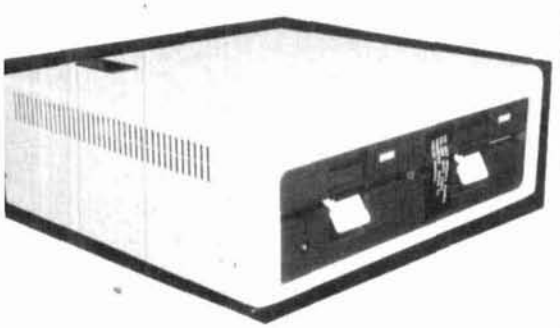

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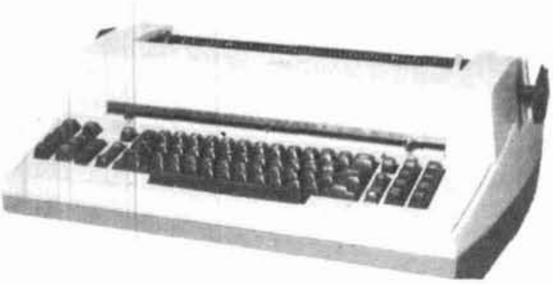

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These rugged, handsome printers were made for one of the giants of the computer industry. They can be used as a standard typewriter or as a printer in a word processing system for true letter quality printing. Solenoids were added to the selectric mechanism which disabled the manual repeat function but still allows electronic repeat functions. It uses standard IBM typing balls. The voltage requirements are standard 115 VAC, 5 VDC at 100 ma, and 24 VDC at 4 amps. All are new in factory boxes, but may require adjustments. We provide literature and schematics with 1 ribbon and cleaning tools. With the addition of our Centronics to Selectric I/O adapter, you could easily interface this printer to almost any micro computer system. Typewriter Printer stock no. RE 1000 A $375.00, 745 manual $30.00 Shpg wt approx. 80 Lbs, shpd by truck, collect.

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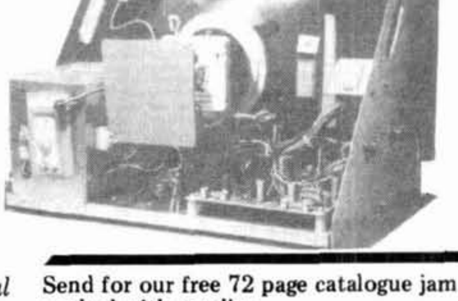

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band attenuation. The passband ripple is similar to Chebyshev designs. However, in the stop band, they also have ripple and reach only a minimum level of out-of-band rejection determined by the design parameters and filter alignment. Elliptical function filters also require extra tuning elements and possibly some peculiar component values. Hence, they are usually only used at audio through HF. A typical low-pass elliptical function filter response is shown in **fig. 3C**.

physical characteristics

Filters are made in many shapes and sizes. As discussed earlier, when the desired stop band rejection increases, the number of components and sections in the filter must increase. At lower frequencies (audio and HF), discrete components such as disc capacitors and inductors are usually used. However, as the frequency increases into the VHF/UHF range, other types of components such as air variables and rods for inductors are used. Also, at VHF/UHF, filters may take on other physical structures such as cavity, microstrip, stripline, combline, interdigital, or helical.

A **cavity filter**, especially the quarter-wave type (**fig. 4A**) is quite common at UHF, is basically an enclosure, usually a cylinder, with a rod typically close to a quarter-wave in length down the center of the enclosure that takes the place of a discrete inductor. By making the rod shorter or longer, it can be resonated, if desired, without a tuning capacitor. This is often referred to in the microwave community as the TEM (Transverse Electromagnetic) mode. However, the rod is often shortened slightly and tuned with a capacitor, typically two metal plates whose spacing can be varied, at the top of the rod to facilitate "tweaking" the filter to frequency. Cavities have low loss if they are large in diameter (between 0.05 and 0.33 λ), close to 77 ohms in impedance (3.6:1 ratio between the inside diameter of cavity and the outside diameter of the rod), have good conductivity particularly at the high current point at the base of the rod, and especially if they are silver plated internally.

However most people ignore or are not aware of the fact that a quarter-wave cavity filter is also resonant at several other frequencies in addition to the design frequency. If the filter is tuned mainly by adjusting the length of the rod, the other resonances will be close to 3, 5, 7 (etc.) times the design frequency. Hence they are not good harmonic filters! These other resonances can be pushed higher and placed above the harmonic by foreshortening the quarter-wave rod and using capacitance tuning as just described. The shorter the rod, the higher the frequency of the other resonances.

Another favorite Amateur filter configuration is the "**half-wave**" type (**fig. 4B**). Basically composed of two quarter-wave filters in tandem, its chief advantages are its requirement of only one tuning capacitor and its very symmetrical out-of-band rejection (more on this later in this article). The inductor can even take the form of a flat strip, thus yielding a mechanical advantage in some situations, since the input and output are at different ends of the filter.

Interdigital filters are very common especially at UHF and above.[7-9] They get their name from their physical appearance — they look like fingers joined (or interdigitated) together (**fig. 4C**). The rods are nearly a quarter-wave long, and ground is alternated from side to side. The spacing between resonators, the rod diameters, and the thickness of the structure are the major factors in determining bandwidth. Because the open ends have some fringing capacitance, it is best to shorten the rods slightly and add a small tweaker such as a silver-plated screw. This type of filter, properly constructed, usually has low passband insertion loss and is easily duplicated. It is readily scaled in frequency by keeping the thickness, rod diameter, and spacing constant, and just changing the length. The new frequency will have the same percentage bandwidth as the original frequency. This type of filter is usually large and also suffers from the overtone problems as mentioned above with the quarter-wave cavity type filter.

Combline filters — so named because they look like the teeth of a metal comb — are very common in the industry, (**fig. 4D**). Their rods or resonators are usually about one-eighth wave long (in contrast to the quarter-wave interdigital type). These filters are usually used where space is at a premium. Frequently the resonators are close together, and partitions or walls are placed between them, with the height of the partitions determining the coupling and hence overall filter bandwidth. The advantage of this type of filter configuration is that if the resonators are kept short, the response to overtones (as discussed above) will be much higher in frequency and may not be detrimental, as in the case of the interdigital type. One advantage or disadvantage, depending on your point of view, is that tuning capacitors are required.

Microstrip and **stripline** techniques are often used, especially when designing combline and interdigital filters. The spacings and impedances are set for the desired filter response. Losses in this type of construction are frequently higher than those using resonators etc. but this type of structure is usually reproducible.

Let us not forget **helical resonator filters**,[10,11] which resemble a large coil, usually with large diameter wire wound like a helix antenna (**fig. 4E**). Placed in a structure similar to the cavity filter, a helical resonator filter is usually used when relatively high inductance and low passband insertion loss are required, especially on the VHF and lower UHF frequencies.

filter anomalies

Several things must be understood before filter design can begin. It is assumed at the outset that all formulas used and the computed values are correct; the principal filter design problems occur with the values of the components and the types of components selected. Components are usually chosen using standard design equations or normalized tables.[4-7,12] It would be very difficult to build a filter if the component values were not standard or readily available. Therefore, it is usually preferable to make some of the components variable, especially in bandpass filters. I prefer to use variable capacitors instead of variable inductors because they usually have higher Q_u and are easier to tune.

If insertion loss is important, and/or if the bandwidth of the filter is narrow, the components chosen must have high Q_u at the filter frequency. Air variables or small tuners made from plated screws are usually preferred at VHF/UHF frequencies. Inductance in series with the capacitor may cause loss or distortion such as a decrease in attenuation at some frequency or frequencies in the rejection band.

However, the greatest filter loss usually occurs in the inductors. The Q_u of an inductor should be as high as possible. For reference, I have shown some typical values of Q_u in **table 1**. *This table is by no means complete*, but can be used as a guide. Note that most discrete inductors have only moderate Q_u while cavities and helicals are high.

To determine the loss of an inductor in a bandpass filter, it is first necessary to determine the loaded Q, "Q_ℓ" of the filter as follows:

$$Q_\ell = \frac{F_o}{F_{c2} - F_{c1}} \qquad \textbf{(1)}$$

where F_o is the center frequency, F_{c1} is the lower cutoff (−3 dB) frequency and F_{c2} is the upper cutoff frequency all in the same units. For example, the filter in **fig. 1** has a center frequency of 432 MHz and upper and lower cutoff frequencies of approximately 440 and 423 MHz respectively. Therefore:

$$Q_\ell = \frac{432}{(440 - 423)} = 25.4$$

The loss in a filter is directly related to the ratio of the Q_u and Q of the filter as shown in **eq. 2**:

$$\text{insertion loss (dB)} = 10 \log_{10} (1 - Q_\ell / Q_u)^2 \qquad \textbf{(2)}$$

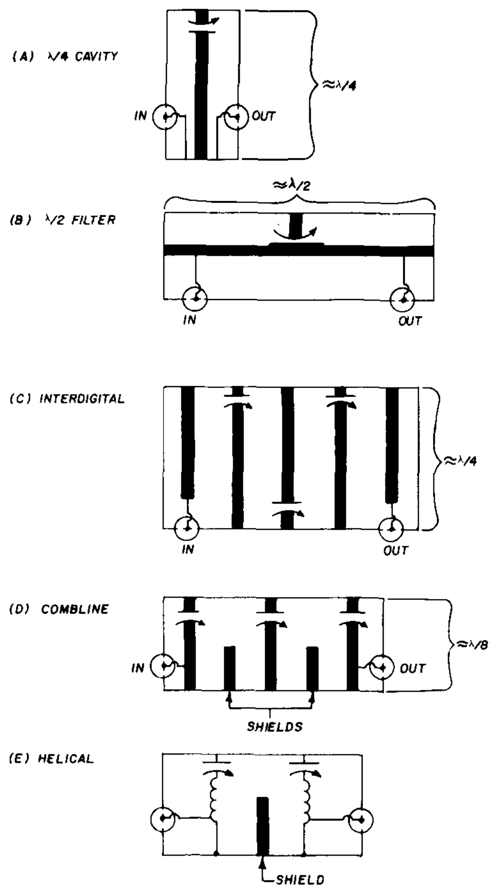

fig. 4. Typical filter geometries.

table 1. Typical Q_u versus frequency for some commonly used inductors.

inductor type	frequency range (MHz)	typical unloaded Q
toroid	1- 100	50- 200
0.25″ (6.35 mm) diameter coil	50- 500	300- 400
0.5″ (12.7 mm) diameter coil	50- 300	400- 500
microstrip (on G-10 PC board)	400-2300	175- 420
microstrip (on PTFE fiberglass)	400-2300	200- 775
1″ (25.4 mm) diameter 77-ohm cavity	300-1000	500-1000
3″ (76.2 mm) diameter 77-ohm cavity	100- 500	1000-1500
1″ (25.4 mm) helical resonator	100- 500	500-1000

For the sake of simplicity, I have drawn a graph for the most common ratios of Q_u/Q_ℓ in **fig. 5**. If the same example is used from **fig. 1**, and the Q_u of the inductor is approximately 1000 (from **table 1**), the Q_u/Q_ℓ ratio is 39.37, and the insertion loss of this filter will be approximately 0.22 dB. Now if the inductor had a Q_u of only 300, the Q_u/Q_ℓ ratio would be 11.8, and the loss would rise to approximately 0.77 dB — a huge increase! *This example shows why cavities are preferred at VHF/UHF frequencies.*

Before leaving this subject, it might be wise to explain how insertion loss can be determined in a multi-section filter. Cohn provides an equation to determine this loss.[13] I have simplified his formula and listed the values or "K" factor necessary to determine the loss for common two through seven-section Butterworth bandpass type filters. Other types of filters may have slightly higher insertion losses. To obtain the loss of a multi-section bandpass filter, use the following equation:

$$\text{total insertion loss (dB)} = K(Q_\ell / Q_u) \tag{3}$$

where K is the number from **table 2** for the number of sections in the filter and Q_ℓ and Q_u are as determined above. For example, if the filter in **fig. 1** had 3 sections but the same Q_u (1000) and Q_ℓ (25.4), the insertion loss would be approximately 0.441 dB, much greater than the single section. If the Q_u were only 300, the insertion loss would climb to 1.47 dB. Hence, you are trading insertion loss for better *out-of-band rejection — not always* a bad compromise!

Insertion loss has one other detrimental effect. Since the insertion loss as you pass through the filter is cumulative, the amount of energy reaching each successive section in the filter is less. As a result, if the insertion loss of a filter is high, the bandwidth of the filter and its ripple characteristics may change from those predicted or calculated. Hence it is best to design a filter with slightly wider bandwidth than required because losses reduce bandwidth when the filter is finally tuned to frequency.

table 2. Approximate insertion loss in a multi-section Butterworth bandpass filter can be determined by using this information in conjunction with *eq. 3*.

number of sections	K factor
2	12.28
3	17.36
4	22.70
5	28.10
6	33.55
7	39.10

Other anomalies depend on the topography chosen. For instance, if the coupling into and out of a bandpass filter is capacitive, the filter will acquire a high-pass characteristic in the rejection band. Inductive coupling, a low-pass characteristic, may also occur. A combination of the two will yield a more symmetrical rejection band. This is illustrated in **fig. 6**.

Finally, input or output VSWR due to component selection, tuning, or loading will cause increased insertion loss, asymmetry in the pass or reject band and/or ripple in the passband. In this regard, bandpass filters with single sections are preferred, especially when they are placed ahead of a low-noise preamplifier since the point of minimum insertion will usually fall at the center of the band. Hence, if there is a severe mismatch (typical of low-noise amplifiers) the chances are that the minimum ripple will remain at the center frequency. To a somewhat lesser degree, 3 or 5-section filters are also preferred over 2 and 4-section filters for the same reason.

designing filters

Low and high-pass filter designs are available in references 4 through 7 and also in 12. Band reject or band stop filters, primarily used in diplexers for FM repeaters where very high attenuation is needed between two close frequencies[14] are documented in references 4 and 5. My favorite bandpass filter design procedures are found in Zverev's book (reference 5). Some selected Chebyshev bandpass filter designs can be found in Anderson's *ham radio* article of June, 1977.[15] Design programs for many of these filters are now available for computer-oriented[16] Amateurs.

Bandpass filters seem to be the most widely used by VHF/UHFers, especially in receivers, transmitters, and ahead of preamplifiers. Hence I have dedicated the major part of this column to that subject and direct you to the applicable reference for the other categories of filters because they are usually easier to design. However many of the suggestions in this column apply to filters of any category.

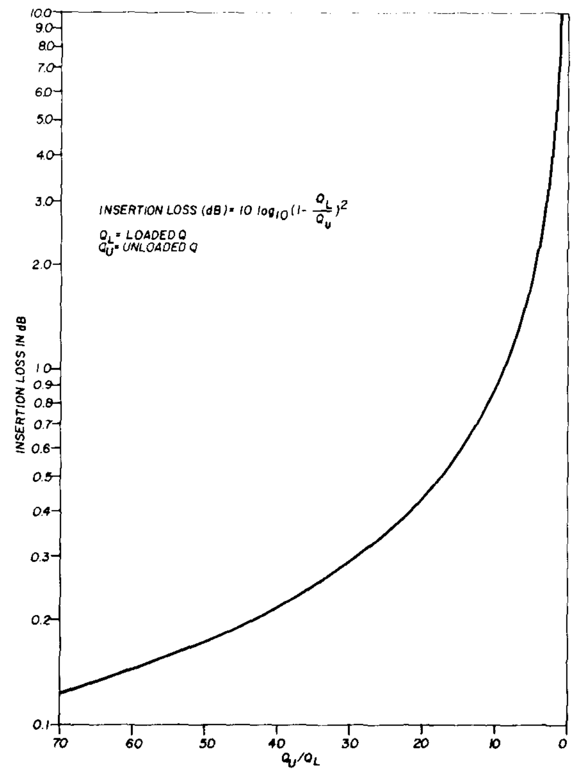

fig. 5. Insertion loss is a function of the loaded and unloaded Q of the filter.

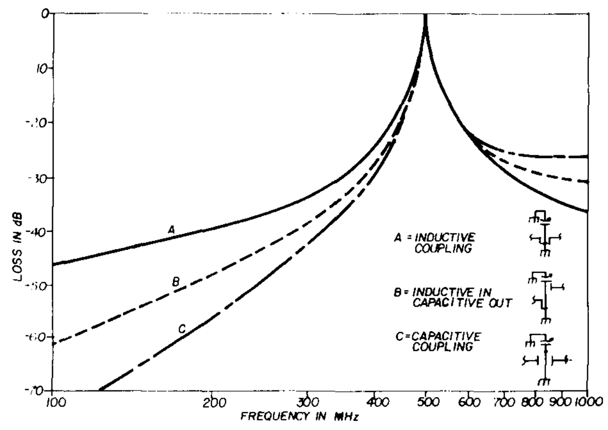

fig. 6. The frequency response of a 500-MHz cavity filter depends on coupling technique.

adjusting and measuring performance

This is really a subject for a whole column in itself. Remembering what has been said so far, the simple single-section filters (such as quarter-wave cavity) can usually be adjusted to frequency simply by placing a good low VSWR 50-ohm termination on the output of the filter and tuning for minimum VSWR. Multi-section filters usually require some sort of sweep setup with detectors. A typical procedure is to first align the filter for approximately the amplitude response expected. Then the final testing and alignment is performed by observing VSWR over the entire bandwidth.

Dishal used a slightly different method, in which he adjusted a slotted line and successively either shorted or opened each section of the filter as it was adjusted.[17] Suffice it to say that the proper alignment of a multi-section filter requires both excellent test equipment and the skill to recognize what is taking place.

summary

It is important to recognize the different electrical and physical properties in order to chose or understand what filter is the type required for a specific application before designing or building it. It is also nice to at least know the difference between a Butterworth, Chebyshev, or Cauer filter, and whether it is a low-pass, high-pass, band stop or bandpass type. Hopefully this article has provided sufficient information to make this possible.

acknowledgements

I would like to thank Ron Matthews and Keith Whynot, WA1GZN, for their helpful suggestions in preparing this month's column.

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important VHF/UHF events in August, 1984

August 5-6: *ARRL UHF Contest*
August 11: *1945 UTC, predicted peak of Perseids meteor shower*
August 28: *Moon at perigee*

ham radio

short circuit

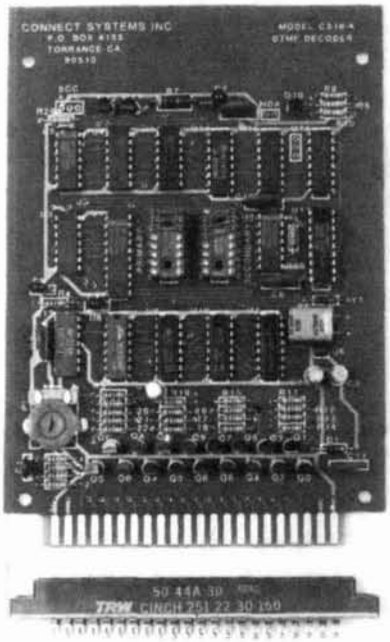
digital audio filter

In WIØER's "A Digital Audio Filter for CW and RTTY" (August, 1983, page 61), U4 and U5 should be labeled LF356N, not LF365N.

NEW products

touch-tone decoder

Connect Systems, Inc., has introduced a new 16-function touch-tone decoder board. Designated model CS-16, the decoder will securely control virtually any apparatus via radio or wireline. The CS-16 is especially useful for controlling various repeater on/off functions.



A unique feature of the CS-16 is dual password control. Two separately user-programmable three-digit passwords create heirarchy control capability. The primary control password can access all 16 of the available functions. The secondary password, however, can access only 8 of the 16 functions. A special primary password command, capable of enabling or disabling secondary password access, is available. The CS-16 provides such a high degree of multi-level security that control can be accomplished directly on voice channels, thus eliminating the need for separate control frequencies.

The CS-16 provides 16 independently controllable on/off latched functions. Each function is provided with an open collector and 5-volt CMOS logic output. A strobe output is also available in open collector and logic format. This output can be used to gate repeater audio so that DTMF control commands are not retransmitted.

A power-up reset feature causes all outputs to be in the "off" state after application of power. An audio pre-amp with level control permits the crystal controlled tone decoder to operate over the wide input range of 10 μV to 2 volts. A strobe LED lights when any of the 16 buttons on a pad is pressed. (The CS-16 can also be used with 12 button pads). An on-board voltage regulator permits operation with a 10-25 VDC power source. The CS-16 incorporates reverse polarity protection and draws less than 20 mA from the supply.

For more information, contact Connect Systems, Inc., 23731 Madison Street, Torrance, California 90505.

Circle #301 on Reader Service Card.

extended warranty on satellite TV equipment

The R.L. Drake Company has announced that it has extended the limited warranty on the new Drake ESR-240 satellite earth station receiver and all other Drake satellite television equipment from one year on parts and 90 days on labor to one year for *both* parts and labor because no problems have been experienced with the new receiver's state-of-the-art infrared tuning feature.

For further information, contact R.L. Drake Company, 540 Richard Street, Miamisburg, Ohio 45342.

two new mobiles from ICOM

ICOM has added two more transceivers to its line of ultra-compact mobiles: the IC-27H 45-watt 2-meter mobile and the IC-47A 25-watt 440 MHz mobile.

Standard features of the IC-27H include 45 watts output, compact size (1-5/8" high × 5-1/2" wide × 9-3/8" deep), a built-in internal speaker for easy mounting, nine full-function memories, 32 built-in PL frequencies, professional communications design and styling, and an IC-HM23 DTMF microphone with up/down buttons. Scanning functions include memory scan, band scan, and priority scan. An internal lithium memory battery backup maintains memories for up to five years.

The features of the IC-47A are similar to those of the IC-27H, with the exception of 25-watt operation and somewhat smaller size.

Both units include the IC-MB27 mobile mount. A variety of options, including an IC-UT16 speech synthesizer and IC-SP4 and SP5 external speakers, are available for both units. The IC-27H is priced at $409; the IC-47A, at $469.

For further details, contact ICOM America, Inc., 2112 116th Avenue, N.E., Bellevue, Washington 98004.

Circle #302 on Reader Service Card.

desoldering pump

A compact spring-powered desoldering pump has been introduced by the Ungar Division o Eldon Industries, Inc.

The Ungar 7870 desoldering pump can be operated with one hand, leaving the other free to hold the soldering iron. A spring-loaded pistor

is set with the thumb and released by pushbut ton. The vacuum created by a piston stroke c less than two inches instantly removes molte solder. The thumb tap is recessed into the har dle to prevent eye injury doing close-toleranc desoldering, and a plated interior rod cleans th tip each time the pump is used.

Further information is available from Ungar P.O. Box 6005, Compton, California 90220.

Circle #304 on Reader Service Card.

new terminal

Robot's new 800C specialty mode terminal an improved version of their Model 800 "supe terminal," provides Amateur Radio operators a all-in-one package with display, storage, an automatic operation for the transmission an reception of RTTY and Morse code signals. A major feature of the 800 is its built-in demodu lator, which uses separate active discriminatc filters for the demodulation of the RTTY signa

Key features of the new 800C terminal includ a 1023 character transmit buffer, ten 64-charac ter message memories with soft partitioning, a RS-232 serial and Centronics parallel printer inter face, color SSTV graphics capability with eigh graphics memories (when used with Robot' new color scan converters), and battery back up on all memories. These new features are als available in a retrofit kit for existing model 800s

For more information, contact Robot Re search, Inc., 7591 Convoy Court, San Diego California 92111.

Circle #303 on Reader Service Card.

product REVIEW

Mini Jini Record Keeper

Mini Jini Record Keeper from Jini Micro Systems is a powerful, yet easy-to-learn, plug-in data-base manager for both the VIC-20 and Commodore 64. (The term "data base" is synonymous with "file cabinet," updated to take advantage of the latest in computer technology.)

In the hamshack we store important information in a number of different and sometimes disorganized ways: in logbooks, cardboard boxes, and drawers. This can all add up to a disorganized and difficult-to-use system of data management.

Mini Jini was originally developed for the PET line of Commodore computers as the JinSam 8.2 Data Manager. This software has been used extensively throughout the business world because of its powerful record keeping capabilities and its easy-to-use design.

NASA, for example, has made extensive use of JinSam in its management of landing site facilities for the space shuttle program. Space shuttles have two main landing sites: one at Cape Canaveral in Florida and the other in California at Edwards Air Force Base. Because of the possibility of problems that might preclude landing at either of these sites, NASA has designated five additional sites around the world. In order to be ready to use any one of these, and to hold costs down, NASA's contingency plan specifies that in the event of an unscheduled landing at any alternate site, equipment would be shipped to the landing site from a central location. Obviously, manual file maintenance of such an elaborate system would be costly and cumbersome. Using their Commodore CBM and the JinSam 8.2, NASA's records now contain fields (i.e., files) for equipment nomenclature, serial number, and present location. In just a few minutes, NASA personnel can do full file searches to produce organized shipping lists of equipment for each or all landing sites.

Since the developers of the JinSam 8.2, Jim and Nancy Iscaro, are both hams, it was only a matter of time before they turned their attention to using JinSam for Amateur Radio purposes. Noting that both the Commodore 64 and VIC-20 are quite popular in the Amateur Radio field, the Iscaros set about the task of converting JinSam to a usable format for the C-64 and VIC-20. The result was Mini Jini. Of tremendous interest is that this program is not limited to Amateur Radio use, but can be used to store a variety of business, household, or personal information. For the Radio Amateur, Mini Jini can be used to log QSOs, print QSL labels, inventory equipment, keep contest logs, organize magazine files, and catalog foreign phrases, to name just a few of its many uses.

Mini Jini comes in a manufactured board that is inserted into either the VIC-20 or C-64 cartridge slot. With a stock (unexpanded) VIC-20, you can store up to 50 full records of 250 characters each. With a 24K memory expander added, the VIC-20 can handle up to 500 records in memory. The C-64 will hold up to 750 records. For permanent file storage, it's necessary to add either a disk drive or cassette recorder.

The well written and informative instruction book makes data entry easy. Mini Jini's manual should answer just about any question you may have; it's also full of helpful hints and tips on how to get the most of Mini Jini's capabilities.

In the ham shack, computers are no longer a luxury. In fact, after seeing how many VIC-20 and Commodore owners responded to our reader survey (see September, 1983, for the survey, and January, 1984, for our editorial response), it's hard to imagine that there's *anyone* who doesn't have a computer to use! Record keeping with computers can be a real plus when you're contesting, QSLing, or organizing your collection of magazine articles. Mini Jini will do it for you with a minimum of fuss and hassle.

For more information, contact Jini Micro-Systems, Box 274 Kingsbridge Street, Riverdale, New York 10463.

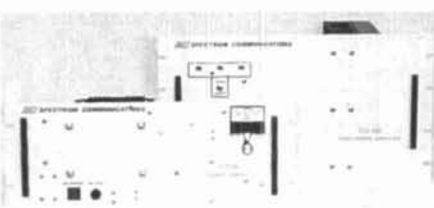
Circle #305 on Reader Service Card.

N1ACH

NEW products

power and power supply

The Spectrum SCA100V is a new 150-watt repeater/base station amplifier that operates in the 136-174 MHz range. Its unique heatsink and high efficiency cooling system design allow cool operation even under continuous duty conditions in a hot environment. The "behind the panel" heatsink permits use in a locking front door cabinet without loss of cooling effectiveness. It also features automatic high-VSWR shutdown/"bypass" with 4X auto-reset circuit and automatic amp bypass (if the power supply should fail or if the amp should overheat), as well as unusually tight RF shielding and heavy-duty construction. A 100-watt UHF version is also available.



NEW products

The companion power supply for tl SCA100V amplifier, the SCP30, may also l used for any type of high-power amplifier, se vice bench, or industrial application requiring very heavy duty supply. Its output is 13.6 VD at 25 amperes, continuous, 30 amperes inte mittent.

For further details, contact Spectrum Cor munications Corp., 1055 West Germantov Parkway, Norristown, Pennsylvania 19401-961

Circle #306 on Reader Service Card.

break-in adapter

Design Electronics Ohio has introduced its f break-in amplifier adapter, the QSK-1500. D signed to mate currently available full break radios — such as *all* Ten-Tec units, the Kenwo TS930, Drake TR-5, the Yaesu FT1, FT980, a FT757, and the ICOM751 — to either comme cial or homebrew linear amplifiers. Installati of the QSK-1500 requires no internal modific tions to most transceivers or amplifiers; a min modification is necessary with Ten-Tec units SSB.

While the QSK-1500 was designed primar with the CW operator in mind, it will also fun tion on SSB and RTTY. High power Amtor now also possible with this unit.

The QSK-1500 uses ultra high speed PIN dio switching and has no clicking or annoying relay The unit is designed to handle 1500 watts RF in a 50-ohm load at 40 WPM. Insertion loss is le than 0.6 dB on receive. Maximum receiver li voltage is 3800 mV before the protective circu is activated. An in-line fuse lamp will trip out 7.5 watts RF. Control lines for keyer must be f positive, cathode keying lines only. Amplifi switch time is less than 800 microseconds. Tl units measure 3 × 6.25 × 3.75 inches (7.6 15.9 × 9.5 cm) control, and 3.2 × 6.6 × 9. inches (8.1 × 16.8 × 23.5 cm) RF unit, ar weigh 5 and 4 pounds (11 kg and 8.8 kg) respe tively. The unit is available for $279 from eith Universal Amateur Radio, Inc., 1280 Aida Driv Reynoldsburg, Ohio 43068, or DEO, 4925 S Hamilton Drive., Grovesport, Ohio 43125.

Circle #307 on Reader Service Card.

new 40-meter antenna

Telex/Hy-Gain has introduced the "Disco erer," a new series of 40-meter antennas deve oped for high-performance operations in r sponse to the effects of declining sunspot a tivity on the 10-20 meter bands.

The new series consists of several configur tions. The Discoverer 7-1 is a 45-foot (13.7 mete rotatable dipole that can be added to many e isting beam antenna installations and tuned either 30 or 40 meters.

The Discoverer 7-2, a two-element beam wi a wind load of only 6 square feet (0.56 meter^2), requires only a 25-foot (7.6 meter) turning radius. In addition to high forward gain and front-to-back ratio, it maintains a broad bandwidth in excess of 190 kHz with SWR below 2:1.

The Discoverer 7-2 can be further enhanced with the addition of a Director Kit, thereby creating a three-element beam. This almost doubles the front-to-back ratio and forward gain, which in turn almost doubles the E.R.P. of the two-element version. All this fits on a 35-foot (10.7 meter) boom. The relatively compact array does not require a heavy-duty tower, but can be safely installed on a less expensive medium-duty tower such as the Hy-Gain HG52SS.

The suggested list price for the Discoverer 7-1 is \$195.00. The Discoverer 7-2 and the Director Kit are listed at \$435.00 and \$272.00 respectively.

For more information, contact Telex Communications, 9600 Aldrich Avenue South, Minneapolis, Minnesota 55420.

Battery Manager™

Designed with the communications specialist in mind, the Battery Manager™ from URDC Measurements, Inc., analyzes and conditions all common types of 2-way radio NICAD batteries for optimum field performance and extended life.

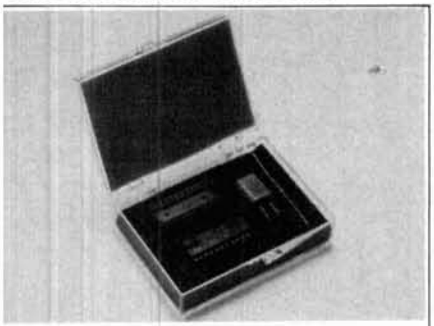
The unit is specifically designed to combat "Memory Effect" — the premature loss of power from a battery that's just been fully charged. Caused by repetitive shallow discharging followed by repeated overcharging, Memory Effect reduces reliability in the field and plays havoc with battery replacement schedules.

With the Battery Manager™, batteries that have been discarded as "not usable" can often be reconditioned and returned to service, and the life of batteries currently in use can be extended.

Battery Manager™ operates on 110V, 60 Hz and can be adapted at the factory for use on 20V, 50 Hz. Its maximum power consumption is 150 watts.

For more information, contact URDC Measurements, Inc., P.O. Box 880, West Jordan, Utah 84084.

Circle #308 on Reader Service Card.



New CMOS DTMF Chip Kit

Teltone's TRK-957 Kit makes it easier and less expensive to breadboard a low-power, central office quality DTMF detection system. All you need is a power source from 5 to 12 VDC. The sensitivity, wide dynamic range, noise immunity, and low-power consumption make the TRK-957 ideal for telephone switching, computer, and remote control applications. The TRK-957 DTMF Kit is only \$24.75. To order call:

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SD1012-5	9.90	SD1136	15.00	SD1301-7	3.00	SD1484-6	1.50
SD1013-3	13.50	SD1136-2	15.00	SD1305	3.00	SD1484-7	1.50
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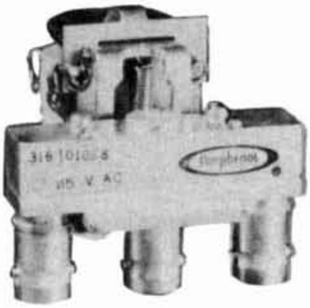

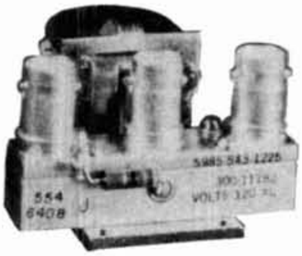

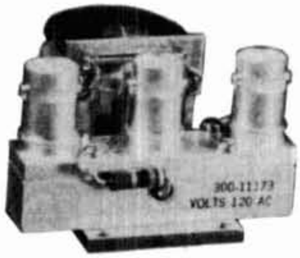

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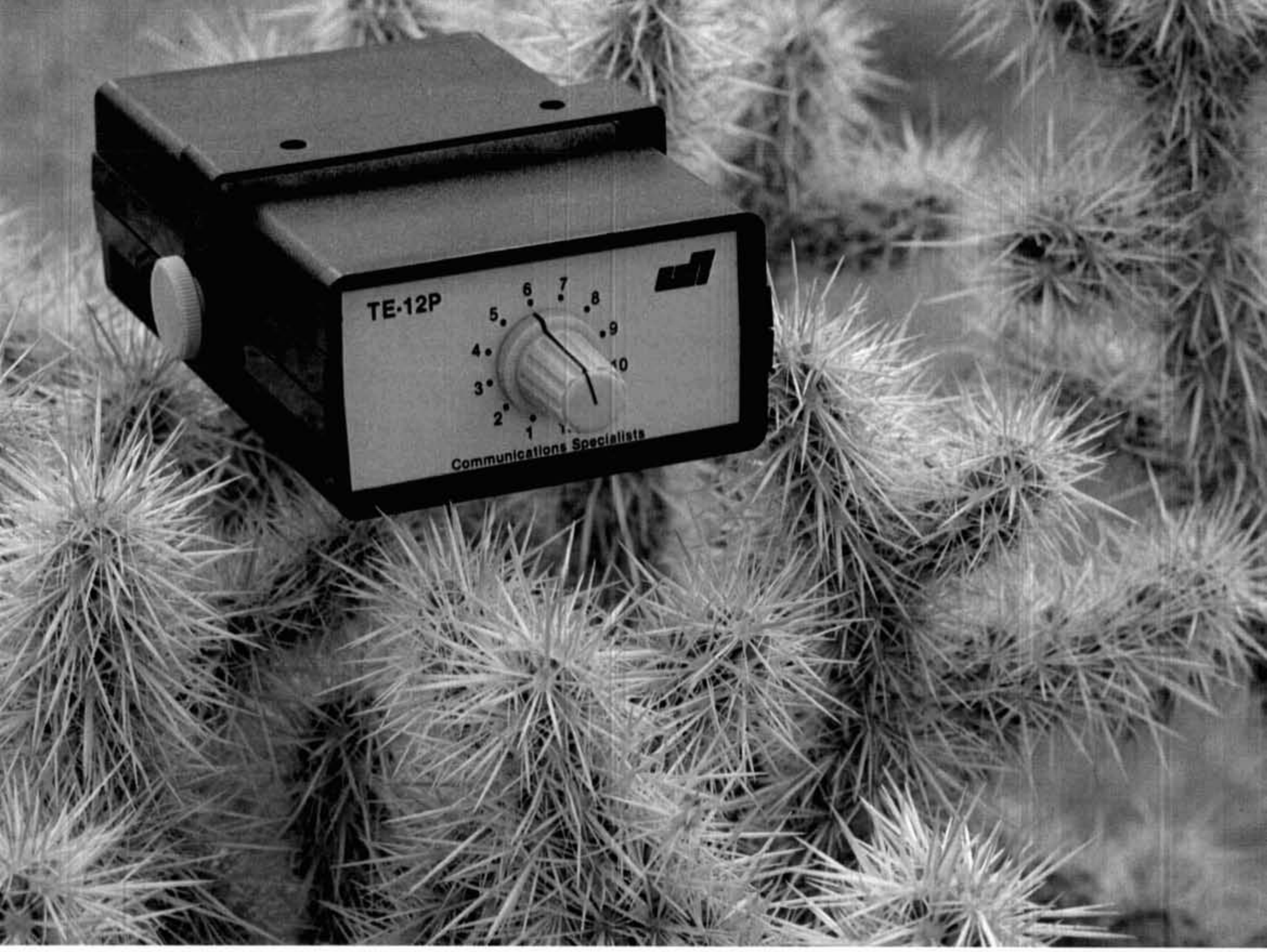

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ROM-116 for TRS-80 RTTY with 5 program tapes and instruction manuals. 1.3 version. $200 or best offer. Ken Eaton, 6418 W. 78th St., Prairie Village, Kansas 66204.

HAM RADIO MAGAZINE Collection: Bound volumes 1969, 1970, 1971, 1972, 1973, 1974, 1975. In HR binders 1976, 1977, 1978, 1979. Loose copies 1980, 1981, 1982, 1983. Best offer for lot. W4UCH, P.O. Box 1065, Chautauqua, NY 14722. (716) 753-2654.

FOR SALE: Swan 350 transceiver w/ps $250. SA2040 antenna tuner $125. QF-1A audio filter $50. Kantronics CW/RTTY interface for Vic-20 with programs board + cables $135. Shipping included. Send money order. Package price $500. Write Jim Howell, KA4EBW, 18 Dan St., Salisbury, NC 28144. (704) 637-0313 evenings.

REPAIR, ALIGNMENT, calibration. Collins written estimates $25; non Collins $50. K1MAN (207) 495-2215.

MICROWAVE MIXERS. Two new Watkins-Johnson M77C X-band DBM's. $125 each. SMA or microstrip. Low noise, high isolation. Cost $382 each. John Perlick, 7435 Brunswick, Brooklyn Park, MN 55443.

CHASSIS and cabinet kits. SASE K3IWK.

NATIONAL RADIO CO equipment manuals price list SASE. Dust covers, NCX 3 or NCX 5 plus NCX A, pair $8.95 PP. Maximilian Fuchs, 11 Plymouth Lane, Swampscott, MA 01907.

ELECTRON TUBES: Receiving, transmitting, microwave . . . all types available. Large stock. Next day delivery most cases. Daily Electronics, 14126 Willow Lane, Westminster, CA 92683. (714) 894-1368.

HAM TRADER WEST "Pink Sheets" 25 cents a word for subscribers, $9 a year bimonthly, Canadians send U.S. funds, posted same day as U.S. from Canada. Others 50 cents a word, commercial 75 cents a word. Name address and phone free. Ham Trader West, Box 202, Lynden, Washington 98264.

WANTED: Cash paid for used speed radar equipment. Write or call: Brian R. Esterman, PO Box 8141, Northfield, Illinois 60093. (312) 251-8901.

$$$$ SUPER SAVINGS on electronics parts, components, supplies, and computer accessories. Free 40-page catalog for SASE. Get on our mailing list. BCD Electro, PO Box 830119, Richardson, TX 75083. Or call (214) 690-1102.

***WANTED:** Old microphones, remote mixers other mic related* items. All pre-1935. Box Paquette, 107 E. National Avenue, Milwaukee, WI 53204.

DELTA LOOP BOOM for 10-20 meters. Lightweight, strong, quality boom with element brackets attached. Element kits *available, or make up your own. Full details.* D.L. Manufacturing, 485 Fifth Avenue, #1042, New York, NY 10017.

STERLING SILVER callsign jewelry pin or tack; $11.95, alligator tie clip; $19.95, all ppd. Info-SASE. Tom's Silver, PO Box 3758, Manchester, NH 03105.

RECONDITIONED TEST EQUIPMENT $1.00 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

FOX-TANGO Newsletters -- Since 1972, the prime source of modifications, improvements, and repair of Yaesu gear, free to Club members. Calendar year dues still only $8 U.S., $9 Canada, $12 elsewhere. Includes five year cumulative index by model numbers, or send $1 for index and sample Newsletter. Fox Tango Club, Box 15944, W. Palm Beach, FL 33416.

RTTY-EXCLUSIVELY for the Amateur Teleprinter. One year $7.00. Beginners RTTY Handbook $8.00 includes journal index. P.O. Box RY, Cardiff, CA 92007.

IMRA International Mission Radio Assn. helps missioners — equipment loaned; weekday net, 14.280 MHz, 2-3 PM Eastern. Br. Frey, 1 Pryer Manor Rd., Larchmont, NY 10538.

"HAMS FOR CHRIST." Reach other Hams with a gospel tract *sure to please.* Clyde Stanfield, WA6HEG, 1570 N. Albright, Upland, CA 91786.

TENNATEST — Antenna noise bridge — out-performs others, accurate, costs less, satisfaction guaranteed, $41.00. Send stamp for details, W8URR, 1025 Wildwood Road, Quincy, MI 49082.

WANTED: Early Hallicrafter "Skyriders" and "Super Skyriders" with silver panels, also "Skyrider Commercial", early transmitters such as HT-1, HT-2, HT-8, and other Hallicrafter gear, parts, accessories, manuals. Chuck Dachis, WD5EOG, The Hallicrafter Collector, 4500 Russell Drive, Austin, Texas 78745.

VERY in-ter-est-ing! Next 4 issues $2. Ham Trader "Yellow Sheets", POB356, Wheaton, IL 60189.

FOR SALE: B&K model E-200D RF signal generator $280.00; electronic navigation model 310L 250kH-110 MHz RF linear amplifier $500.00; Leader model LSG-231 FM stereo signal generator $300.00; Eico model 150 solid state signal tracer $100.00; Lafayette Pip-Speak stereo speakers $50.00; Leader VLM model LP-70B 20k ohm per volt $40.00; Minolta SRT-200 35mm camera with UV filter, 50mm lens and case $125.00; RF Power Labs model V350 2 meter 350W linear amp. with fan cool $800.00; Monroe simplex autopatch, commercial quality, with various remote functions with Yaesu CPU-2500 2 meter memorizer radio $1250.00. TR-110 B&K Isopack isolator transformer $100.00. Mitchell Rakoff, 114-41 Queens Blvd., Suite 148, Forest Hills, NY 11375 (212) 591-0002.

Coming Events

ACTIVITIES

"Places to go..."

ALABAMA: The Huntsville Hamfest, Saturday and Sunday, August 18 and 19, Von Braun Civic Center, Huntsville. No admission charge. Exhibits, forums, air-conditioned indoor flea market and non-ham activities. Tours of the Alabama Space & Rocket Center available. A limited number of camp sites with hookups at VBCC. Reserved flea market tables available $4/day. Talk in on 34/94. For information: Huntsville Hamfest, 2804 S. Memorial Parkway, Huntsville, AL 35801.

WYOMING: The fifth annual High Plains Ham Roundup, sponsored by the Northern Colorado ARC, University of Wyoming ARC and Shy-Wy ARC, September 7, 8 and 9, Medicine Bow National Forest, Yellow Pine Campground, 35 miles west of Cheyenne. Campfire cookout and bring-your-own covered dish supper Saturday with singalong music and entertainment by regional talent. Barbequed hamburgers and refreshments provided by the committee. Giant tailgate swapfest, transmitter hunt and technical displays. No registration fee. Modest Forest Service charge for campers. Talk in on 22/82 and 25/85. For information: W7CGK, 1321 E. 22 Street, Cheyenne, WY 82001.

RADIO EXPO '84 sponsored by the Chicago FM Club, Saturday and Sunday, September 22 and 23, Lake County Fairgrounds, Rt. 120 & 45, Grayslake, IL. Major manufacturers and gigantic outdoor flea market. Flea market opens 6 AM. Exhibits 9 AM. Free parking and overnight camping. Reservec indoor flea market $5/day. Tickets $3.00 advance, $4.00 a gate, good for both days. Seminars, technical talks and ladies programs. Talk in on 146.16/76. SASE to Radio Expo '84, Bo 1532, Evanston, IL 60204 or (312) 582-6923.

FLORIDA: The Platinum Coast Amateur Radio Society's annual Hamfest, September 8 and 9, Melbourne Auditorium Melbourne. Swap tables, meetings, forums, awards, tailgating For information or reservations: PCARS, PO Box 1004, Melbourne, FL 32901.

ONTARIO, CANADA: The Radio Society of Ontario's 16tl annual Convention, October 5, 6 and 7, Westin Hotel, Ottawa Friday night eyeball and dance. Saturday and Sunday technical sessions, demonstrations and commercial exhibits. Saturday night banquet and dance. For information: RSO Convention Committee, PO Box 15806 Station "F", Ottawa Ontario K2C 3S7.

PENNSYLVANIA: The 47th annual South Hills Brasspounder and Modulators Hamfest, August 5, 9 AM to 4 PM, South Carr pus of the Community College of Allegheny County, Pitts burgh. Tickets $3 each or 2/$5. Indoor/outdoor flea marke space available. Food and refreshments available. Free park ing. Talk in on 146.13/73 and 146.52 simplex. For informa tion: Jack B. Wood, 448 Jenne Dr., Pittsburgh, PA 15236

PENNSYLVANIA: Change of location for the Mid-Atlantic AR Hamfest, August 12. (See announcement in July HR.) It wi be held at the Bucks County Drive-in, Route 611, Warringtor

MINNESOTA: The St. Cloud Amateur Radio Club's annu Hamfest, Sunday, August 12, 8 AM to 4 PM, Sauk Rapids M

icipal Park, Sauk Rapids. Talk in on 146.34/94. For informa-
on: St. Cloud ARC, PO Box 141, St. Cloud, MN 56302.

EW JERSEY: The 25th GCARC Ham/Compfest, sponsored y the Gloucester County ARC, August 26, 8 AM to 4 PM, loucester County College, Sewell. Admission $2.00 advance, 2.50 at door. Tailgating $3.00 per space. Seminars, contests, omputer demos, flea market, refreshments. Official VEC test-g center, testing Novice thru Extra. No pre-registration nec-ssary; 610 forms available. Talk in on 147.78/18, 146.52 sim-ex, 223.36/224.96. For information or reservations: Milt Gold-an, K3WIL, 801 Crown Point Rd., Westville, NJ 08093. (609) 56-0500 or John M. Fisher, K2JF, PO Box 370, Pitman, NJ 3071. (609) 589-2318.

WA: The Des Moines Radio Amateur Association's Ham Computerfest, August 19, 9 AM to 5 PM, Veteran's Memorial uditorium, Des Moines. Donation $3.00 advance, $4.00 at oor. Expanded flea market, Amateur and computer dealers, onsignment tables. Refreshments available. Talk in on 46.22/82 and 440.5. For information and reservations: Bob ucker, KDØEO, PO Box 3711, Urbandale, IA 50322 (515) 76-4415 or Louis Seibert, NØELI, 7515 Roseland, Urbandale, 50322 (515) 276-0272.

AINE: The 1984 Windsor Hamfest, Saturday, September 8, /indsor Fairgrounds. Flea market, programs, speakers, dis-ibutors, light meals and the traditional Saturday bean and asserole supper. Gate donation only one dollar. Camping vailable Friday and Saturday nights. Talk in on 146.22/82 epeater. For information: Don Hanson, N1AZH, RFD #2, Box 678, Greene, Maine 04236. (207) 946-7557.

DIANA: The Tippecanoe Amateur Radio Association's 13th nnual Hamfest, Sunday, August 19, Tippecanoe County Fair-rounds, Teal Road and 18th Street, Lafayette. Grounds open t 7 AM. Tickets $3.00. Large flea market, dealers, refresh-ents and fun. Talk in on 13/73 or 52. For tickets or informa-on: Lafayette Hamfest, Route 1, Box 63, West Point, IN 7992.

ENTUCKY: The Central Kentucky ARRL Hamfest, spon-ored by the Bluegrass Amateur Radio Society, Sunday, ugust 12, 8 AM to 5 PM, Scott County High School, Longlick oad and US 25, Georgetown. Tech forums, awards, exhibits. C facilities. Free outside flea market space. Tickets $3.50 dvance and $4.00 at gate. For information or tickets: Edward Bono, WA4ONE, P.O. Box 4411, Lexington, KY 40504.

KLAHOMA-KANSAS State Line Area: Great Salt Plains 2nd nnual Hamfest, August 26, 9 AM to 5 PM, Community Build-g, south side of Great Salt Plains Lake. Tech forums, meet-gs, free swap tables, refreshments, Novice exams and noon otluck dinner. Overnight camping and RV hookups at Lakes tate Park. Talk in on 147.90-.30 Salt Plains Repeater. For formation: Steven Walz, WA5UTO, Box 222, Cherokee, OK 3728. (405) 596-3487.

EW JERSEY: The Ramapo Mountain ARC, WA2SNA, pre-ents its 8th annual flea market August 18, Oakland Ameri-an Legion Hall, 65 Oak St., Oakland. (20 miles from GW ridge). Admission $1.00. Non-ham family members free. In-oor tables $6.50. Tailgating $3.00. Talk in on 147.49/146.49 nd 52. For information: Tom Risseeuw, N2AAZ, 63 Page Dr., akland, NJ 07436. 337-8389 after 6 PM.

IISSOURI: The St. Charles ARC's Hamfest '84, August 26, t. Charles City Hall Complex. Barbeque provided by the Har-ester Lions. Nearby Riverfront Park and historic south main treet area. General admission $1.00. Talk in on 146.07/67 nd 52 simplex. For information: Ron Ochu, KOØZ, 1914 N. th St., St. Charles, MO 63301.

IRGINIA/WEST VIRGINIA: The Bluefield Hamfest, Computer Satellite TV Fair, Sunday, August 26, 9 AM to 3 PM, Brush-ork Armory-Civic Center, 1 mile north of Bluefield, West Vir-inia on US 52. Sponsored by the East River ARC. Admis-ion $3.00. Children under 12 free. Large indoor flea market nd other activities. Paved parking, food on site. Talk in on 44.89/145.49 and 146.52. For information: Don Williams, /A4K, 412 Ridgeway Drive, Bluefield, VA 24605.

ENNESSEE: The Short Mountain Repeater Club is sponsor-g the Lebanon Hamfest, Sunday, August 26, Cedars of Leb-non State Park, US 231, Lebanon. Outdoors only. Bring your wn tables. Food and drink available. Talk in on 46.31/146.91. For information: Morris Duke, W4WXQ, 210 isspayne Drive, Donelson, TN 37214.

ENNSYLVANIA: The Uniontown ARC (W3PIE) will hold its 5th annual Gabfest, Saturday, September 8, Club grounds, ld Pittsburgh Road off Rt. 5 & 119 bypass, Uniontown. Free offee, free parking, free Swap & Shop with registration of 3.00 each, 2/$5.00. Good food at refreshment stand. Talk on 147.645-.045 & 144.57-.17. For information: John Cer-ak, WB3DOD, UARC Gabfest Committee, PO Box 433, epublic, PA 15475. (412) 246-2870.

ENNSYLVANIA: The Central Pennsylvania Repeater ssociation's 11th annual Hamfest/Computerfest, August 26, ershey. Adjacent to "Hersheypark" Chocolate town USA. egistration $3.00. Wives and children free. Special reduced dmission to Hersheypark for families of registrants. Large door dealer and flea market area. 10' indoor spaces $8 each. tables $4 each. Single electric plugs $1 each. Large outdoor tailgating area. Refreshments available. Talk in on 145.47, 146.76 and 146.52. For information: Timothy R. Fanus, WB3DNA, 6140 Chambers Hill Road, Harrisburg, PA 17111. (717) 564-0897 (Noon to 8 PM).

MICHIGAN: The Grand Rapids Amateur Radio Association's annual Swap and Shop, Saturday, September 15, Hudsonville Fairgrounds. Indoor sales area and outdoor trunk swap area. Gates open 8 AM. Talk in on 146.16/76. For information: Grand Rapids ARA, PO Box 1248, Grand Rapids, MI 49501.

PENNSYLVANIA: The Tioga County Amateur Radio Club's 8th annual Hamfest, Saturday, August 25, Island Park, Blossburg. 9 AM to 5 PM. Flea market, dealers, traders, computer demo, QSL contest, transmitter hunt, XYL and Harmonic programs, RC airplanes and more. Talk in on 146-19/79, 146-52/52 and CB. Admission $3.00. XYLs and kids free. For information: Carl E. Kimble, WB3EUE, PO Box 37, Cowanesque, PA 16918. (814) 367-5345.

IOWA: The Iowa 75 Meter Net will sponsor a Hamfest and picnic, Sunday, August 26, W.K.W. Park, North of Hampton. A potluck meal at noon followed by a short program. Talk in on Mason City 146.15-65. For information: WDØFWB or WBØJFF.

INDIANA: The Marshall County Amateur Radio Club's annual Hamfest, Sunday, August 26, 8 AM to 2 PM, Marshall County 4H Fairgrounds, Argos. All kinds of radio gear. Dealer tables available — 8'/$5. Good food and drink. Ladies' activities. Talk in on 146.52 simplex. Tickets $2.00 advance; $3.00 at door. For information: Marshall County ARC, PO Box 151, Plymouth, IN 46563 or call Bob Nellans, KB9DE (219) 892-5224.

OPERATING EVENTS

"Things to do..."

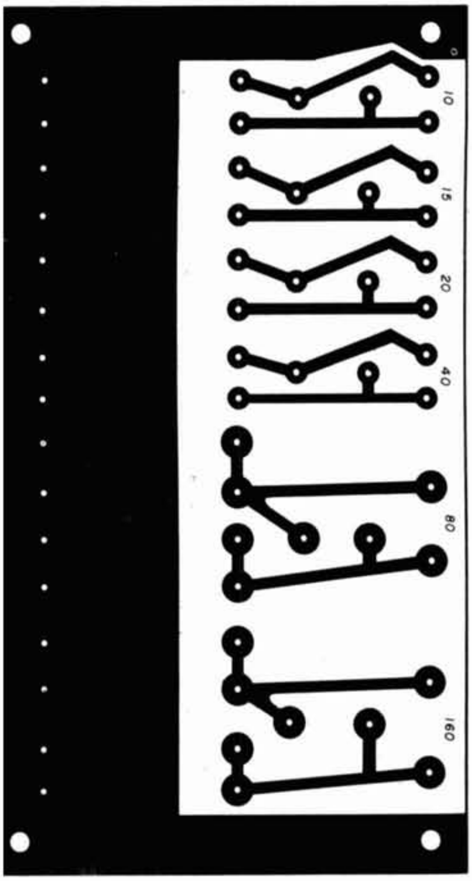
AUGUST 18-19: The Bergen Amateur Radio Association, Paramus, New Jersey, will operate special event station, K2TM, from 1500 to 2400Z to celebrate the Club's 21st anniversary. Certificate for large SASE and QSL via K2UFM, 31 Forest Drive, Hillsdale, NJ 07642.

AUGUST 18-19: The Cascades Amateur Radio Society (CARS) in conjunction with the Michigan Space Center, Jackson, Michigan, will operate WB8CSQ during Space Day activities. 0000 GMT August 18 through 1700 GMT August 19. For a special Space Day certificate, send log info and $1.00, to cover postage and materials, to CARS, Space Day '84, PO Box 512, Jackson, MI 49204.

SEPTEMBER 8: The West Alabama Amateur Radio Society (WAARS) will operate the 2nd annual special event station, KE4TN, from the campus of the University of Alabama, 1300Z to 2400Z, to commemorate the great college football coach, Paul 'Bear' Bryant. The Club will offer a handsome commemorative certificate to any station worked. Send $1 and a large SASE to: West Alabama ARS, PO Box 1741, Tuscaloosa, AL 35403.

AUGUST 11-13: 25th Annual New Jersey QSO Party. Sponsored by the Englewood Amateur Radio Association, Inc. From 2000 UTC Saturday, August 11 to 0700 UTC Sunday, August 12 and 1300 UTC Sunday, August 12 to 0200 UTC Monday, August 13. Phone and CW considered same contest. Suggested frequencies: 1810, 3535, 3900, 7035, 7135, 7235, 14035, 14280, 21100, 21355, 28100, 28610, 50-50.5, and 144-146. Exchange: QSO number, RST, and QTH (ARRL section or country). New Jersey stations send county for their QTH. Logs and comments to: Englewood Amateur Radio Association, Inc., PO Box 528, Englewood, NJ 07631-0528. Include a #10 SASE for results.

SEPTEMBER 9-15: The Southern Counties Amateur Radio Association (SCARA) is planning to have a special events station during the Miss America Pageant. Check September Ham Radio for details.



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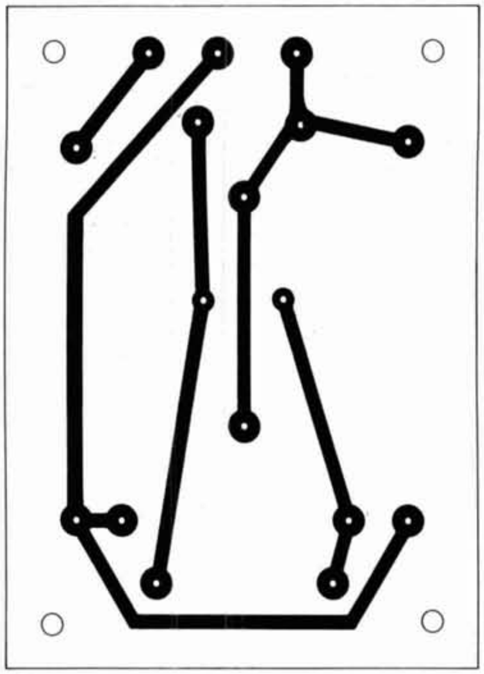

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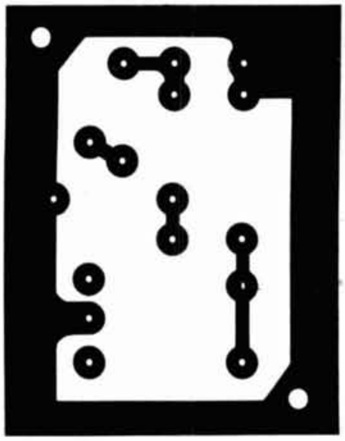

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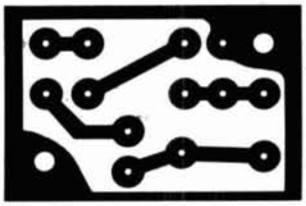

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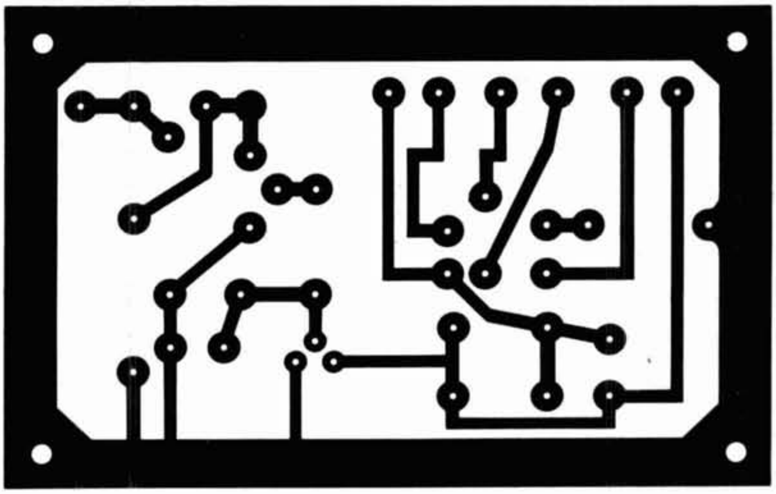

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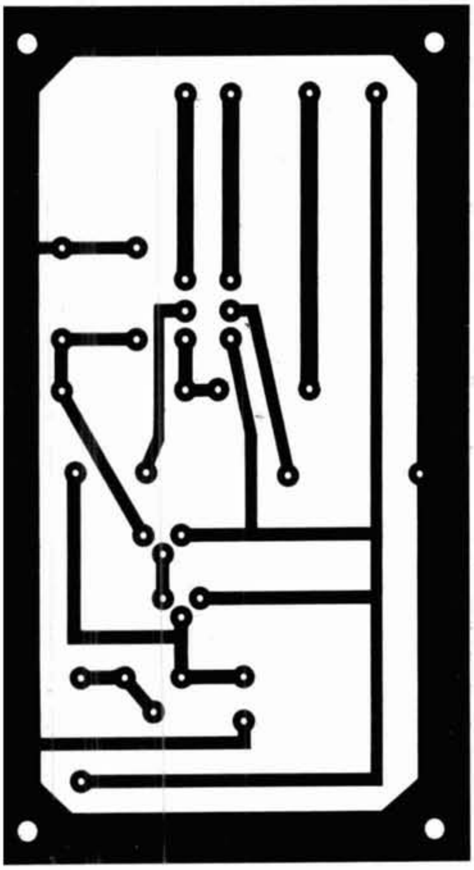

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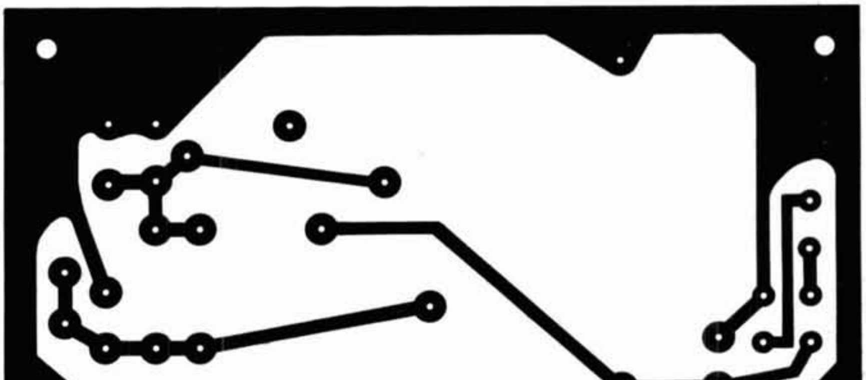

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Aluma ___ 110
Amateur-Wholesale ___ 111, 112
ARRL ___ 113
Analog Tech. ___ 114
Astron ___ 115
Austin Antenna ___ 116
B & W *
Barry *
Bauman ___ 121
B.G. Micro ___ 117, 118, 119
BHCo ___ 120
Birch Hill ___ 122
Buckmaster ___ 123
Butternut *
C & A Roberts ___ 124
Ceco ___ 125
CES ___ 126
Clearwater Computer ___ 127
Coaxial Dynamics ___ 128
Comm. Concepts ___ 129
Comm. Spec. ___ 130
Computer Trader ___ 131
Connect Systems ___ 132, 301
Dokay ___ 133
Doppler ___ 134
Drake *
Dynetic Systems ___ 135
Encomm ___ 136
Eng. Cons. ___ 137
Fluke *
GLB Elec. ___ 138
GMB Systems *
Ham MasterTapes ___ 139
HRB ___ 140
Hamtronics, N.Y. ___ 141
Handi-Tek ___ 142
Harvey Radio ___ 143
Heath ___ 144
Henry ___ 145
Hewlett-Packard ___ 146
Icom ___ 147, 148, 302
J & J Satellite TV ___ 149
Jini Micro-Systems ___ 305
KLM ___ 150
Kantronics ___ 151, 152
Kenwood *
MFJ ___ 153
MHz Elec. ___ 154
Madison ___ 155
Maggiore ___ 156
Memphis Amateur Elec. ___ 157
Meshna ___ 158
Micro-Mart *
Micro Systems ___ 159
Microwave Filter ___ 160
Midwest ___ 161
Mirage ___ 162
Missouri Radio ___ 163
Morning Dist. ___ 164
Mosley ___ 165, 166, 167
NCG ___ 168
Nail Co. ___ 169
Nampa ___ 170
Nemal ___ 171
Nevada Sat. ___ 172
N&V ___ 173
P.C. Elec. ___ 174
Pro-Search ___ 175
RF Enterprises ___ 176
RF Products ___ 177
Callbook ___ 178
Radio Expo *
Ramsey ___ 179
Robot ___ 303
Roensch ___ 180
Sartori ___ 181
Sat. TV Mag. ___ 182
Spectrum Comm. ___ 306
Spectrum Inter. ___ 183
Spectrum West ___ 184
Spi-Ro Dist. ___ 185
Starfinder ___ 186
TE Systems ___ 187
TNT Radio ___ 188
Telex *
Teltone ___ 189
Texas Towers ___ 190
UNR-Rohn *
Ungar ___ 304
Univ. Amateur Radio ___ 307
Universal Elec. ___ 191
University Microfilms *
URDC ___ 308
VHF Comm. ___ 192
Vanguard ___ 193
Varian ___ 194
Vector Radio ___ 195
Webster Comm. ___ 196
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August 1984

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103	115	127	139	151	163	175	187	199	211	223	235	247	259	271	283	295	307	319	331	343
104	116	128	140	152	164	176	188	200	212	224	236	248	260	272	284	296	308	320	332	344
105	117	129	141	153	165	177	189	201	213	225	237	249	261	273	285	297	309	321	333	345
106	118	130	142	154	166	178	190	202	214	226	238	250	262	274	286	298	310	322	334	346
107	119	131	143	155	167	179	191	203	215	227	239	251	263	275	287	299	311	323	335	347
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Exclusive KDK 6 in 1 control is now joined by 6 exciting new KDK features:

NEW! % Soft Orange background Liquid Crystal Display (LCD) for direct sunlight viewing plus lighting for night viewing.

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NEW! % Chrome front panel with accent knobs and lighter color on case to match today's auto decor.

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NEW! % Repositioned controls for more convenient operation.

The Exclusive KDK 6 in 1 Knob.

- Only memories with data are scanned; blanks are skipped.
- Complete memory back-up with power unplugged. Re-chargeable Ni-Cd with capability of several months back-up of memory.
- Single frequency sub-audible tone generator included as a standard feature.
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- Odd repeater splits can be handled with the memory in the AxB mode.
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- Modular construction with pluggable interconnecting wiring.
- Touch-Tone® microphone TM-2 is standard with each radio.
- Change channels, skip-scan or step up and down the band from TM-2 microphone.
- Audible beep for end-of-band or last memory location for better "eye's off" operation.

The KDK FM-2033 represents a significant advance in user convenience and simplicity of operation for the radio user. The KDK '33' series of transceivers provides excellent readability in any lighting condition for either the operating frequency or the memory channel number in use. The use of a warm orange background for the LCD displays improves the readability by providing an easy on the eyes contrast improvement.

Simplicity of operation has always been the mark of the KDK design team and the FM-2033 is no exception. From the single knob frequency and memory selection to the automatic recall of the desired repeater offset from memory, the FM-2033 continues to provide relaxed, comfortable mobile operation.

Once the 10 memory frequencies have been selected, a single knob is all that is required for operation on the standard simplex or repeater channels. Using the audible beep as the end of memory marker allows setting to a particular channel without even looking at the radio.

In the scan mode, scanning for a busy memory or pre-programmed band scan keeps you up to date on the happenings in the area. Very busy frequencies can be skipped by using the up key on the TM-2 microphone. If a full 10 memories are not used, the unused ones can be marked for scan skip so that no time is wasted checking them.

The FM-2033 provides a clean 25 watt output signal across 142 - 149.995 MHz to operate in balance with most repeater signals and provide quieting on the simplex operations. M.A.R.S. (NAVY too!) and C.A.P. frequencies are also accommodated.

You want convenience, reliability and easy operation for your mobile station and a tough to beat dollar value. Check out the FM-2033 at your local dealer TODAY or send a QSL for specifications.

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Specifications are nominal and are subject to change. All KDK transceivers meet or exceed FCC regulations regarding spurious emissions.

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