

JUNE 1984 / \$2.50

ham radio

magazine



TOWERS

DESIGN

INSTALLATION

MAINTENANCE

hr
focus
on
communications
technology

*also: the peaked lowpass — a look at the
ultraspherical filter • microphone calibration
• impedance matching • applied Yagi antenna
design • VHF/UHF world • ham radio techniques*

ICOM IC-27H

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Now ICOM offers the best choices in compact 2-meter FM mobiles...the IC-27H 45-watt compact (1 1/2" H x 5 1/2" W x 9 3/4" D) and the IC-27A 25-watt super compact mobile. These units are the smallest full-featured 2-meter mobile transceivers available, and they feature an internal speaker for easy installation.



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9 Memories. The IC-27A and IC-27H have nine memories avail-

able 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.

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IC-HM23

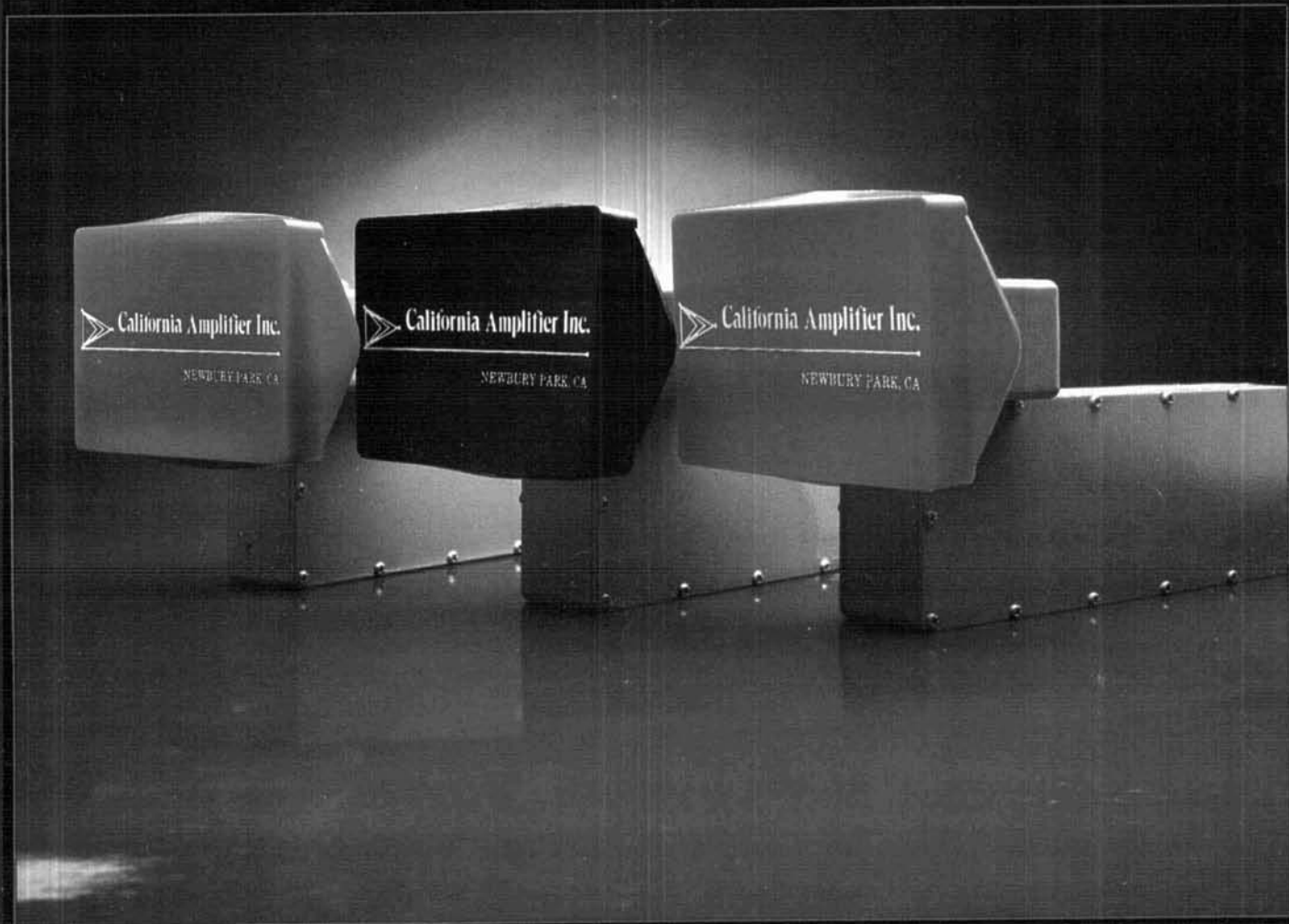
IC-27H



IC-27A

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✓ 123

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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, program-mable 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 program-mable 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
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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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REFLECTIONS REFLECTIONS

SCORE: 99 FOR . . . 1 AGAINST

Of the thousands of towers installed in the United States last year, 99 percent remain standing. This is truly a remarkable statistic, considering how many of these structures were installed using less than the best techniques and, to boot, were hardly ever maintained.

Of those that came down, we could say that some unusual weather condition (hurricane, tornado, or ice storm) or some other extraordinary occurrence was to blame — but stop and think how many of these would still be standing today if the proper foundation had been laid, if wire instead of nylon rope had been used for guys, if that 10 feet of additional masting hadn't been used .

Do you recognize any of these situations? Is your present installation ready to become a negative statistic? If so, read on.

O.K., we're all Amateurs, but just for the moment, let's borrow some good advice from the engineering disciplines (or maybe it's just good old common sense). Before putting up that 6-element super deluxe 27 dBn gain (decibels with respect to a conductive noodle) Yagi atop the 102-foot perch, sit down, take pencil in hand and think it through. A safe tower/antenna installation (or any installation for that matter) can and should be engineered in three simple steps: DESIGN it according to the manufacturer's specifications, INSTALL it correctly, and MAINTAIN it. Unfortunately, most of us (and I don't exclude myself) are in such a rush to become operational — taking advantage of the good weather and time off from work, vacation, or chores — that we just can't afford to take the time to do it right. Or can we? Can we afford to come home one day and find an irate neighbor shouting and pointing to our aluminum thing of beauty, still attached to our tower, protruding upside down from *his* roof?

Just because we're Radio "Amateurs," it doesn't mean that our installations have to be "amateur." And it doesn't mean that all commercial installations are necessarily safer. A case in point: a friend of mine was doing a site survey for a cable TV outfit and had to climb one of the existing towers for the preliminary observation phase. Well, it was getting late in the day and, to be quite honest, my friend was a wee bit leery about climbing that tower because of something unnerving — but not readily identifiable — about the foundation and the sandy soil. When he came back the next day to climb the tower, he found the tower on the ground, having fallen by its own accord during the night.

To help prevent this kind of near-disaster, and real disasters as well, the theme of this issue (if you haven't already guessed) is *towers*. In a sequence of articles not dissimilar to a Greek trilogy, Roger Cox (WBØDGF), John Haerle (WB5IIR), and Steve Makulec (KB9IW) discuss the three important steps of tower construction: design, installation, and maintainance — and there's nothing mythological about that.

Rich Rosen, K2RR
Editor-in-Chief

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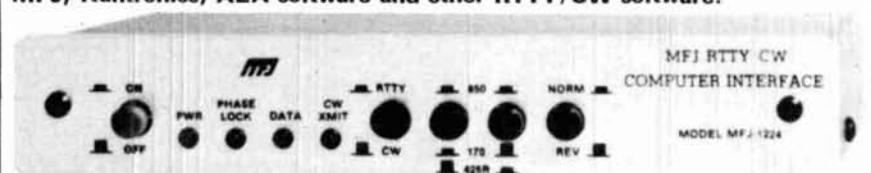
Plugs between receiver and VIC-20, Apple, TRS-80C, Atari, TI-99, Commodore 64 and most other personal computers. Requires appropriate software.

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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

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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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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.

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

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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 Gallo 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.

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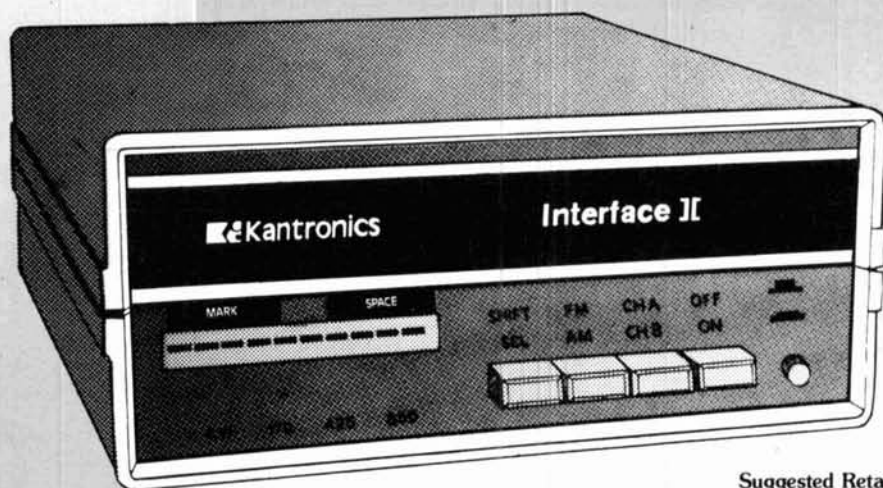
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Interface II is the new Kantronics transceiver-to-computer interface. Interface II features a highly sensitive front end with mark and space filtering. Even the most discerning operator will be surprised with the Interface II's ability to dig out signals in poor band conditions. Our unique tuning system even displays signal fading.

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Hamtext

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UTU allows any computer with an RS232 port and a terminal program to interface with any transceiver. Additional software isn't necessary with UTU, as an internal microcomputer gives the unit data processing capabilities to send and receive in four coded amateur formats; Morse code, Radioteletype, ASCII, and AMTOR.

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The Kantronics Universal Terminal Unit can send and receive CW at 6-99 WPM; RTTY 60, 67, 75, 100, and 132 WPM; ASCII 110, 150, 200, and 300 baud; and AMTOR. Dual tone detection and our unique bargraph tuning system make tuning fast and easy. Additional LEDs indicate Lock and Valid status during AMTOR operation. The RS232 port is TTL or RS232 level compatible.

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PRESSURE IS BUILDING IN THE 900 MHz SPECTRUM for a variety of possible uses, at least some potentially in conflict with the Amateur 902-928 MHz allocation that came out of the 1979 WARC. Mura, a leading producer of cordless phones and other consumer electronics, has petitioned the FCC to establish a new "Consumer Radio Service" at 935-938 MHz. Mura's proposal would provide 120 channels using automatically identified radios with a five-mile range at a projected cost of under \$100 each. Mura also proposes phasing out 27 MHz and GMRS CB, and rejects GE's earlier proposal for a 900 MHz service with repeaters and telephone interconnect as simply a variation of the new cellular communications system.

Cordless Phones Are Yet Another Prospective 900 MHz User, proposed by the Electronic Industries Association in another Petition for Rule Making. The EIA wants two 2-MHz bands in the 900 MHz region, separated by at least 45 MHz, to become available by January 1, 1987. The FCC did recently add 10 new "interim" cordless phone channels at 46/49 MHz.

All This Is In Addition To The Rapid Growth Of Paging, cellular radio and other two-way services in the 800-1000 MHz spectrum. However, on March 28 the ARRL filed its own Petition for Rule Making, asking for early implementation of privileges for Technician and higher class licensees on the 902-928 MHz Amateur band. The FCC reports very little previous Amateur input about this band. At the same time, the ARRL also asked for use of the new 24-MHz band, by General Class and higher. Yet another petition, by five Amateurs who all hold experimental licenses for both the new 18 and 24-MHz Amateur allocations, asks that Amateur operation be permitted on both bands on a non-interference basis.

THE FIRST VOLUNTEER-ADMINISTERED AMATEUR EXAMS WERE GIVEN APRIL 17 IN ALASKA, giving the No. 1 VEC, Anchorage Amateur Radio Club, still another first in the program. 42 Tech and General exams were given in their session. The Dayton ARA wasn't far behind, giving about 400 exams during its April 28-29 Hamvention weekend. Dissatisfaction over ARRL inaction on the VEC program seems widespread, and rumors of some sort of forthcoming shakeups at Newington were circulating at the Hamvention.

Amateur Frustration With Lack Of Upgrade Opportunity is now becoming serious in some areas. The third call area, for one, is now booked solid through the year's end, when FCC-administered exams end and the volunteer program must take over. However, a third call area VEC, the Laurel (Maryland) ARC, is expected to be certified shortly.

A Seventh District VEC, The Boeing Employees Amateur Radio Society, has been accepted by the FCC, and the Dallas ARC has been certified as the VEC for the fifth district. In the second and eighth call areas additional VECs are also coming on board. However, the first, zero, and sixth districts still have no known prospects, though a sixth district group is reported to be preparing to make a proposal.

The FCC's NPRM On Exam Fees Drew Only a Handful Of Comments from several clubs, a few concerned individuals, and of course the ARRL. Most supported the concept of expense reimbursement for examiners as well as the VECs, under the direction of the VECs. It is hoped the Commission will be able to authorize fee collection before the summer recess.

The Revised Novice Exam Program, In Place Since Last Summer, is working well for the most part, though Gettysburg says they still have some problems. Some Amateur examiners still don't realize they're supposed to write, administer, and grade the exams themselves, and are still writing Gettysburg for exams or sending applicants' answer sheets there for grading. The other major problem is with improperly filled out Form 610s: the examiner either neglects to certify that both the CW and written exams were passed, or neglects to include a signed statement certifying that the examination was properly administered.

OPERATING AFTER HIS LICENSE WAS LIFTED BROUGHT A SUSPENDED sentence with a threat of prison to a California ex-Amateur. The former N6BII, who lost his license for jamming WESCARS and other 40-meter operations was sentenced to a 90-day suspended sentence and three years probation in Federal District Court April 19. Under the terms of his probation, however, he can go to jail if he even talks over another Amateur's station during the probation period, unless the FCC chooses to relicense him.

EXPANSION OF ADDITIONAL PHONE BANDS IS STILL in the FCC's hopper, but staff cuts at the Commission and implementation of the Volunteer Exam Program have kept it on the back burner. There's hope that the Commissioners will be able to act on expansion before the summer recess, but what direction expansion (if any) will take is very much up in the air.

DAYTON HAMVENTION'S "HAM OF THE YEAR" IS DAVE BELL, W6AQ, honored "...for dedicated use of his Cinematographic skills to bring the story of Amateur Radio to the world." This year's "Special Achievement Award" went to Ethel Smith, K4LMB, for her efforts on behalf of the YLRL. The "Technical Achievement Award" went to Lyle Johnson, WA7GXD, for development of the Tucson Terminal Node Controller for packet radio. Congratulations to all!

A NUMBER OF SCHOLARSHIPS FOR AMATEURS who are now or will be attending a full-time college are being offered by the Foundation for Amateur Radio. Write them at 6903 Rhode Island Ave., College Park, Maryland 20740, for application information.

EXTENSIVE REVISION OF 2-METER REPEATER FREQUENCIES ALONG THE U.S.-MEXICAN border may be coming in the wake of recent interference problems. Mexican government authorities have met with their Amateurs to discuss on-going across-the-border coordination difficulties, and have proposed joint meetings with the FCC and U.S. Amateurs to resolve them.

THE STANDARD OF EXCELLENCE

The world of CW, RTTY, and new DUAL AMTOR is as close as your fingertips with the new brilliantly innovative state-of-the-art microcomputer controlled EXL-5000E.*

Automatic Sender/Receiver: Due to the most up to date computer technology, just a console and keyboard can accomplish complete automatic send/receive of Morse Code (CW), Baudot Code (RTTY), ASCII Code (RTTY) and new ARQ/FEC (AMTOR).

Code: Morse (CW includes Kana), Baudot (RTTY), ASCII (RTTY), JIS (RTTY), ARQ/FEC (AMTOR).

Characters: Alphabet, Figures, Symbols, Special Characters, Kana.

Built-in Monitor: 5" high resolution, delayed persistence green monitor — provides sharp clear image with no jiggle or jitter even under fluorescent lighting. Also has a provision for composite video signal output.

Time Clock: Displays Month, Date, Hour and Minute on the screen.

Time/Transmission/Receiving Feature: The built-in timer enables completely automatic TX/RX without operator's attendance.

Selcal (Selective Calling) System: With this feature, the unit only receives messages following a preset code. Built-in Demodulator for High Performance: Newly designed high speed RTTY demodulator has receiving capability of as fast as 300 Baud. Three-step shifts select either 170Hz, 425Hz or 850Hz shift with manual fine tune control of space channel for odd shifts. HIGH (Mark Frequency 2125Hz)/LOW (Mark Frequency 1275Hz) tone pair select. Mark only or Space only copy capability for selective fading. ARQ/FEC features incorporated.

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.

Color: Light grey with dark grey trim — matches most current transceivers. **Dimensions:** 363(W) x 121(H) x 351(D) mm: Terminal Unit.

Warranty: One Year Limited

Specifications Subject to Change



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*Dual Amtor: Commercial quality, the EXL-5000E incorporates two completely separate modems to fully support the amateur Amtor codes and all of the CCIR recommendations 476-2 for commercial requirements.

Attention Moonbouncers

and Satellite Communications Enthusiasts

Introducing New Ultra High Performance Antennas from KLM Electronics, Inc.

KLM Electronics is fueling the Moonbounce and Oscar 10 revolution with Antenna Equipment that delivers truly Out-of-This-World performance.

For the Moonbouncer, our New 2M-16LBX is designed to be the highest gain 2 meter antenna available on the market today by more than a full db, making the 2M-16LBX an outstanding performer as a single antenna or in Moonbounce (EME) arrays.

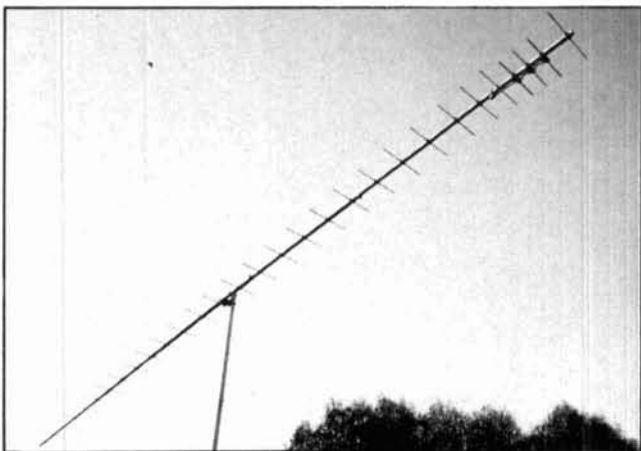
The New 432-30LBX follows the same pattern as the 2M-16LBX, and soon will become the industry's standard of comparison.

Featuring straight forward construction, and an innovative tapered boom that greatly reduces windload and adds strength and durability. Virtually unbreakable, insulated, 3/16" rod parasitic elements are anchored through the boom to insure years of trouble-free performance.

For the satellite enthusiasts, the 2M-22C high gain 2 meter, circular polarized antenna, features the same rugged construction and total flexibility as our very popular 2M-14C with a 2db increase in gain.

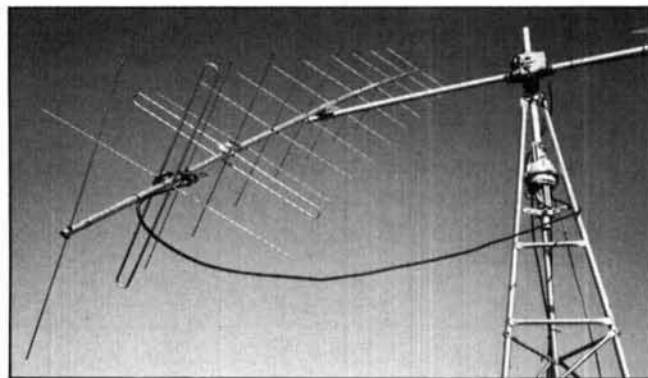
Four or more 2M-22Cs make an excellent array for Moonbounce (EME) by eliminating Faraday fading.

Fiberglass/aluminum stacking frames are available as well as 2 and 4 port power dividers and phasing harnesses to optimize the performance of these type arrays. Watch for our new elevation drive system coming soon.



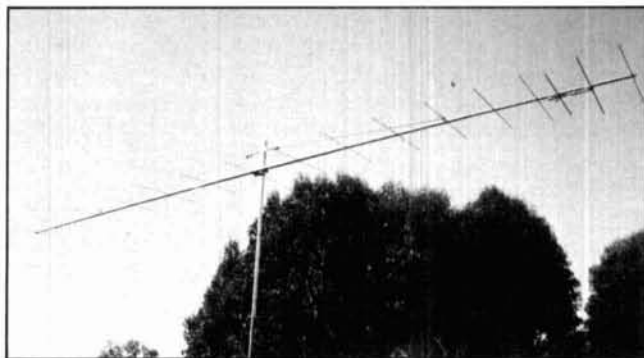
432-30LBX

BANDWIDTH	430-440 MHz
GAIN	17.3 dBd
BEAMWIDTH	20°
FEED IMP	50 ohms unbal.
BALUN	included
BOOM LENGTH	21 ft. 9 in.
F/B	20 dB F/S
VSWR	1.5:1
WINDLOAD	1.43 sq. ft. (typical)
TURNING RADIUS	12 ft. 5 in.
WT. (lbs.)	9 lbs.



2M-22C

BANDWIDTH	144-148 MHz
GAIN	13 dBd
BEAMWIDTH	34°
FEED IMP	50 ohms unbal.
BALUN	(2) 4:1 coax
BOOM LENGTH	19 ft. 1 in. (tapered)
VSWR	1.5:1
WINDLOAD	1.85 sq. ft.
ELLIPTICITY	3 dB max.
CIRCULARITY SWITCHER	CS-3 included
WT. (lbs.)	11 lbs.

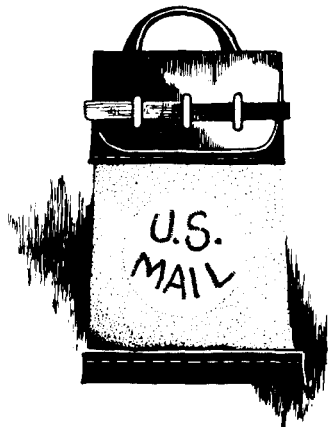


2M-16LBX

BANDWIDTH	143-146 MHz
GAIN	(144 MHz) 14.8 dBdc
BEAMWIDTH	(V) 28°, (H) 33°
FEED IMP	50 ohms unbal.
BALUN	4:1 RG303, Teflon
BOOM LENGTH	28 ft. 1 in. (tapered)
VSWR	1.4:1
WINDLOAD	(H) 1.75 sq. ft. (V) 2.44 sq. ft.
WT. (lbs.)	10 lbs.
TURNING RADIUS	15 ft. 6 in.

✓ 154

KLM electronics, Inc.
P.O. Box 816
Morgan Hill, CA 95037



comments

can you help?

Dear HR:

I need a schematic for the ES 221K frequency counter advertised by ESE in the October, 1974, issue of *ham radio*, page 90. I have a problem with the counter, but no manual or schematic.

A.J. Massa, W5VSR
New Orleans, Louisiana

Dear HR:

I need a schematic and/or manual for a Model 555/N oscilloscope made by the Data Instruments Division of Pennsauken, New Jersey. Upon writing to them I found that they have moved (or closed) without leaving a forwarding address.

I am willing to pay for a photocopy of this data. Please contact me at the address below.

Tom Adams, K9TA
110 N. Few St. Apt. #2
Madison, Wisconsin 53703

aiming for excellence

Dear HR:

Your excellent editorial ("Reflections," February, 1984, page 6) really tells it like it is. I wish every Amateur would read it and take your advice.

In most endeavors people strive for excellence. The shooter, golfer, bowler, artist, craftsman, and so on, aspire to excellence — why shouldn't Amateur Radio operators seek a similar goal?

I made some friendly suggestions recently to a group of several newly licensed Amateurs on how to improve

their operating procedure. You would not believe the reaction to my suggestions. There were such comments as:

"You have no responsibility for the way we choose to operate."

"Ham radio is a hobby for the average citizen and was not intended for engineers — hence the name, *Amateur Radio*."

"You old-timers want to take over and run us newcomers out."

"You give technical talks to the club only to show how smart you are."

These are pretty sick comments, but of course, they come from a very few insecure people. The majority of hams are mighty fine people.

I operated a DX station for three years in China and the Phillipines. When I encountered the operating rudeness to which you refer I had a very effective response. Even though the signal was very loud, I would report it as impossible to copy or even ascertain the call. A call on the QSO frequency was an immediate entry to my blacklist. Let me assure you that some pretty big names in the DX rat-race never got a QSO from me while I was in Canton, Swatow, Amoy, or Foochow.

Keep up the good work.

I.L. McNally, K6WX
Sun City, California

better SSB

Dear HR:

I was pleased to read the article: "Better-Sounding SSB" in the February, 1984, issue of *ham radio*. I for one have always maintained that SSB should sound just as good as the voice at the mike! However, for years "communications quality" has been in vogue. The simple changes mentioned by Mr. Measures are good. Now if some enlightened manufacturer would just lead the way and recognize that many hams would prefer smooth, undistorted audio, I might finally buy a new rig!

Let's have more such articles!

James E. Taylor, W2OZH
Webster, New York

optical receiver cost

Dear HR:

I found Poon and Pieper's "Construct an Optical FM Receiver," (November, 1983, page 53) very interesting. The drawings and equations resemble those found in my engineering log book as of late. This is quite state-of-the-art technology, and experimentation should be encouraged; however, the authors did not mention the cost of their project. To prevent anyone seriously interested in persuing this project from becoming discouraged, I thought I might pass along my costing estimate of the items specified. Depending on the type and power of laser purchased and quality of lenses used, the cost of the project will run between \$858.00 and \$1228.00. (This, by the way, is relatively cheap for a basic acousto-optic receiver.)

Good luck.

David A. Clingerman, W6OAL
Newbury Park, California

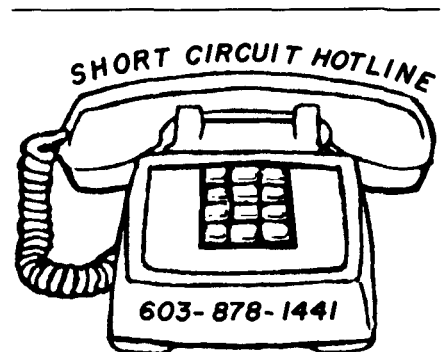
(A call to Edmund Scientific revealed that an Aerotech 1 milliwatt Helium-Neon laser could be purchased for \$330 and a complete set of spherical/cylindrical lenses for under \$50 . . . Ed)

HF operations

Dear HR:

I would like to correspond with anyone involved in HF mobile operation or the design of HF solid-state amplifiers.

Phil Zelter-Jenkins
70, Cross Oak Road, Berkhamsted
Hertfordshire, HP4-3HZ, England



match your antenna to your tower

Here's how to
calculate wind area,
wind load, and
bending moment

Have you heard the story about the ham across town who bought a new \$500 long-boom tribander to replace his older, smaller beam? He rented a "cherry-picker" at \$50 an hour to have it installed on top of the tower he'd originally bought for his 5/8-wave CB antenna in the days before he'd become a ham. The rotator, a small CDE unit he'd bought for \$10 at a flea market, had worked fine with the TH3JR that he'd also purchased soon after getting his ham ticket.

A few months later, a snowstorm driven by 50 MPH winds demolished his entire antenna system, and worse yet, sent the tribander crashing through the roof of his neighbor's house. He wound up in a hassle with his insurance company over the damages, and the neighbor soon began circulating a petition to ban antennas and towers from that city.

You don't think this could happen? Look at the towns of Burbank, Illinois, and Cerritos, California, and see what Amateurs in those communities are fighting. A ruined antenna and tower may not only rob your wallet, but may also rob you and your friends of your operating privileges because of the negative publicity that inevitably follows such an incident.

the match game

When someone says that an antenna is perfectly "matched," most people assume that he or she means that the VSWR is a perfect 1:1. But there's another kind of "match" that's at least as important as VSWR and essential in preventing the kind of mayhem described above. This is the match that occurs when an

antenna is *physically* mated to its mast, rotator, tower, and any other antenna on the tower.

How can you determine whether your antenna is properly "matched"? Well, for starters, check the specifications of the equipment you're now using. Don't wait until something happens; you may have added a small VHF antenna or a 30/40 meter add-on kit without realizing that you've exceeded the wind-loading of your tower or rotator.

Start by referring to your antenna instruction or assembly manual. All legitimate antenna manufacturers include both electrical and mechanical specifications with their products. If you can't find your manual, or if the specifications are not listed, write or call the manufacturer's customer service department for this information.

wind area

Look for the entry titled "Wind Area" or "Effective Surface Area" under "Mechanical Specifications." This number, expressed in square feet or square meters, is a measure of the physical size of the antenna. It represents the maximum surface area against which the wind could theoretically push. The total wind area figure should represent the "worst-case" surface area of the antenna — a combination of both the total boom and total element surface areas.

If two or more antennas are mounted within approximately 2 feet of each other, their wind areas can simply be added together to provide a total Antenna System Wind Area. This wind area should be equivalent to or less than the rated wind area maximums of the rotator and tower.

As an example, consider a tribander with a wind area of 5.7 square feet (0.53 square meter) and a 2-meter vertical with an area of 1.5 square feet (0.14 square meter) mounted 2 feet (0.61 meter) above the tribander. The total Antenna System Wind Area of this system would be 7.2 square feet (0.67 square meter),

By Roger A. Cox, WB0DGF, Telex Communications, Inc./Hy-Gain Division, 8601 Northeast Highway 6, Lincoln, Nebraska 68505

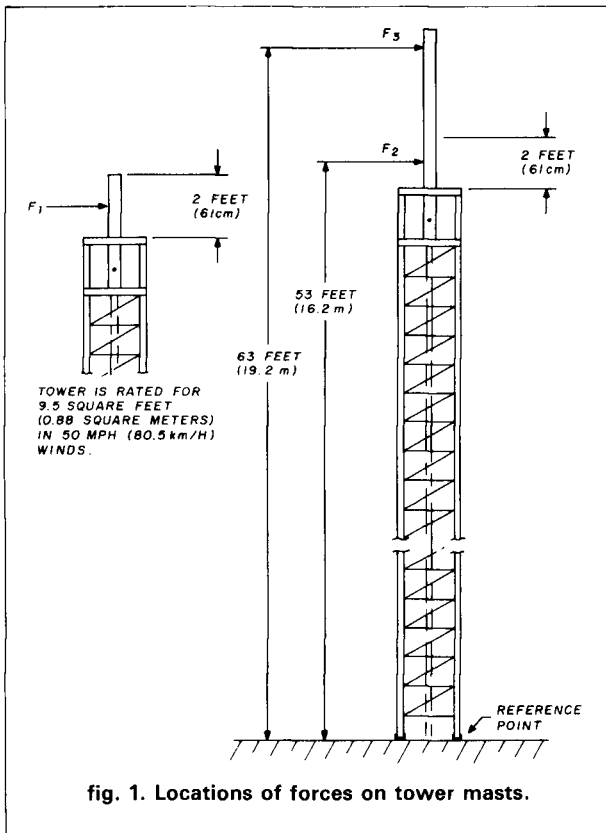


fig. 1. Locations of forces on tower masts.

and would easily match a tower rated at 9 square feet (0.84 square meter) or a rotator rated at 8.5 square feet (0.79 square meter).

Determining wind area becomes more complex when you want to stack two or more HF beams or numerous arrays of VHF Yagis, because under these circumstances the separation required for good electrical performance is almost always greater than 2 feet (0.61 meter).

To analyze complex antenna systems made up of antennas spaced *more* than 2 feet (0.61 meter) apart, you need to know how each antenna contributes to the loading of the entire system.¹ Check your manual under "Mechanical Specifications" once more; you should be able to find the "Wind Load" of the antenna at a specific wind velocity. [Usually a wind velocity of either 80 (129 km/hour) or 100 MPH (161 km/hour) is used.]

wind load

The wind load of an antenna is related to the wind area of the antenna through the equation:

$$F = PA \quad (1)$$

where F is the wind load force in pounds, P is the wind pressure in lb./ft.², and A is the antenna wind area in ft.². P is dependent upon the wind velocity, V , and is usually* found from the equation:

$$P = 0.004 V^2 \quad (2)$$

where V is the wind velocity in MPH. At 80 MPH, $P = 25.6$; at 100 MPH, $P = 40$ lb./ft.².

In fig. 1 a tower with a wind load limit of 9.5 square feet in 50 MPH winds is shown. From eq. 2 we can find the pressure, P , which the wind exerts on the antenna in a 50 MPH wind.

$$P = 0.004 (50)^2 \\ = 10 \text{ lb./ft.}^2$$

In order to find the maximum force which may be exerted on the tower, we use eq. 1.

$$F = PA = 10(9.5) = 95 \text{ lbs.}$$

Therefore the maximum allowable force within the 2-foot limit is 95 pounds.

the bending moment

In order to evaluate the effects of placing more than one antenna on a mast above the tower, we must look at the bending moment, M , with respect to the weakest point in our tower/mast system. The moment, M , is found by

$$M = FD \quad (3)$$

where F is the force and D is the distance to the weakest point. The moments may be added together for the various antennas as long as the same point is used as a reference. In example 1, if we suspected that the tower base was our weakest point, and that our force F_1 , was applied to the mast 53 feet above the point, the moment, M_1 could be expressed as:

$$M_1 = F_1 D = 95(53) = 5035 \text{ ft. lbs.}$$

If we were to replace F_1 with an antenna that exhibited 50 pounds of force, and added another antenna 10 feet above it that exhibited 40 pounds of force, would we exceed the allowable moment of 5035 ft. lbs.? Your first guess may be no, because the forces add up to only 90 pounds and this is less than the 95 pounds we had before. And if you were to compare wind areas, you would find that the 50 pound antenna at 5 square feet and 40 pound antenna at 4 square feet also add up to less than 9.5 square feet, or rated wind area for this tower.

But if you were to add up the moments,

$$M = \Sigma FD \quad (\Sigma = \text{sum of} \dots)$$

$$M_2 = 50 (53) = 2650$$

$$M_3 = 40 (63) = 2520$$

$$M_2 + M_3 = 5170 \text{ ft. lbs.}$$

*The equation $P = 0.004 V^2$ takes wind gusts and turbulence into consideration. For a steady (laminar) flow, the equation $P = 0.00256 V^2$ should be used. Consult the Uniform Building Code (UBC) for a more thorough explanation.

you would find that they easily exceed the moment limit of 5035 ft. lbs.

The base of the tower may not always be the weakest point of your tower/mast system. Other susceptible points are the point of attachment of the top set of guy wires, a house bracket, a junction in a telescoping tower or mast, or even the point of attachment of the mast to the tower. If you've used short inserts to reinforce the mast, the end of any insert within the mast may be a point of vulnerability as well. Your best bet is to follow the tower and mast manufacturer's recommendations whenever you stack large antennas.

rotator wind area

As in determining the wind area of your antenna, you should begin analysis of your rotator's wind area by reading your instruction manual. If the specifications are not listed, or if you cannot find your manual, write or call the manufacturer's Customer Service Department for this information.

Look in the specifications section for the entry titled "Maximum Wind Area." There will be two different entries — one for mast mounting and one for inside tower installations. For mast mounting, there will also be a maximum distance of the antenna above the rotator provided; this is usually 2 feet (0.61 meter).

Just as in the previous example, if all of your antennas are mounted within this range (2 feet/0.61 meter) you may add the antenna wind areas together and compare that total to the rotator's rating.

loading

If you're using a small tower or mast, with the rotator installed on top, be extra careful to observe the rotator's mechanical limitations on side thrust. Use the procedures shown in the wind load section of this article with the rotator's rated wind area and wind speed to determine the maximum force that can be applied within 2 feet (0.61 meter) of the top of the rotator. If no wind speed is given, use a conservative figure such as 50 MPH.

As an example, consider the Hy-Gain CD4511. When mast-mounted, its rated wind area is 5.0 square feet (0.46 square meter). I will use 50 MPH as the wind speed. Using eqs. 1 and 2:

$$F = 0.004 V^2 A = 0.004 (50)^2(5) = 50 \text{ lbs.}$$

In this case, using a distance of 2 feet (0.61 meter) above the rotator, the moment is 100 ft. lbs. You can use the same procedures shown in the bending moment section to evaluate the effects of placing more than one antenna on a mast above a rotator.

Although stacking antennas above a rotator installed on top of a mast or tower is not recommended, it can be done if the maximum moment limitations are adhered to. The weakest point in this case is assumed to be the center of the rotator.

Although slightly exceeding the maximum ratings of a rotator may not break or permanently damage it, doing so will more than likely impair its operation in some way, especially during windy conditions. Continued use in this manner is sure to shorten the useful life of your rotator.

If you install a rotator inside a tower, a different set of mechanical limitations applies. The side thrust is now less important, but the stall and braking torque of the rotator is more important. This is why a different wind area rating is listed for rotators installed within a tower.

The rotator's wind area rating within a tower is usually related more to the braking power rather than to the stall torque of the rotator. The braking power is the maximum allowable torque that the antenna load may present to the rotator without causing it to rotate. This torque is usually not a steady torque, but rather a pulsing, almost sinusoidal torque produced by the antenna rocking back and forth in a violent wind storm.

moment of inertia

The amount of torque produced by this rocking action is directly related to the moment of inertia of the antenna. The moment of inertia is similar to the bending moment as discussed earlier, because it is related to force and its distance from a reference axis. However, complex structures such as antennas must be analyzed as the summation of all the moments produced by the various portions of the antenna. Also, since each moment is directly related to the mass of each antenna portion and the square of its distance to the axis, an antenna with a very long boom with heavy elements will have *more* total moment of inertia than an antenna with a short boom with very light elements, even though they may have the same total wind area! This has produced some difficulty in assigning wind area ratings for rotators. Luckily most commercially available Amateur antennas have short enough booms so that their wind areas and moments of inertia are closely related. However, on long-boom homebrew, commercial, or military-type antennas, one has to be extremely cautious when selecting a rotator when given only a wind area rating.

Although the wind area rating of a rotator is not wholly determined by the rotator stall torque, a higher stall torque is required for turning larger antennas. On a calm day, the act of rotating the antenna produces wind against each element and boom. This wind is a force that opposes the direction of rotation. If, at full speed, this force produces the amount of torque required to stall the rotator, the rotator will slow down until the wind force is less than that which produces a stall. Therefore, a rotator with a small stall torque will sometimes turn more slowly than one with a higher

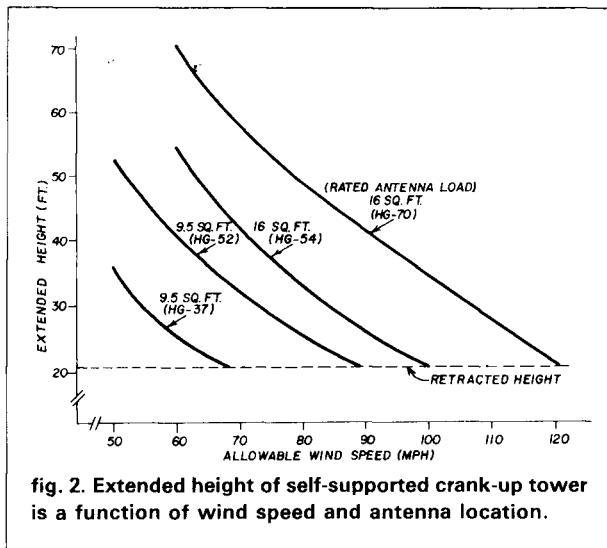


fig. 2. Extended height of self-supported crank-up tower is a function of wind speed and antenna location.

stall torque. On a windy day, the rotator with less stall torque may not be able to overcome the forces produced by the wind.

towers

Every tower ever commercially manufactured has some kind of instruction manual or specification guide, no matter whether it is a crank-up, guyed, or self-supporting tower built of steel or aluminum tubular or right-angle stock.

The manuals accompanying crank-up towers, with which I am most familiar, list a "wind load limit." This is the maximum wind area in square feet (or square meters) that the tower will *safely* hold at its maximum height at a particular wind velocity. The industry standard is to rate these towers at either 50 MPH (80.5 km/hour) or 60 MPH (96.6 km/hour).

Because of the specific nature of crank-up towers, the owner can crank the tower up and down for antenna installation and servicing and also crank the tower down whenever high winds are expected. With the tower completely retracted, the bending moment at the base of the tower caused by the antenna load is significantly reduced.

If you're willing to crank the tower down every time strong winds are expected, it's possible to expect your antenna system to survive near-hurricane conditions even with the maximum allowable antenna wind area. Fig. 2 shows the wind velocities under which you can expect a Hy-Gain crank-up tower to survive given the maximum rated antenna loads at the extended heights shown in the graph.

For example, if you have a 9.5 square foot (0.8 square meter) antenna load on your Hy-Gain HG-52SS tower, which is cranked down to 21 feet (6.4 meters), you can expect your system to survive a wind velocity of 90 MPH (145 km/hour). (This assumes, of course, that the tower was properly installed, and that

all the manufacturer's recommendations were followed.)

You can also expect your fully extended tower to survive higher wind velocities than specified if the antenna wind area is less than the maximum rating for the particular size tower. Fig. 3 shows how the maximum antenna wind area for a given tower varies with the allowable wind velocity. For example, the HG-70HD, which is rated at 16 square feet (1.5 square meters) in 60 MPH (96.6 km/hour) winds, can safely handle only 10 square feet (0.9 square meter) in 70 MPH (113 km/hour) winds.

As you can also see from fig. 3, larger antenna loads may be possible if lower wind velocity figures are used. Unless your tower is sheltered from the wind, it would be dangerous to assume that the wind would always stay under 30 MPH (48 km/hour). These figures should be used only as a demonstration of what may be possible in your installation. Other factors such as the type of soil, ice loading, and wind-driven sand (sandstorms) may affect your particular installation. Again, your best bet is to follow the manufacturer's recommendations on anything questionable.

The manufacturers of guyed towers (such as the Rohn Model 25G and Model 45G) usually recommend specific guying configurations depending on the height of the tower and the specific area of the country in which installation is planned.³ The maximum wind area is specified as "allowable load" for each type of tower.

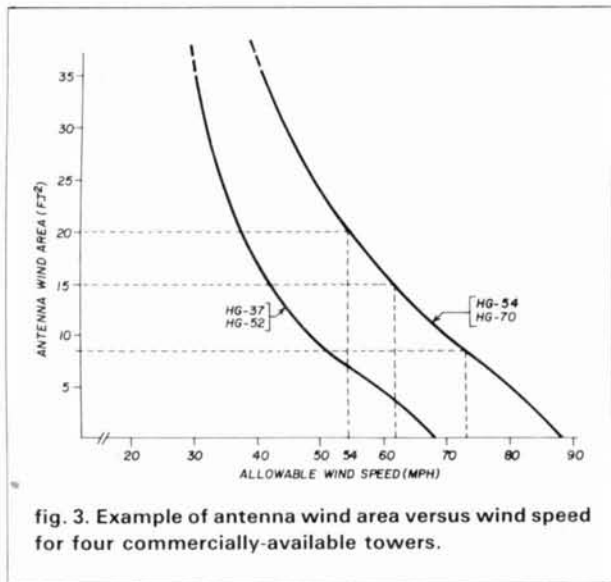
The Electronic Industries Association has divided the continental U.S. into 3 wind load zones (see fig. 4).⁴

Zone A encompasses most of the United States. Short towers constructed within this zone should be capable of withstanding loading of 30 pounds per square foot (147 kilograms per square meter). This corresponds to approximately 87 MPH (140 km/hour) winds.

Zone B encompasses northwest Washington, north-central California, part of the northern Great Plains and northern Rockies, the area surrounding Madison, Wisconsin, and most of the Gulf Coast and eastern seaboard. Short towers within this zone should be capable of withstanding loading of 40 pounds per square foot (196 kilograms per square meter). This corresponds to approximately 100 MPH (161 km/hour) winds.

Zone C encompasses two areas, the southeast tip of Florida and most of the eastern coast of North Carolina. Short towers within this zone should be capable of withstanding loading of 50 pounds per square foot (245 kilograms per square meter). This corresponds to approximately 112 MPH (180 km/hour) winds.

Fig. 5 shows typical guying configurations for the Rohn Model 25G guyed tower installed in Zone A at various heights. This configuration is for an "allowable load" of 6 square feet (0.56 square meter).



Self-supporting towers are similar to crank-up towers in their specifications. They usually specify a maximum wind area or wind load limit at a particular wind velocity. If a particular manufacturer does not list a wind velocity with the load rating, you should ask for this figure from its customer service department. If the wind velocity rating given is less than 50 MPH (80.5 kmph), you may wish to add guys to your tower if you are at or near the rated load. If the wind velocity given is greater than 80 MPH (129 kmph), the rated loading should be safe unless you live in Zones B or C, as previously mentioned. If you do live in one of these zones, be sure to choose a tower with a rated wind velocity figure greater than 100 MPH (161 kmph), or be prepared to add guys.

masts

While the mast doesn't receive as much attention as the tower or rotator in the ratings game, it can be of vital importance in maintaining the integrity of your antenna system.

Only a few manufacturers supply masts for antenna systems. Normally it's easier and cheaper for an individual to purchase a length of steel tubing at the local lumber yard or electrical supply store than it is to purchase it by mail order. For the average antenna installation, this is quite adequate. A length of 2-inch (51 mm) O.D. schedule 40 or schedule 80 pipe is suitable for a tribander and a small VHF antenna. However, if you plan to stack HF antennas in Christmas-tree fashion to assemble an array of VHF antennas for EME, you may wish to analyze your system and consider other possibilities.

Following the previous examples given, find the wind area for each antenna, boom, and mast in your system. Use these wind areas and an appropriate wind velocity to determine the loading from each. Multiply these loads by the distance to the nearest supporting boom, mast, or tower to find the bending moments of these points. To analyze the flexural strength at these points, you'll need to have information about the structural member at each point.

You will also need the initial moment of inertia, I , of the cross section about the neutral axis. This can be obtained from:

$$I = \frac{\pi(d_1^4 - d_2^4)}{64} \text{ in.}^4 \quad (4)$$

(for a circular cross section)

where d_1 is the members O.D. in inches, and d_2 is the members I.D. in inches.

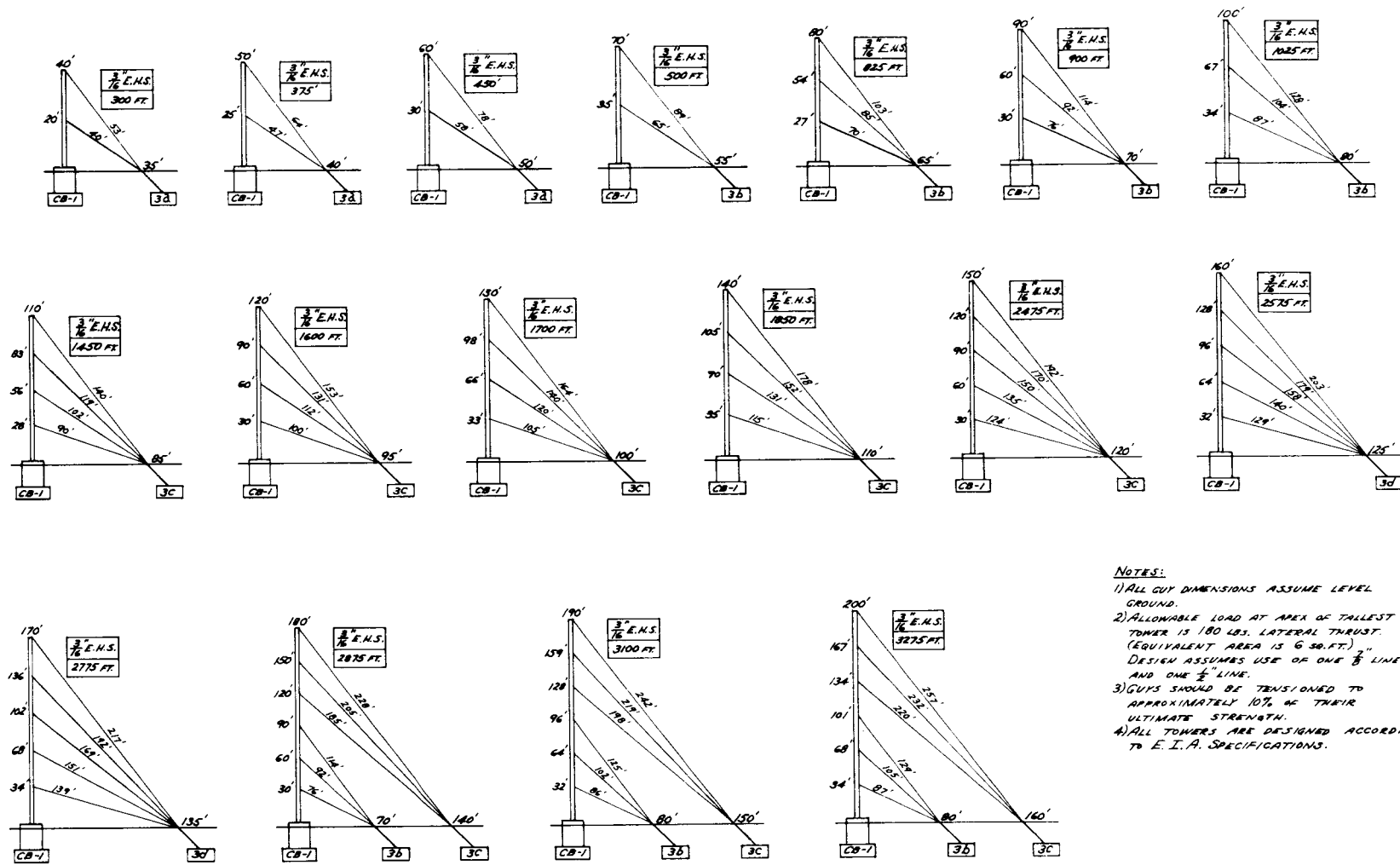
U.S. WIND LOADING ZONES

Recommended wind loading zones values of wind loading in pounds per square foot for tower designs as recommended by Electronic Industries Association (RS222C).

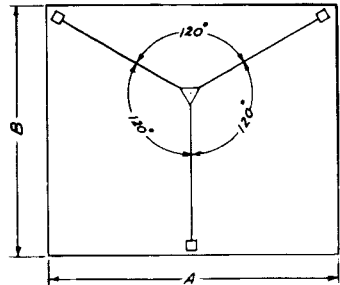
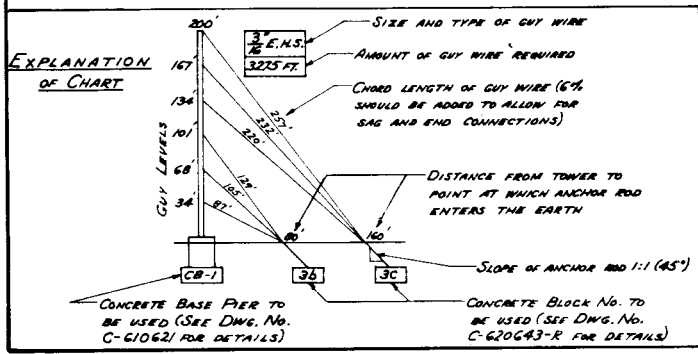
WIND LOADS FOR VARIOUS AREAS IN U. S.			
Tower Height	ZONE		
	A	B	C
Under 300 Ft.	30 Lbs./Sq. Ft.	40 Lbs./Sq. Ft.	50 Lbs./Sq. Ft.
301 Ft. to 650 Ft.	35 Lbs./Sq. Ft.	48 Lbs./Sq. Ft.	60 Lbs./Sq. Ft.
Over 650 Ft.	50 Lbs./Sq. Ft.	65 Lbs./Sq. Ft.	85 Lbs./Sq. Ft.
MAP CODE			



Fig. 4. Chart details recommended wind loading on towers of various heights, per E.I.A. RS222C.



- NOTES:**
- 1) ALL GUY DIMENSIONS ASSUME LEVEL GROUND.
 - 2) ALLOWABLE LOAD AT APEX OF TALLEST TOWER IS 180 LBS. LATERAL THRUST. (EQUIVALENT AREA IS 6 SQ. FT.) DESIGN ASSUMES USE OF ONE $\frac{3}{8}$ " LINE AND ONE $\frac{1}{2}$ " LINE.
 - 3) GUYS SHOULD BE TENSIONED TO APPROXIMATELY 10% OF THEIR ULTIMATE STRENGTH.
 - 4) ALL TOWERS ARE DESIGNED ACCORDING TO E. I. A. SPECIFICATIONS.



FOR SPACE REQUIREMENT REFER TO DWG. NO. C-640531

fig. 5. Guying details for various heights of Rohn 25 tower. (Reprinted with permission from Rohn Manufacturing, Peoria, Illinois.)

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You will also need the initial distance from the neutral axis to the extreme fiber where failure occurs, c .

$$c = \frac{d_1}{2} \text{ inches} \quad (5)$$

The flexural strength can then be obtained by

$$f = \frac{12 M c}{I} \text{ lbs./in.}^2 \text{ (psi)} \quad (6)$$

The constant 12 is necessary for the feet-to-inch conversion if the moment is expressed in foot pounds.

When the flexural strength exceeds the yield strength given for the particular member, the member will deform or break. The yield strength for tubular steel is typically 50,000 - 100,000 pounds per square inch. You will need to check with your local supplier to obtain this information.

Your masts and supporting booms should be strong enough to support your antenna system and be able to withstand the environmental conditions in your area. For example, if you live near salt water or in a highly industrialized area, you should be especially vigilant about preventing and correcting corrosion.

Normally antenna and tower manufacturers are aware of these concerns and take steps to protect their product. Antennas are made from a corrosion-resistant alloy of aluminum, usually 6063-T6 or 6061-T6. Towers are normally hot-dip galvanized steel.

Masts purchased locally may not have any protection at all. If the mast has a very thick wall, this may not be a problem, but thin-walled steel or aluminum may be susceptible to corrosion if not protected.

summary

It may be unwise to follow the old saying, "If it doesn't come down, it isn't big enough." It's to your advantage to ensure the integrity of your antenna/tower system by matching the components so that your antenna system stays where it's supposed to stay. Know the limitations of your system's components and how each component interacts with the other and with the environment. It's up to the manufacturer to supply you with sufficient information to enable you to analyze your system, so that you can enjoy your hobby and not have to worry about your installation or your neighbor's roof.

references

1. Eugene Fuller, W2FZJ, "The Application of Stress Analysis to Antenna Systems," *ham radio*, October, 1971, page 23.
2. Telex/Hy-Gain Amateur Radio Catalog, 1983 edition, Telex Communications, Inc., 9600 Aldrich Avenue, South, Minneapolis, Minnesota 55426.
3. Unarco/Rohn Tower Catalog, 1976 edition, Rohn, P.O. Box 2000, Peoria, Illinois 61656.
4. EIA Standard: Structural Standards for Steel Antenna Towers and Antenna Supporting Structures, RS-222-C, Engineering Department, Electronic Industries Association, Washington, D.C., March, 1976.

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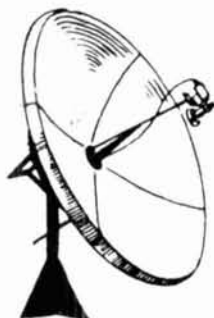
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TOWER INSTALLATION:

make it sturdy, make it safe

For beginner to expert —
useful information for
safe tower installation

It's no joke to wake up some morning after a bad storm, walk outside, and see all or part of your tower lying haphazardly on the ground. Even less amusing is the sight of your antenna lying in the yard next door. People can be hurt — even lose their lives — because a tower wasn't big enough for its job, or wasn't erected properly . . . or both. Careful consideration of several factors can help prevent disaster and enhance your peace of mind. These factors are the tower type and size, versus the load on top; the adequacy of the tower base; a proper guying system; safe guy anchors; and proper tower maintenance.

choosing the right tower

Your first and main concern is wind. It can do unbelievable things to a tower, and it's of prime importance that you have the greatest respect for that fact. A basic rule of thumb is that if there's the slightest doubt, make your tower *stronger* than the situation seems to merit. A little extra money spent on your tower may be the cheapest insurance you'll ever buy.

The force the wind exerts against your tower depends on the number of square feet of surface area presented to the wind by the tower and the antennas, masts, and rotors on top. The tower manufacturer provides a specification indicating the maximum load, in square feet of antennas and related equipment, that the tower can bear. This specification means, of course, that you don't have to add the square footage of the tower to the antenna load. In other words, it means that the tower is strong enough to handle the specified load as well as whatever square footage is presented by the tower itself.

In turn, the antenna manufacturer gives you the square footage presented to the wind by its antenna. What it all adds up to is that if the tower manufactur-

er says its tower will handle a 16-square foot load and the antenna specification is 12 square feet, you're on safe ground, even after adding the mast and rotator. If, however, antenna, mast, and rotator come to just 16 square feet, that might be a little too close for comfort.

Another important consideration when choosing the correct tower for maximum safety is where you live. The Electronic Industries Association has done quite a bit of research, assembling meteorological data, county by county, throughout the United States, specifying the maximum wind likely to be encountered in any given location.

The United States (as well as most other areas on earth) is divided into three zones: Zone A, with winds up to 87 MPH (140 km/hr); Zone B, with winds up to 100 MPH (161 km/hr); and Zone C, with winds up to 112 MPH (180 km/hr). If the tower has been manufactured to meet standards established by the Electronic Industries Association, the manufacturer will specify, along with the square footage of the antenna's wind load, in which zone that square footage will apply. Of course, this specification assumes that the tower owner has followed the tower manufacturer's rules for installation and has installed an appropriate base and guy system.

It's a good idea to question the supplier and/or manufacturer before making your final selection. If you choose the correct tower and install it according to the manufacturer's recommended procedure, any reputable manufacturer should stand behind its product. If you want to learn about tower selection, installation, and maintenance, contact either a dealer or a tower manufacturer and obtain a copy of a complete catalog. Rohn, for example, provides a catalog (for a modest charge) that contains a wealth of valuable information applicable not only to Rohn towers but to towers in general.*

the tower base

It's important to determine whether the base will be used for a guyed tower or a self-supporting tower — and there's a big difference. In the case of the guyed tower, the force of the wind against the tower is translated by the guys from a lateral force into a

By John M. Haerle, WB5IIR, Route 2, Box 348, Frisco, Texas 75034

downward compression. This places that force plus the dead weight of the tower *on the base*, with the initial tension of the guys also included in the total "weight" to be supported by the base.

The self-supporting tower poses a totally different problem, as far as the base requirement is concerned. Without guys to offer added support, the concrete base on which the tower stands must be much larger, just to keep the wind from uprooting the tower as it might uproot a tree and its entire root structure.

In the absence of guys, the wind force against the tower exerts downward pressure *on the legs* of the tower opposite the side from which the wind is blowing. Equally important is a strong upward lifting force on the legs nearest the source of the wind. *This means that the manner in which the tower is anchored into the base is very important.* A frequent cause of tower failure comes from trying to use a tower designed as a guyed tower as a self-supporting tower. Somehow, the reasoning seems to be that since Rohn 45G sections, for example, are quite strong, it should be OK to put up 40 or 50 feet without guys and mount a tri-band beam up there. But the base arrangement was simply not designed to bear this kind of load. Oh, I know, somebody out there is saying, "What's he talking about? That's exactly what I'm doing." My answer is, "I hope you're supporting only a 2-meter antenna, that you live in Zone A, and that the fates are kind!" I've seen people get away with — for a while — tower setups that would give a good mechanical engineer nightmares. Always review your tower plan with an experienced tower builder or mechanical engineer. It probably won't cost much — if anything at all, and may save a lot.

Follow the manufacturer's recommendations for your base. Use steel reinforcement bars ("rebar") to strengthen the base. Keeping the steel bars sealed inside the concrete will minimize rust problems. *It is extremely important to keep all ground rods outside and at least 4 inches from the base, bonding these rods directly to the steel tower itself.* If a ground rod goes through the concrete base, lightning can split the base in its search for a path to ground.

guy systems

Most guy systems consist of three guys at each of several levels, equally spaced around the tower and equal in length, with sets of guys spaced up the tower at intervals no greater than 30 feet (even closer if the tower is heavily loaded). For a three-guy system, the guys should ideally be anchored at a distance equal to 80 percent of the tower height. For a light load, such as a small tribander, this distance can be reduced, to say, 65 percent of the tower height. Where you cannot extend the guys this far, or where there is less available space on one side of the tower, you can

reduce the distance from the tower to the anchor to as little as 40 percent of the tower height by using four guys at each level. However, as with three guys, their lengths and the spacing between them must be perfectly symmetrical.

Incorrect choice of guy wire is a frequent contributor to tower failure. Somehow the rumor has gotten around that aircraft control cable is suitable for use as guy wire. While it will rust, is harder to work with, and is about 25 percent weaker than real guy wire, you can get by with it . . . but do you really want to? The correct guy wire for most ham towers is 3/16 inch seven-strand EHS (extra high strength) wire. I recommend that you use nothing smaller than this. It will even handle some towers over 100 feet tall, depending on zone, and wind load. Follow the tower manufacturer's recommendation and you will find yourself using either 3/16 inch or for the really big ones, 1/4 inch EHS wire.

It's important, too, that these guys be tensioned properly. A good rule of thumb is to tension the wire to about 10 percent of its breaking strength. It should go without saying that the tension should be equal on all guys at a given level. The reason for using pre-stretched steel wire at the proper tension is that the tower must be prevented from twisting when the beam is buffeted by high winds. More towers are destroyed by twisting torque forces than in any other way; they just twist in the wind and collapse. For this reason, when you're using long-boom antennas or stacked monobanders, it's advisable to use special "guy assemblies" on the tower, providing stiff steel arms to improve the leverage the guys can exert in preventing the twist.

Be sure to use top-quality galvanized hardware for your guys. This is no place to save money, and the difference between the cheap kind and the rustproof kind is simply not worth the gamble. Use three clamps at each junction, and put the "U" of each clamp over the short, or so-called "dead-end" side of the cable. Use "thimbles" (those horseshoe-shaped pieces) which prevent the cable from kinking when it goes through the eye of a turnbuckle or a hole in a steel plate. Be sure to use the correct turnbuckle for the size of the guy you're using. Don't scrimp on turnbuckles; be sure they're rustproof and that the eyes are forged, not cast. Finally, when you've tightened up the turnbuckles, run a piece of guy wire through the body and both eyes of the turnbuckle in a "figure-eight" configuration to prevent the turnbuckle from working loose. If more than one guy terminates at such a point, use only one figure-eight wire, passing it through all the eyes and turnbuckle bodies.

Connecting the other ends of these guys to the tower is generally accomplished in either of two ways. When using the guy assemblies previously discussed, the guys are looped through the holes in the ends of

*UNR Rohn, Inc., Box 2000, Peoria, Illinois 61656.

the torque arms, using thimbles to prevent kinking; if there are no guy assemblies and the tower members are tubular (such as Rohn), take a single turn around the vertical member, where the cross-members intersect the vertical part. Be sure the loop also goes around the bends in the cross-members, encompassing both bends and the vertical part, compressing them instead of pulling them apart. After making the single turn around the tower in this fashion, fasten with three clamps as usual.

the anchors

Conventional anchoring for most Amateur towers employs the screw-type anchor. This is a 4-foot by 5/8-inch steel rod with a forged eye at one end and a 6-inch diameter auger on the other end. This is simply screwed into the ground at the same angle taken by the guy wire that will be attached to it. This makes a surprisingly strong anchor for some pretty sizable towers. For example, the 68-foot Rohn 45G fold-over tower uses this one. In any case, consult the manufacturer's recommendation. The other anchor normally used when the screw-type is not strong enough is the concrete anchor. This is a 5-foot by 5/8-inch steel rod, with a forged eye on one end and a crook on the other end, encased in concrete. When two or more guys terminate at the same anchor, equalizing plates are often used to divide the tension equally between the guys. Through-the-wall anchors and other types are available for those cases where restricted space does not provide room for conventional ground anchors. Again, the big Rohn catalog describes every conceivable kind of special hardware and includes detailed instructions on how to use such items.

tower maintenance

Most of this is just common sense and we really know pretty much what to do. But time flies and we never seem to get around to maintenance as often as we should. We should check our guys for equal and proper tension. When checking for equal tension, we should use a long carpenter's level, placing it against the vertical part of the tower to be sure that it is truly vertical, or "plumb." A perfectly vertical tower is not affected by the unusual stresses invariably present when a tower is off "plumb." All bolts and nuts should be checked for tightness and replaced if they are rusty. Anything that shows rust but cannot be replaced (such as the tower itself), should be treated. This can be done most effectively with a cold-galvanize spray, which will form a chemical bond with the good galvanizing around the rust spot and prevent further rust formation, making the spot virtually as good as new. There are several brands of this material; the one I have used with good success is made by LPS.*

*LPS® Cold Galvanize, Holt/Lloyd LPS, 4647 Hugh Howell Road, Tucker, Georgia 30084.

conclusion

Be very careful about hinging towers at the base and "walking" them up. This may appear to be the easiest way to erect 40 or 50 feet of tower, but more often than not, it is the most difficult and most dangerous. If you have plenty of people present — at least one of whom understands mechanical stresses — proceed carefully. If not, you may find it easier for just two people to put that tower up, one on the tower with a safety-belt and a "gin-pole," and the other on the ground to handle the pulley rope and pick up the tools the other drops.

In regard to the mast you put in the top of the tower to support your beam, be aware that if the height of the mast above the tower is, say, 10 feet, and the wind is blowing only 60 miles an hour against 8 square feet of antenna, there are some horrendous forces trying to convert that mast to rubble. *You'll be safest with a good steel mast.* A good aluminum-alloy mast may be lighter and just as strong right up to the instant that it crystalizes — something that doesn't happen to a tough steel mast.

High-quality close-woven nylon can do a good job when used for the right job — for instance, for supporting masts or the ends of dipoles. But for towers, it's a different story: twisting destroys towers so, very simply, nylon guys will stretch enough to let them twist; steel guys won't. Incidentally, when guying masts, use only close-woven nylon. The older it gets, the tougher it gets, but the hot sun will eventually disintegrate Dacron and other synthetics.

One more comment on anchors and bases: all that I've said so far has been predicated on the assumption that you'll be constructing your tower over normal soil. When the soil is swampy or sandy, consult an experienced tower builder or a civil engineer.

A couple of notes on climbing: *Spend the money for a good quality, approved safety belt.* It's cheap insurance. (A friend and former colleague lost his life using a home-made safety belt.) When climbing a tower, you come to the moment of truth every time you have to unhook the belt to move up around a set of guys. It may be a little more trouble but it's a good idea to equip your belt with *two* lanyards. You can then leave one fastened around the tower below the guys until you've fastened the other one above the guys . . . after which you can unfasten the lower one and move up with complete safety. If you're squeamish about climbing towers, this system will provide both safety and reassurance.

An excellent source of information on this subject is "Structural Standards for Steel Antenna Towers and Antenna Supporting Structures," *EIA Standard RS-222-C*, March, 1976, available from EIA, 2001 Eye Street, N.W., Washington, D. C. 20006, at \$7.40.

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TOWER MAINTENANCE:

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Those of us fortunate enough to have towers with moderate to complex antenna systems sometimes take them for granted. Even though we've invested substantial amounts of time and money in planning and erecting our systems, once they're up we tend to head for the ham shack and forget that they're there. Only the rotator control and the S-meter remind us that there's something out there, after all.

That's why I've designated a specific time of year — well before winter sets in — for a thorough annual inspection of every inch of metal in my system.

Good planning keeps the number of trips up the tower to a minimum, and the work pleasurable.

Choose a comfortable time of year; windy, hot or cold days will only discourage you from staying on the tower any length of time. I usually do my inspection in the fall, when temperatures are moderate and it's a joy to be up there. There's a built-in benefit for your system, too, in choosing fall as the time for your annual inspection. After a summer of heat and ultraviolet stress — and battering by the winds of thunderstorms and perhaps even hurricanes, the stiffening temperatures of winter can bring tape and cables to their natural end. Those who live in areas where seasonal changes are less severe may opt for a different time.

inspect the antenna

Gather the appropriate tools (pliers, wrenches, tape, sealant, etc.) and an approved (not home-made) safety belt. Climb up once, check and correct any deficiencies on the way down, and celebrate your good planning.

Most of your time will be spent right at the top, where you'll first make a visual inspection of the antennas. Although most of the hardware will be beyond your reach, a look at the general condition will reveal a great deal. Loose or missing hardware is a sure sign of trouble. Sometimes scratches and the general pattern of weathering will indicate any elements turned from original position. After your visual inspection is complete, *shake* the whole assembly; you'll hear or see anything that's come loose.

The first part of the beams to deteriorate is often the support cable for the boom. Check that thoroughly, because without it the wind tolerance of your beam may be far less than you think. All broken or missing parts should be replaced, even if that calls for a major antenna party. Electrical connections should also be checked thoroughly, since an increase in the resistance at the feedpoint can mean needless loss of power. I routinely spray all connections with clear acrylic sealer. Available in the spray paint section of most hardware stores, this product will prevent corrosion on the connections. A saturating coat sprayed over all connections once every two or three years is easy to apply and seals all cracks, yet allows disassembly when necessary.

don't forget the feedline

While at the top of the tower, remember to check the attachment of the feedline to the antenna and mast. This provides strain relief for the antenna connection. Tight taping is normally used here, but even the stresses of normal turning can loosen these support points. Although most of us use electrical tape for this, fiberglass reinforced strapping tape will serve

By Steve Makulec, KB9IW, 8041 Hilltop Court East, Winnebago, Illinois 61088

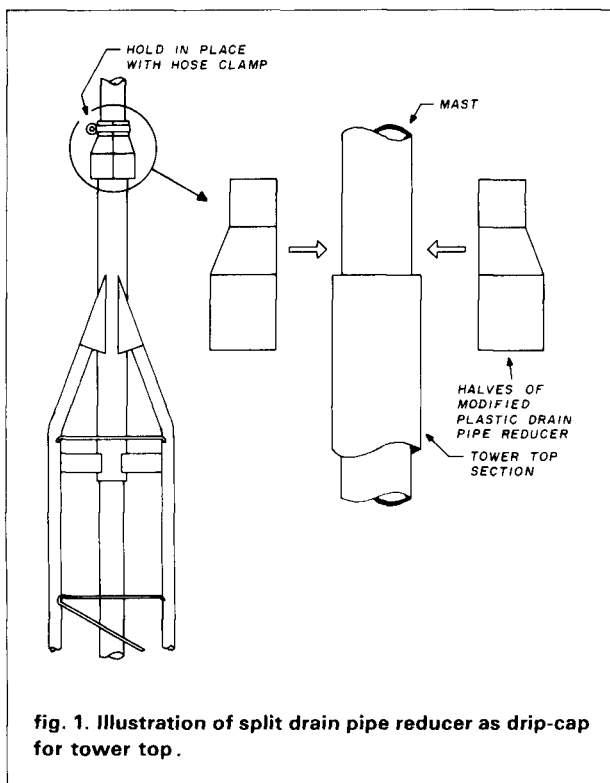


fig. 1. Illustration of split drain pipe reducer as drip-cap for tower top.

well at high-stress points such as this. If loose, retaping is in order; pay particular attention to the loop of feedline necessary to allow rotation of the antenna. Multiple feedlines can be taped together to support each other, but a larger loop should be allowed to accommodate the additional stiffness. (If you put the antenna at the center of its rotation *before* climbing the tower, it will be easier to visualize where this rotation loop must be located, and any necessary repair will thus be easier to spot and simpler to do.)

grease fittings: good idea

A step down the tower's top section will allow inspection of the mast bearing. Check and replenish the lubrication of this bearing if necessary. Most of us use a top section that has no true bearing, utilizing a top pipe section to guide the mast instead; these sections are particularly difficult to lubricate, since the pipe length may be as long as 30 inches. The mast in most installations like this fits loosely, with approximately 0.1 inch (2.5 mm) diametrical clearance. Using a hand grease gun to inject grease through the various holes already in the tower pipe makes this chore easier, and a homemade rubber washer will serve as a seal when pressed over the hole with the grease gun while lubricating.

To simplify lubrication of the entire length of the pipe, I installed automotive grease fittings in a few places along the tower pipe. If you do this, take care to choose fittings that are flat on their bottoms, and install them so they don't protrude into the inside of the tower pipe, because this would cause a wear point

on the mast. One alternative is to leave the fittings in only during the lubrication process and then cover the holes with tape. I admit that while installation of the fittings is a cinch on a new tower still on the ground, it could be quite a challenge on an existing tower.

Water and dirt must be kept out of the bearing area. If they're not, your antenna may freeze in place during the winter. You can easily install a drip cap to prevent this, using readily available hardware.

My mast pipe, like most, is a standard pipe size. For the typical installation, 1.5 inch (38.1 mm) pipe which is 1.9 inch (48.3 mm) OD fits through a 2 inch (50.8 mm) ID tower tube, which is in turn about 2.25 inches (57.2 mm) OD. Since the mast pipe is a standard pipe size, a 1.5 inch (38.1 mm) to 2 inch (50.8 mm) reducer for plastic drainpipe makes an excellent drip cap (see fig. 1). Just cut it in half with a hacksaw, file out the internal chamfered stop, and fit the two halves snugly over the mast pipe. Use an automotive hose clamp to hold it in place over the top of the tower pipe; water and dirt will be excluded, and the mast will rotate freely for a longer length of time than it might without protection (see fig. 1). For other standard mast pipe sizes, different size reducers are required; there should be no problem as long as the water pipe used for the mast and the plastic drain pipe follow the same size conventions.

on the way down

On your way down, check all cables for proper support, replacing tape as necessary. Look for any rust; it's a sure sign that galvanizing in that spot on the tower has been scraped off. Remove the rust with a light sanding and seal with acrylic sealer or aluminum paint.

Check bolts and nuts for tightness, both at the tower section joints and on any other hardware. Guy wire attachment points are particularly important. Treat all bolts to prevent their nuts from rotating off should loosening occur; this can be done by striking a center punch against the bolt thread protruding beyond the nut. By slightly upsetting the thread, you'll prevent the nut from vibrating off, but don't be so aggressive that you destroy both the thread and your chances of disassembly later on.

on the ground

Back on ground level, check the cable entry into the house to make sure it is still properly sealed. Check the connections to the tower ground system, too, both for tightness and for any signs of corrosion that would cause poor contact. If the grounding wires have become kinked for any reason, straighten them as needed for optimum protection against lightning.

Now take a walk around the yard. Are all guy wires and turnbuckles secure, all nuts and bolts tight? Here in particular, upsetting the threads of the bolts as described above is appropriate, since they generally can't

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be tightened completely and still allow equalizer plate motion. Note the condition and tension of the guy wires: any signs of rust or wear in the wire calls for immediate replacement. In checking tension, remember that it will change from season to season with rising and falling temperatures, which is why I check mine in the fall when temperatures are moderate. This factor is important enough for tower manufacturers to recommend different guy wire tension for different temperatures at the time of installation. Lacking the equipment needed to measure tension, a rule of thumb is to tighten the turnbuckles as much as you can with your bare hands. This will normally leave some sag in the wires, especially if insulators are installed, but don't worry. The last bit of sag requires a great deal of tension to remove and puts undue stress on the wires and the tower. Remember that the wires are pulling not only *out* but also *down*, and all that force has to be supported by the tower.

Finally, if you haven't installed safety loops and checked them, install one now at each guy anchor. A safety loop may be as simple as a short loop of guy wire threaded through the guy wire ends and the anchor rod loop, with the ends held together with normal wire clamps. The loop serves to catch the guy wires and save the tower if a turnbuckle should break. The loop may also be threaded through the turnbuckles in figure-eight fashion to keep the turnbuckles from loosening.

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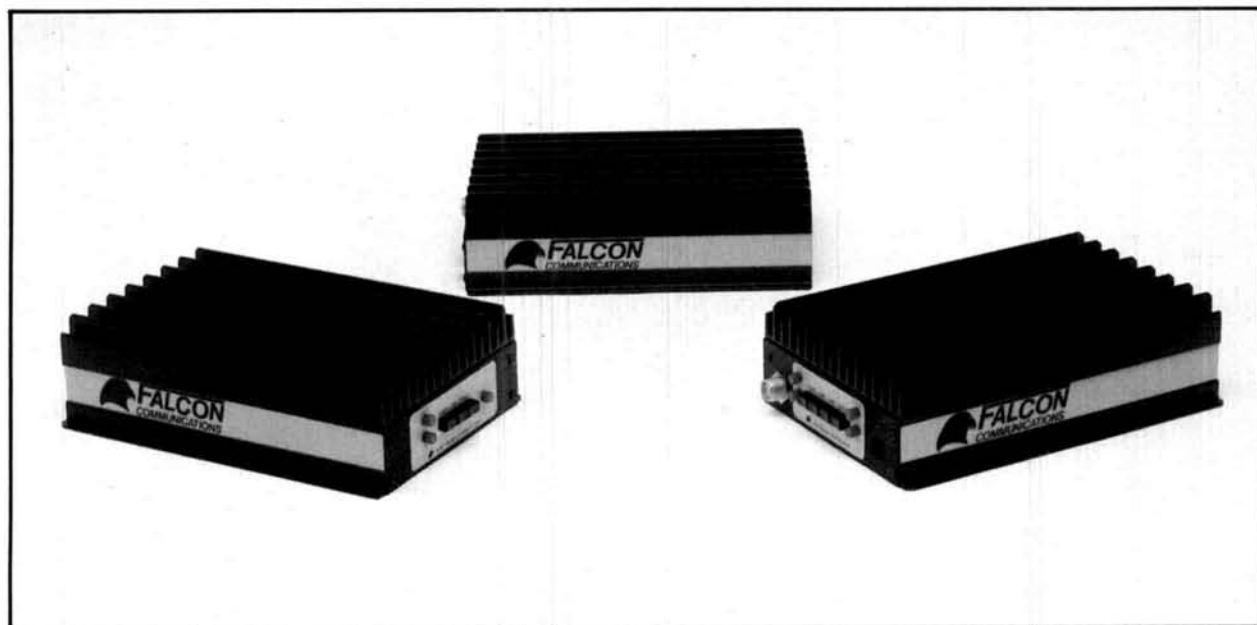
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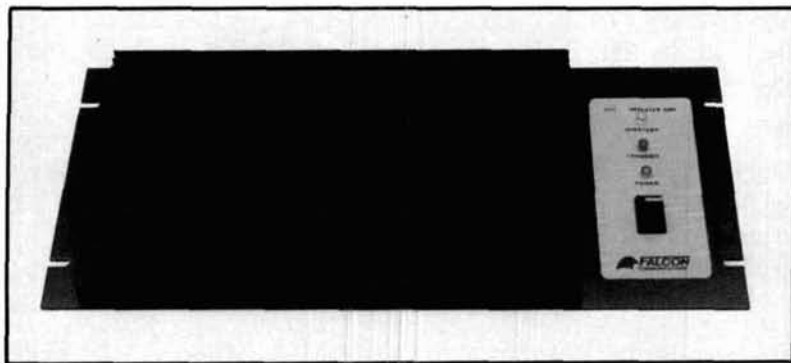
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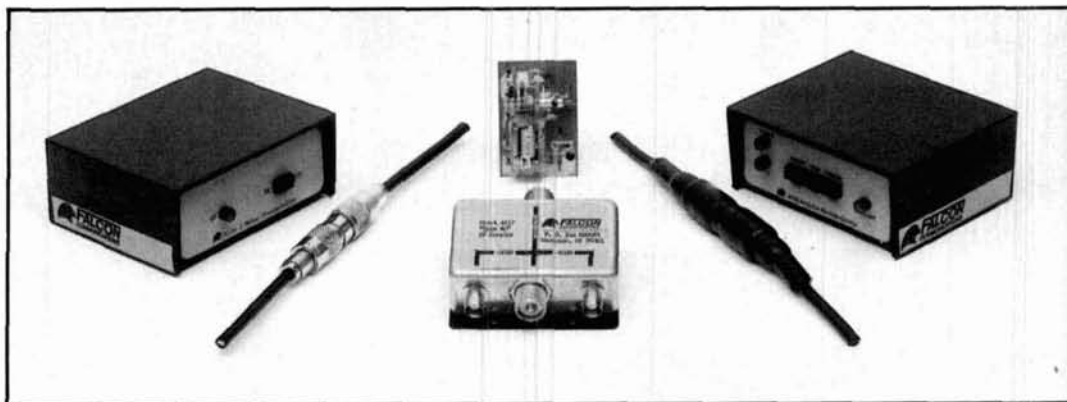
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applied Yagi antenna design

part 2:

220 MHz and the Greenblum design data

220 MHz Yagis
with different tapers
provide best gain
and F/B figures

This article addresses antenna design for the 220 MHz VHF band. In comparison to 144 MHz, this band offers similar propagation conditions, with a reduction in antenna size of approximately 35 percent. Hence, for the same physical boom length, more gain and a sharper pattern can be realized. The antennas described for 220 MHz differ from those analyzed for 144 MHz¹ for another reason as well: the Greenblum antenna design data, rather than the Kmosko-Johnson data used in last month's article, is used for the 220 MHz Yagis.

If widespread and long term publishing and republishing are reliable indicators of popularity, then Greenblum's set of charts and curves must be one of the best known design tools in all of Amateur Radio. This formerly Telrex-proprietary data was first published in 1956 as a two-part series.^{2,3} One of the first non-Telrex VHF applications was Tilton's six-element 50 MHz Yagi.⁴ Applications for other VHF and UHF bands followed.⁵ A recent computer-optimized 144 MHz moonbounce antenna developed by Joe Reisert, W1JR, was also based on Greenblum's data.⁶

Yet, as is the case for the 220 MHz band to which this article is addressed, Greenblum's design data remains somewhat of an enigma. Neither Greenblum nor those who republished his charts and tables ever specified a reflector length. Reflector spacing is given, as

are director lengths and spacings, but no reflector lengths are provided. As part of the preliminary work in preparing this article, Greenblum antennas using mid-range element spacing values were modeled. With a 100:1 wavelength-to-diameter ratio, maximum gain with six elements occurred with a reflector length of 0.49 wavelengths. The overall pattern was, however, of little use. Reflector lengths dropped as element numbers were reduced, until a reflector of 0.479 wavelengths was reached for the two-element beam. As these antennas would be of little use at 220 MHz, their modeling was not pursued any further.

technical background

As was the case with Lawson,⁷ Greenblum's design calculations were derived from Uda and Mushiake.⁸ Greenblum's reactance charts and his formula are referenced to the very same pages in Uda and Mushiake's work as those to which Lawson referred. In 1978, Powers⁹ reconfirmed the basic Greenblum data by using element spacings from the middle of the specified ranges for all parasitics. Gain and F/B figures similar to those originally stated by Greenblum were said to have been obtained.

Tilton's previously cited work produced a different set of element lengths and spacings. He found that the more or less traditional tapering schemes in use for VHF/UHF antennas resulted in an increase in forward gain. Element spacings used were towards the lower end of the specified range. When the Tilton/Greenblum designs are compared against Viezbicke's findings,¹⁰ very favorable boom-to-gain ratio comparisons are realized. One further measure of the value of Tilton's modifications was the use of his 50 MHz design by a well known commercial antenna manufac-

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table 1. Reference Tilton/Greenblum 220.5 MHz antenna with specified element spacings and parasitic element lengths to be supplied with each computer iteration.

element	length (inches)	cumulative spacing (inches)	cumulative spacing (λ)
1 Reflector	—	0.0	0.0
2 driven element	25.686378	7.5	0.14011
3 director 1	—	15.0	0.28022
4 director 2	—	24.0	0.44836
5 director 3	—	36.5	0.68188
6 director 4	—	50.5	0.94343
7 director 5	—	65.0	1.21431
8 director 6	—	83.0	1.55058
9 director 7	—	101.0	1.88685
10 director 8	—	119.0	2.22312
11 director 9	—	137.0	2.55939
12 director 10	—	155.0	2.89566
13 director 11	—	173.0	3.23193

turer. In view of Tilton's reputation and the widespread availability of his lifelong work in VHF/UHF antenna applications, a Tilton/Greenblum design will serve as the basis for computer iteration of a 220 MHz Yagi antenna.

the Tilton/Greenblum design

As a result of his previously cited work with the Greenblum data, Tilton published documentation on two 220 MHz antennas. An eleven-element Yagi appeared in the 1968 *Radio Amateur's Handbook*,¹¹ and a seven-element Yagi appeared in *The Radio Amateur's VHF Manual*.¹² The longer design is a scaling and reoptimization of a 432 MHz antenna of eleven elements. Based on the nature of the Greenblum data, these would appear to be two very different 220 MHz antennas.

For purposes of computer iteration, the eleven-element antenna is extended to thirteen elements by adding two more directors. Table 1 shows the reference design upon which this article is based. Since it is predicated on the Greenblum design data, the tapering scheme continues through the additional directors, and their spacing is identical to the spacing of the ninth director.

The design frequency is 220.5 MHz, which allows optimizing the design to cover the weak signal area of the 220 MHz band. Yagis at this frequency are more inherently broadbanded than at 144 MHz. With few exceptions, the designs optimized at 220.5 MHz will work equally well over the first few megahertz of the entire band. There are strong indications that Tilton's eleven-element design was optimized close to this design frequency, and that the seven-element Yagi was optimized at 221.5 MHz.

table 2. Optimized gain iteration for a 0.000 taper with a 26.375-inch reflector.

director 1 (inches)	gain (dBi)	F/B(dB)
22.000	14.081	22.951
22.125	14.238	23.961
22.250	14.396	24.725
22.375	14.555	24.863
22.500	14.712	24.122
22.625	14.863	22.680
22.750	15.005	20.929
22.875	15.131	19.149
23.000	15.234	17.465
23.125	15.305	15.923
23.250	15.332	14.537
23.375	15.304	13.317
23.500	15.212	12.281
23.625	15.051	11.460
23.750	14.821	10.909
23.875	14.527	10.729
24.000	14.162	11.100

table 3. Optimized F/B iteration for a 0.000 taper with a 26.875-inch reflector.

director 1 (inches)	gain (dBi)	F/B(dB)
21.750	13.618	29.037
21.875	13.776	29.793
22.000	13.937	29.739
22.125	14.099	28.388
22.250	14.262	26.588
22.375	14.424	24.622
22.500	14.582	22.817
22.625	14.733	21.115
22.750	14.872	19.563
22.875	14.994	18.153
23.000	15.092	16.874
23.125	15.158	15.721
23.250	15.184	14.696
23.375	15.163	13.805
23.500	15.093	13.064
23.625	14.971	12.498
23.750	14.801	12.135
23.875	14.578	12.001
24.000	14.271	12.060

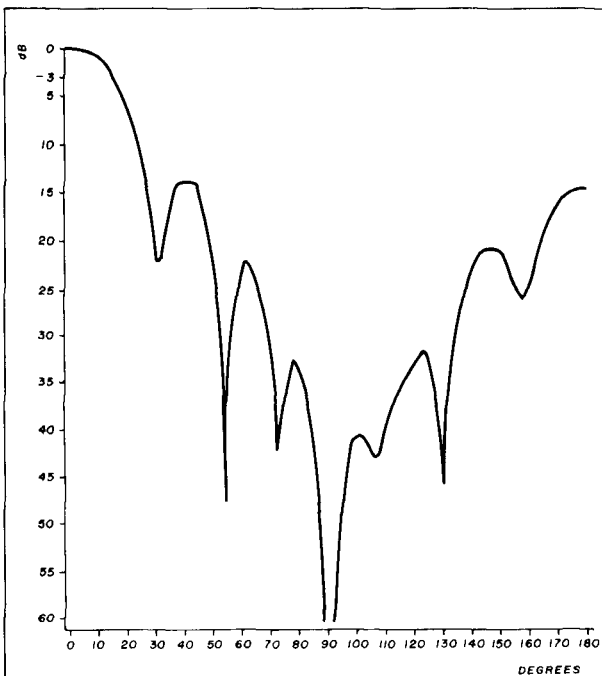
table 4. Frequency response parameters for the zero taper gain optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	14.737	16.075
217.5	15.007	16.472
218.5	15.194	16.169
219.5	15.301	15.425
220.5	15.332	14.537
221.5	15.295	13.695
222.5	15.201	13.003
223.5	15.065	12.515
224.5	14.903	12.266

Tilton included matching techniques with the designs for both of his antennas. The iterated thirteen-element antenna can easily use the same matching hardware as the eleven-element antenna because the two additional directors are not going to change the antenna's input impedance by very much. And because Tilton used wooden booms for his antennas, *element length conversion calculations are not necessary for the reference antenna. The element diameter remains at 0.125 inches. As 0.0625 inches represents the closest tolerance to which most Amateurs can cut antenna elements, tapering schemes will be expressed in multiples of 0.0625*

table 5. Frequency response parameters for the zero taper F/B optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	13.436	19.360
217.5	13.533	21.773
218.5	13.620	24.604
219.5	13.700	27.743
220.5	13.776	29.793
221.5	13.852	28.567
222.5	13.928	25.867
223.5	14.004	23.402
224.5	14.079	21.381



FREQ = 220.500 DIR 1 = 23.2500
 EL NUM = 13 TAPER = 0.0000
 EL DIAM = 0.12500 F GAIN = 15.332
 REF = 26.3750 FB = 14.537

fig. 1. Gain optimized antenna with a zero taper.

inches. In terms of the parasitic element iteration lengths, multiples of 0.125 inches are used. No real differences were found at 220 MHz by using a finer increment.

computer-designed Tilton/Greenblum antennas

Tilton presented one long Greenblum antenna for 220 MHz. This antenna had a taper of 0.125 inches. For purposes of exploring this design via computer iteration, five antennas are presented. In increments of 0.0625 inches, their tapers vary from zero to 0.25 inches. Each antenna is presented with tables showing optimized gain and F/B iterations, calculated performance across an 8-MHz bandwidth (216.5 MHz -

table 6. Optimized gain iteration for a taper of 0.0625 with a 26.375 inch reflector.

director 1 (inches)	gain (dBi)	F/B (dB)
22.000	13.745	20.212
22.125	13.894	20.984
22.250	14.046	21.837
22.375	14.201	22.748
22.500	14.358	23.639
22.625	14.515	24.341
22.750	14.671	24.582
22.875	14.824	24.141
23.000	14.971	23.063
23.125	15.108	21.617
23.250	15.230	20.063
23.375	15.331	18.553
23.500	15.402	17.161
23.625	15.437	15.924
23.750	15.427	14.868
23.875	15.366	14.025
24.000	15.250	13.446

table 7. Optimized F/B iteration for a taper of 0.0625 with a 26.875 inch reflector.

director 1 (inches)	gain (dBi)	F/B (dB)
22.000	13.597	27.636
22.150	13.753	28.716
22.250	13.912	29.485
22.375	14.073	29.543
22.500	14.235	28.702
22.625	14.397	27.227
22.750	14.558	25.514
22.875	14.714	23.809
23.000	14.862	22.211
23.125	15.000	20.753
23.250	15.121	19.437
23.375	15.221	18.266
23.500	15.294	17.241
23.625	15.334	16.372
23.750	15.337	15.679
23.875	15.301	15.194
24.000	15.224	14.969

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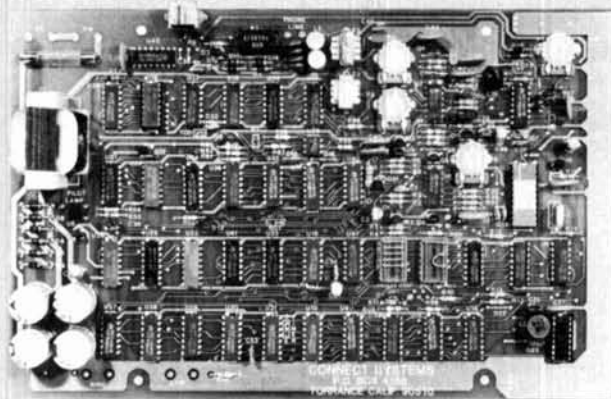
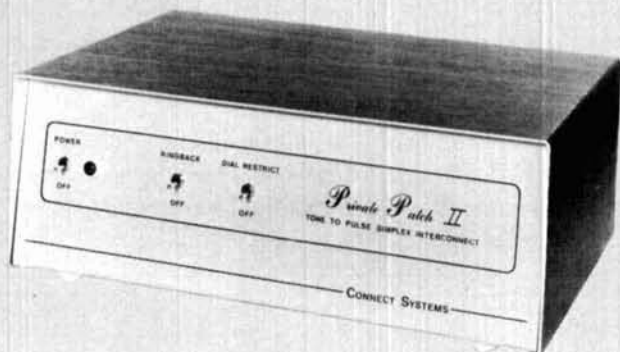
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table 8. Frequency response parameters for the 0.0625 taper gain optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	14.748	16.050
217.5	15.096	16.967
218.5	15.280	16.992
219.5	15.391	16.552
220.5	15.437	15.924
221.5	15.426	15.328
222.5	15.372	14.904
223.5	15.287	14.750
224.5	15.180	14.954

table 9. Frequency response parameters for the 0.0625 taper F/B optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	13.694	20.134
217.5	13.802	22.671
218.5	13.898	25.607
219.5	13.988	28.547
220.5	14.073	29.543
221.5	14.156	27.645
222.5	14.238	25.084
223.5	14.318	22.869
224.5	14.396	21.061

table 10. Optimized gain iteration for a taper of 0.125 with a 26.875 inch reflector.

director 1 (inches)	gain (dBi)	F/B (dB)
22.000	13.286	24.765
22.125	13.434	25.662
22.250	13.586	26.654
22.375	13.740	27.707
22.500	13.898	28.715
22.625	14.057	29.450
22.750	13.325	18.066
22.875	14.380	28.934
23.000	14.540	27.676
23.125	14.698	26.146
23.250	14.850	24.586
23.375	14.994	23.113
23.500	15.127	21.774
23.625	15.243	20.587
23.750	15.339	19.563
23.875	15.410	18.718
24.000	15.543	18.078
24.125	15.556	20.338
24.250	15.439	17.632
24.375	15.371	18.042
24.500	15.243	19.164
24.625	15.014	21.422
24.750	14.608	24.627
24.875	13.952	22.689
25.000	13.093	17.932

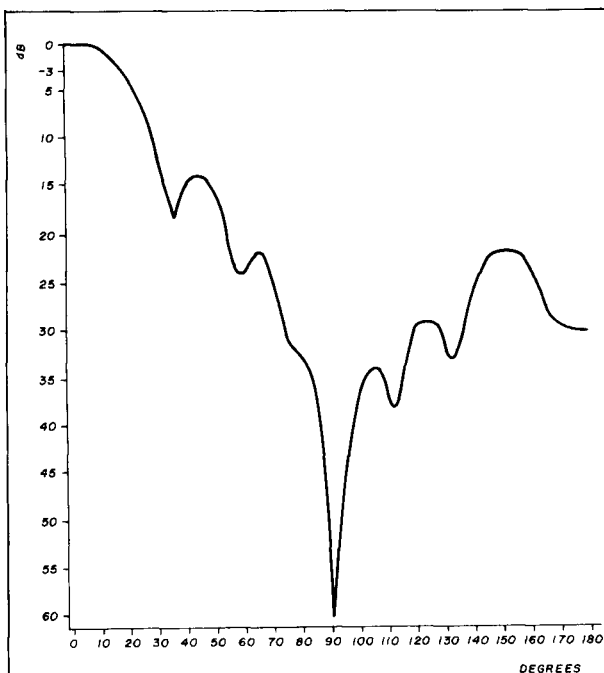


fig. 2. F/B optimized antenna with a zero taper.

224.5 MHz) for each optimized antenna, and cartesian plots of each antenna.

taper = 0.000

Table 2 presents the gain optimizing iteration that resulted in 15.332 dBi of gain, and table 3 presents the F/B optimizing iteration and its calculated result of 29.793 dB of F/B. Differences of over 1.4 dB in gain and 15 dB in F/B ratio exist between these antennas. Tables 4 and 5 present these antennas' respective calculated performance over the specified bandwidth. Both antennas show marked peaks at 220.5 MHz in their respectively optimized parameters. Figs. 1 and

2 present these antennas' respective E-plane plots. The differences in main lobe width and depth are readily apparent, as is the difference in signal attenuation from 160 to 180 degrees. It is interesting to note the obvious differences between optimized antennas with a zero taper when both antennas are based on a design approach that requires a measurable taper.

taper = 0.0625

Table 6 presents the gain optimizing iteration that resulted in 15.437 dBi of gain, and table 7 presents the F/B optimizing iteration and its calculated result of 29.543 dB. Nearly 1.4 dB of gain and over 13.6 dB of F/B separate these antennas. Tables 8 and 9 present these antennas' calculated performance over the specified bandwidth. Both antennas show peaks at

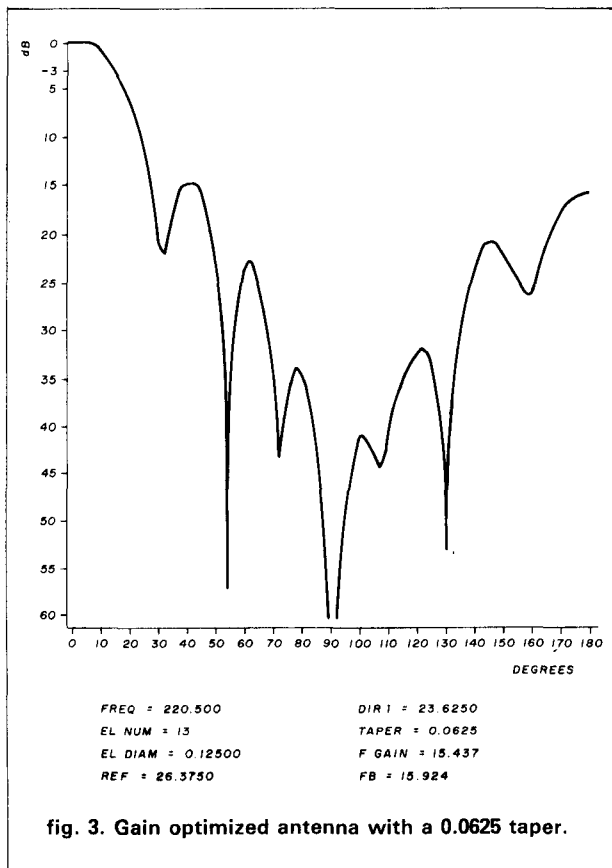


fig. 3. Gain optimized antenna with a 0.0625 taper.

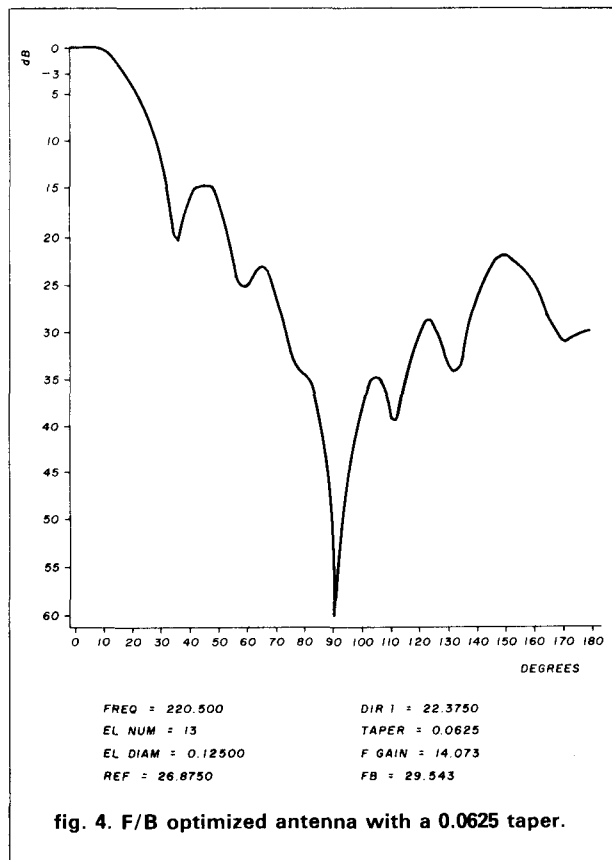


fig. 4. F/B optimized antenna with a 0.0625 taper.

table 11. Optimized F/B iteration for a taper of 0.125 with a 26.375 inch reflector.

director 1 (inches)	gain (dBi)	F/B (dB)
22.000	13.441	18.614
22.125	13.581	19.146
22.250	13.725	19.740
22.375	13.873	20.402
22.500	14.022	21.136
22.625	14.175	21.935
22.750	14.329	22.773
22.875	14.483	23.580
23.000	14.638	24.213
23.125	14.790	24.465
23.250	14.938	24.161
23.375	15.079	23.310
23.500	15.208	22.106
23.625	15.322	20.768
23.750	15.415	19.450
23.875	15.480	18.242
24.000	15.511	17.198
24.125	15.504	16.363
24.250	15.452	15.793
24.375	15.352	15.575
24.500	15.195	15.862
24.625	14.957	16.951
24.750	14.597	19.543
24.875	14.052	26.141
25.000	13.318	32.565
25.125	12.599	21.157

table 12. Frequency response parameters for the 0.125 taper gain optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	15.371	20.118
217.5	15.444	19.343
218.5	15.479	18.549
219.5	15.484	17.955
220.5	15.556	20.338
221.5	15.423	17.879
222.5	15.396	18.630
223.5	15.257	20.619
224.5	15.067	24.350

220.5 MHz for their respectively optimized parameters. Figs. 3 and 4 present these antennas' respective E-plane plots. As was the case for the zero taper antennas, there are obvious differences in main lobe width and depth, and in signal attenuation over the rear-most 20 degrees. The slight taper does not seem to have made much difference in the comparisons between the two 0.0625 antennas and the zero taper antennas. Both gain optimized antennas have the same reflector length, and this is also true of the two F/B optimized antennas. The 0.0625 antennas both have longer director lengths than their zero taper counterparts. Because element spacing has remained constant, this difference is due to director tapering.

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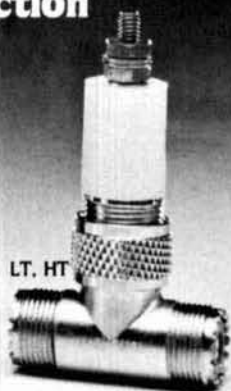
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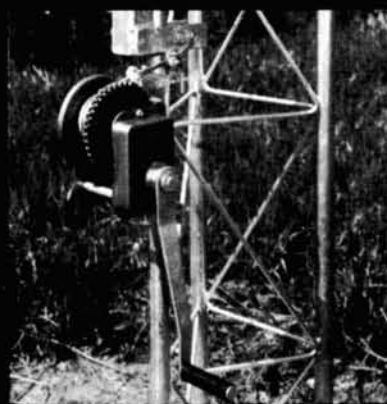


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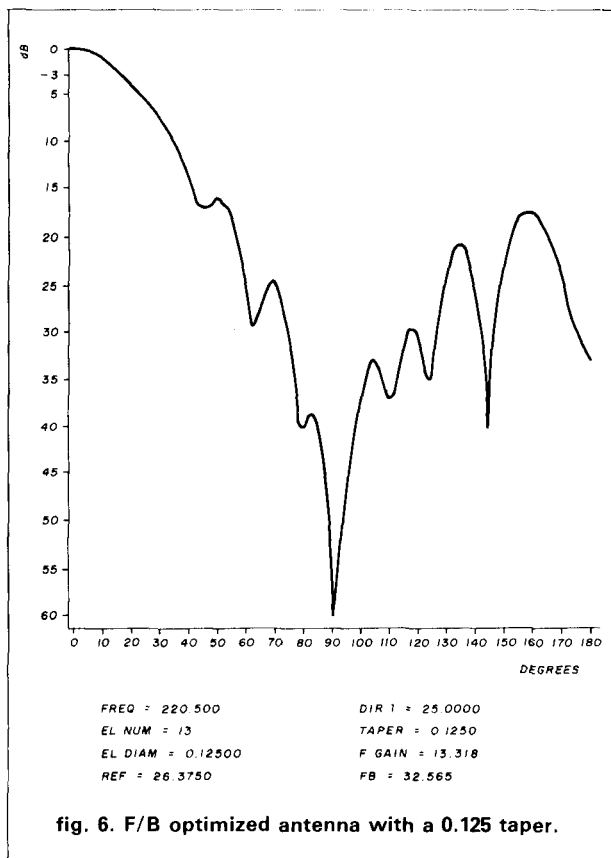
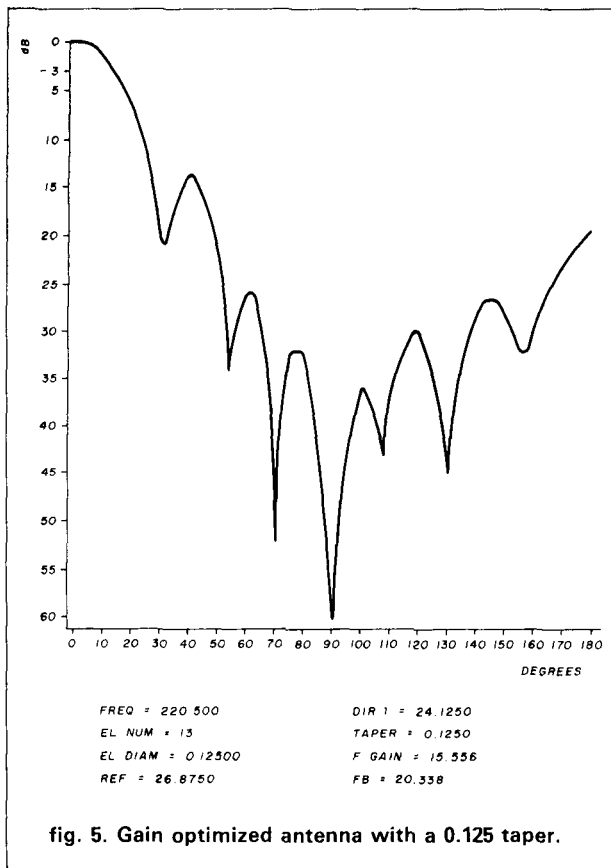


table 13. Frequency response parameters for the 0.125 taper F/B optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	14.650	12.560
217.5	14.489	14.049
218.5	14.264	16.806
219.5	13.903	22.937
220.5	13.318	32.565
221.5	12.630	20.061
222.5	12.274	17.038
223.5	12.411	14.964
224.5	12.412	13.429

table 14. Optimized gain and F/B iteration for a taper of 0.1875 with a 27.0 inch reflector.

director 1 (inches)	gain (dBi)	F/B (dB)
22.875	14.004	29.444
23.000	14.165	29.547
23.125	14.326	29.052
23.250	14.487	28.061
23.375	14.646	26.802
23.500	14.800	25.472
23.625	14.947	24.189
23.750	15.084	23.012
23.875	15.209	21.973
24.000	15.317	21.096
24.125	15.404	20.405
24.250	15.467	19.941
24.375	15.501	19.768
24.500	15.598	21.030
24.625	15.455	20.831
24.750	15.341	22.712
24.875	15.121	26.857
25.000	14.743	37.306
25.125	14.191	26.858
25.250	13.580	21.249

taper = 0.125

Table 10 presents the gain optimizing iteration that resulted in 15.556 dBi of gain, and table 11 presents the F/B optimizing iteration that resulted in 32.565 dB of F/B. Over 1.2 dB of gain and over 12 dB of F/B separate these two antennas. Tables 12 and 13 present these antennas' respective calculated performance over the specified bandwidth. Both antennas show easily determined peaks at 220.5 MHz in their respectively optimized parameters. The high F/B figure is the result of significant single frequency vectorial cancellation. A very good F/B will be recognized over the entire weak signal band segment. Figs. 5 and 6 present these antennas' respective E-plane plots. The differences in main lobe width and depth are major. In comparison, the F/B optimized antenna almost does without a clearly defined main lobe, and its increased signal attenuation from 170 to 180 degrees comes at a nearly 10 dB (average) reduction in signal attenuation from 120 to 165 degrees. The high degree

table 15. Frequency response parameters for the 0.1875 taper gain optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	15.449	21.271
217.5	15.503	20.549
218.5	15.528	19.973
219.5	15.527	19.734
220.5	15.598	21.030
221.5	15.442	21.004
222.5	15.330	23.280
223.5	15.124	28.150
224.5	14.765	30.512

table 16. Frequency response parameters for the 0.1875 taper F/B optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	15.520	18.340
217.5	15.547	19.245
218.5	15.337	21.196
219.5	15.118	25.498
220.5	14.743	37.306
221.5	14.184	25.206
222.5	13.543	19.359
223.5	13.117	17.571
224.5	13.179	18.989

of optimization of a single parameter comes at a comparative cost in performance over the rest of this antenna's pattern. Tilton's selection of a gain optimized antenna of this taper is soundly based on his own actual measurements and what this model's calculations have again realized. The F/B level realized by the gain optimized antenna produces a sharp pattern as well as an F/B ratio easily in keeping with the 220 MHz band's level of activity. In comparison with the zero taper antenna and the 0.0625 taper antennas, the 0.125 antenna has a longer first director. As element spacing is fixed, this difference is due to the increased director tapering.

taper = 0.1875

Table 14 presents the gain optimizing iteration that resulted in 15.598 dBi of gain, and it is also the F/B optimizing iteration that resulted in 37.306 dB of F/B. Just over 0.85 dB of gain and just under 16.3 dB of F/B separate these two antennas. Tables 15 and 16 present these antennas' calculated performance over the specified bandwidth. Both antennas show easily located peaks at 220.5 MHz in their respectively optimized parameters. As was the case for the 0.125 taper antenna, this F/B optimized antenna's high F/B figure is the result of single frequency vectorial cancellation.

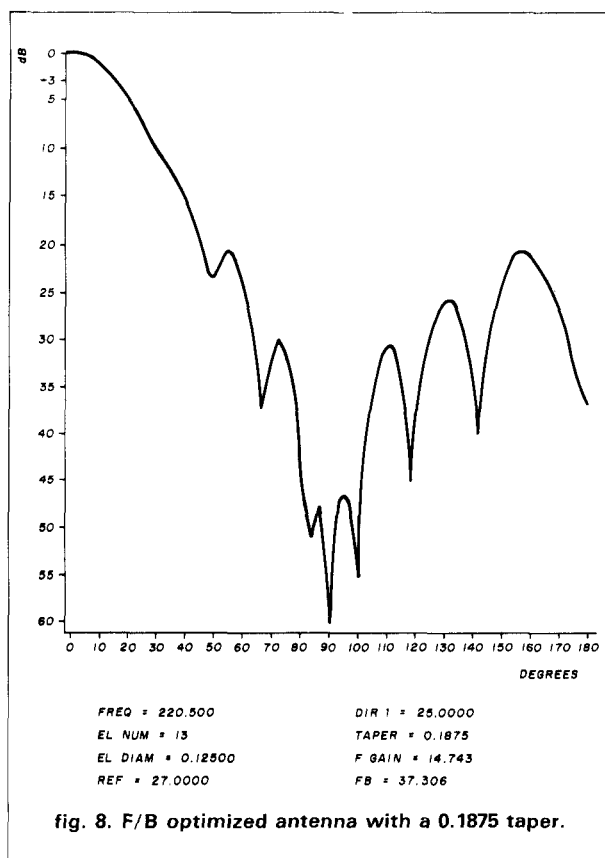
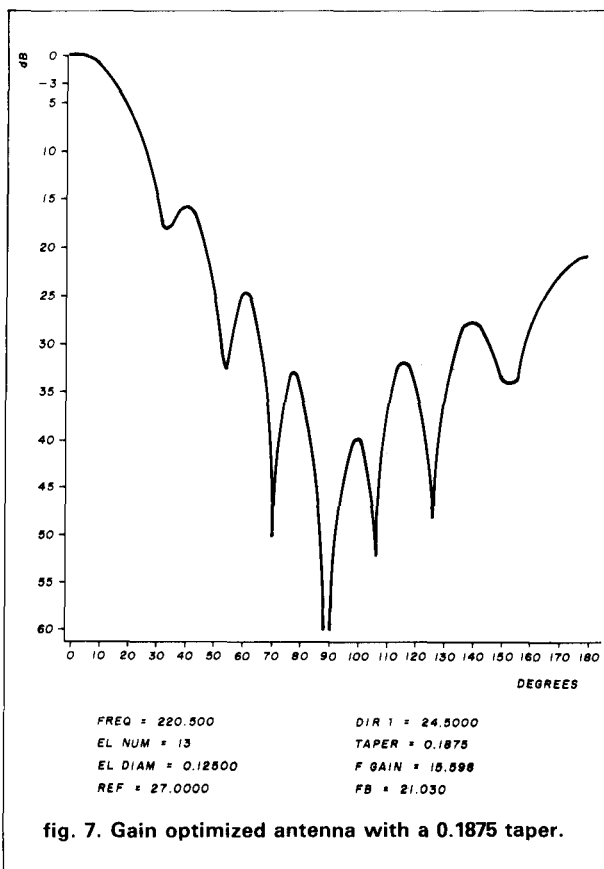


table 17. Optimized gain iteration for a taper of 0.25 with a 26.625 inch reflector.

director 1 (inches)	gain (dBi)	F/B (dB)
23.000	13.976	24.234
23.125	14.128	25.153
23.250	14.282	26.147
23.375	14.435	27.156
23.500	14.589	28.037
23.625	14.740	28.539
23.750	14.887	28.406
23.875	15.028	27.614
24.000	15.160	26.403
24.125	15.279	25.055
24.250	15.382	23.755
24.375	15.464	22.599
24.500	15.519	21.638
24.625	15.543	20.910
24.750	15.529	20.458
24.875	15.467	20.331
25.000	15.342	20.580
25.125	15.133	21.206
25.250	14.823	22.051
25.375	14.441	22.903
25.500	14.114	24.715
25.625	14.030	28.976
25.750	14.062	19.353
25.875	13.857	16.152
26.000	6.991	4.234

table 18. Optimized F/B iteration for a taper of 0.25 with a 26.875 inch reflector.

director 1 (inches)	gain (dBi)	F/B (dB)
23.000	13.901	27.711
23.125	14.057	28.746
23.250	14.214	29.606
23.375	14.372	30.219
23.500	14.530	30.137
23.625	14.685	29.369
23.750	14.835	28.147
23.875	14.980	26.760
24.000	15.115	25.397
24.125	15.237	24.153
24.250	15.344	23.072
24.375	15.429	22.182
24.500	15.490	21.509
24.625	15.519	21.093
24.750	15.510	20.990
24.875	15.450	21.272
25.000	15.320	22.011
25.125	15.095	23.134
25.250	14.759	24.066
25.375	14.351	24.140
25.500	14.030	24.943
25.625	13.994	27.748
25.750	14.026	18.951
25.875	13.842	16.766
26.000	5.770	3.280

Here too, a very fine F/B will be realized over the entire weak signal area. **Figs. 7 and 8** present these antennas' respective E-plane plots. The 0.1875 antennas compare with one another in a manner similar to the 0.125 antennas. The high cost of the high F/B ratio is all too apparent. The gain optimized 0.1875 antenna has a clean pattern and a respectable F/B. Both 0.1875 antennas have the same reflector length but continue the trend toward longer director lengths with an increased taper. However, the 0.125 and 0.1875 F/B optimized antennas have initial directors of the same length. Their difference is the latter's longer reflector.

taper = 0.25

Table 17 presents the gain optimizing iteration that resulted in 15.543 dBi of gain, and **table 18** presents the F/B optimizing iteration that resulted in 30.129 dB of F/B. Slightly more than 1.1 dB of gain and nearly 10 dB of F/B separate these two antennas. **Tables 19 and 20** present these antennas' calculated performance over the specified bandwidth. Both antennas have easily located peaks at 220.5 MHz in their respectively optimized parameters. Unlike the two previous F/B optimized antennas, the 0.25 taper F/B optimized antenna does not have a high single frequency F/B, and maintains a near-optimized F/B across the entire weak signal area. **Figs. 9 and 10** present the 0.25 antennas' E-plane plots. Though the gain optimized antenna has the narrower main lobe, both antennas have clearly defined main lobes. This is in contrast to the pairs of antennas compared at the 0.1875 and 0.125 tapers. Along a similar vein, the great disparities noted in the signal attenuation characteristics between antennas of the two most recently presented tapers, exist only to a limited degree between the 0.25 taper antennas. While the gain optimized 0.25 taper antenna continues the trend to longer director lengths, the F/B optimized antenna significantly *reverses* this tendency.

summary

The computer iterations performed on a family of ten 220 MHz Tilton/Greenblum Yagis indicate that the user needs to have a clear understanding of his or her antenna requirements before making a selection. There are great differences between the gain and F/B optimized antennas within each tapering approach. Additionally, for each of the optimized antennas, the best value of the other (non-optimized) parameter generally occurred at a frequency far removed from the design frequency of 220.5 MHz. Given the broadband nature of Yagis on this band, very little gain is lost during even extensive changes in frequency. For some of the F/B optimized antennas, there are marked penalties in F/B for even slight frequency changes.

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RS-10A	7.5	10	4 x 7 1/2 x 10 3/4	11
RS-12A	9	12	4 1/2 x 8 x 9	13
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MODEL	Continuous Duty (Amps) @13.8VDC@10VDC@5VDC	ICS* (Amps) @13.8V	Size (IN) H x W x D	Shipping Wt (lbs)
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MODEL	Continuous Duty (Amps)	ICS* Amps	Size (IN) H x W x D	Shipping Wt (lbs)
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RS-10S	7.5	10	4 x 7 1/2 x 10 1/2	12
RS-10L(For LTR)	7.5	10	4 x 9 x 13	13
RS-12S	9	12	4 1/2 x 8 x 9	13
RS-20S	16	20	5 x 9 x 10 1/2	18

table 19. Frequency response parameters for the 0.25 taper gain optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	15.210	20.451
217.5	15.360	21.259
218.5	15.462	21.417
219.5	15.522	21.186
220.5	15.543	20.910
221.5	15.528	20.845
222.5	15.469	21.154
223.5	15.354	21.922
224.5	15.156	22.978

table 20. Frequency response parameters for the 0.25 taper F/B optimized antenna.

frequency	gain (dBi)	F/B (dB)
216.5	13.948	20.464
217.5	14.067	22.851
218.5	14.175	25.567
219.5	14.276	28.419
220.5	14.372	30.219
221.5	14.466	29.425
222.5	14.557	27.249
223.5	14.646	25.119
224.5	14.732	23.343

With the exception of the zero, 0.0625, and 0.25 taper antennas, F/B optimization is very clearly the result of single frequency vectorial cancellation. A user interested in reasonably high F/Bs that will be recognized across the entire weak signal area (of the band) could easily choose from among the various 0.0625 and 0.25 taper F/B optimized antennas. There is the added bonus of reasonably good gain figures and clearly defined main lobes. The 0.125 and 0.1875 taper F/B optimized antennas have very broad main lobes and are single frequency F/B antennas. Overall, the user in need of a high F/B may find the 0.25 taper F/B optimized antenna to be the best choice.

For the gain-oriented user, the gain optimized antennas with the 0.125 and 0.1875 tapers are a logical choice. Both provide respectable F/B along with a well defined front lobe and an overall clean pattern. While the 0.1875 antenna provides a slight increase in calculated gain, Tilton's 0.125 antenna is every bit as good.

There is a rather intriguing by-product of the Tilton/Greenblum iterations. A boomlength of 3.23 wavelengths is extremely close to the boomlength of 3.2 wavelengths used by Viezbicke. This invites an obvious comparison between the NBS Yagi and the Yagis optimized for this article.

Using the Lawson model to iterate the 3.2 wavelength NBS Yagi results in a computed gain of 15.2

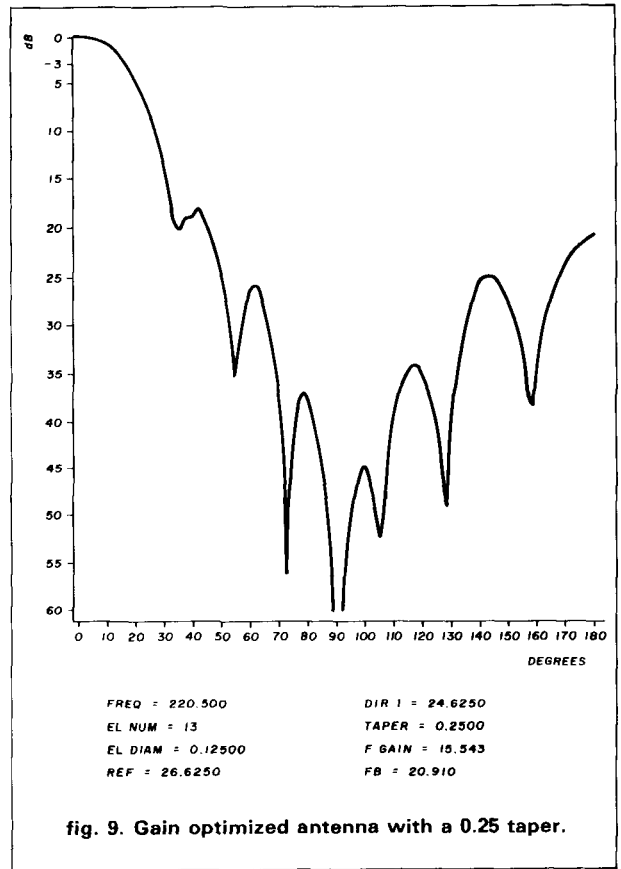


fig. 9. Gain optimized antenna with a 0.25 taper.

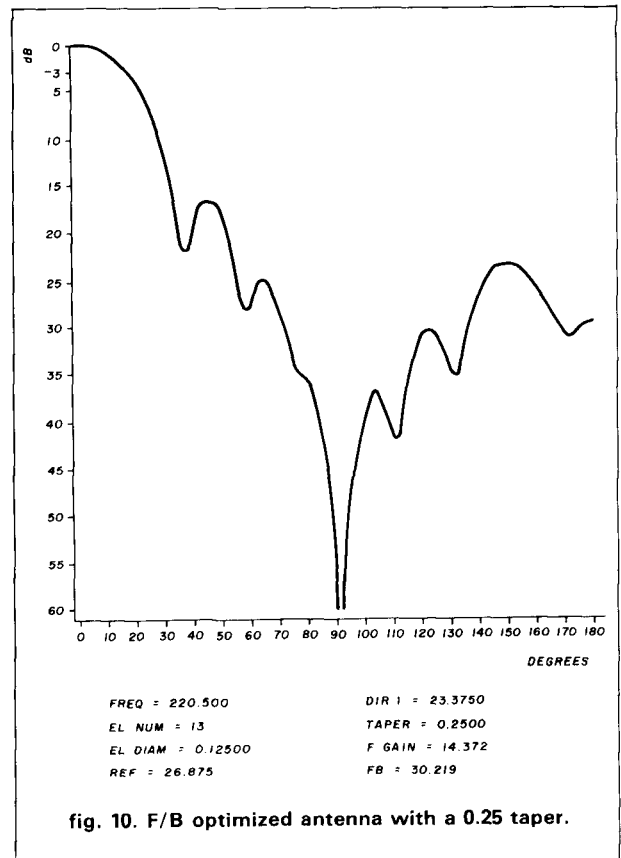
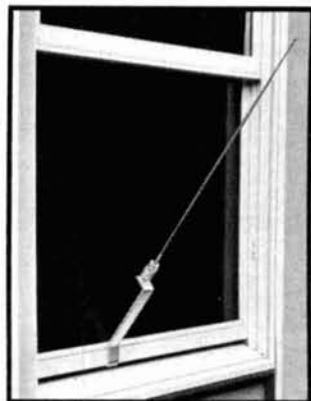


fig. 10. F/B optimized antenna with a 0.25 taper.

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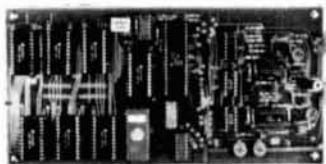
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dBi.¹³ Any of the five Tilton/Greenblum gain optimized Yagis produced gains in excess of this figure. The amount of excess (gain) ranged from 0.132 to 0.398 dB, with a boom only 0.03 wavelengths longer. While longer booms generally result in larger gains, this difference is too small to account for more than the minutest part of the differences in gain. Also, all five gain optimized Yagis have a first minor lobe whose amplitude is from 1 to 4 dB less than that of the NBS Yagi. What is even more interesting is the fact that the NBS Yagi uses four more elements than the Tilton/Greenblum Yagi.

The NBS Yagis are element length-optimized with equal director spacing. The Tilton/Greenblum Yagis resulting from computer iteration are also element length-optimized, but director spacing is initially unequal and followed by equally spaced directors. All NBS Yagis use a reflector spacing of 0.2 wavelengths, while the Greenblum design varies reflector spacing as a function of boom length. It would appear that gain optimized Yagis designed as a result of optimizing two variables are more effective than those designed by optimizing a single variable. With fewer elements they are also easier to build. It is only fair to also note that the NBS 3.2 wavelength antenna has an F/B of from 3 to 10 dB above any of the five gain optimized Yagis.

Next month's installment in this series will present computer-iterated alternative Yagis drawn from two well-known 432 MHz design approaches. Iteration-based inferences will be made on a third design, also of long standing. Perhaps as in the case of 220 MHz, 432 MHz may bring a little surprise.

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impedance matching: a brief review

There's no mystery
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In April the author discussed the basics of resonant circuits; this month, he walks us through the fundamentals of impedance matching. Both articles are adapted and reprinted with permission from *RF Circuit Design*, published by Howard W. Sams & Company, Indianapolis, Indiana.*

Impedance matching is often necessary in the design of RF circuitry to provide the maximum possible transfer of power between a source and its load. Probably the most vivid example of the need of such a transfer of power occurs in the front-end of any sensitive receiver. Obviously, any *unnecessary* loss in a circuit which is already handling extremely small signal levels simply cannot be tolerated. Therefore, in most instances, extreme care must be taken during the initial design of such a front-end to make sure that each device in the chain is matched to its load.

background

A well-known theorem states that for DC circuits, maximum power will be transferred from a source to its load if the *load resistance* equals the *source resistance*. A simple proof of this theorem is shown in **fig. 1**. In this figure, for convenience, the source is normalized for a resistance of one ohm and a voltage of one volt.

In dealing with AC or time-varying waveforms, however, that same theorem states that the maximum transfer of power from a source to its load occurs when the *load impedance* (Z_L) is equal to the *complex conjugate* of the *source impedance*. *Complex conjugate* simply refers to a complex impedance having the same *real part* with an opposite reactance. Thus, if the source impedance were $Z_s = R + jX$, then its complex conjugate would be $Z_s^* = R - jX$.

If you followed the mathematics in **fig. 1**, then it should be obvious why maximum transfer of power does occur when the load impedance is the complex conjugate of the source. This is shown schematically in **fig. 2**. The source (Z_s), with a series reactive component of $+jX$ (an inductor), is driving its complex conjugate load impedance consisting of a $-jX$ reactance (capacitor) in series with R_L . The $+jX$ component of the source and the $-jX$ component of the load are in series and thus cancel each other, leaving only R_s and R_L which are equal by definition. Since R_s and R_L are equal, maximum power transfer will occur. So when we speak of a source driving its complex conjugate, we are simply referring to a condition in which any *source* reactance is resonated with an equal and opposite *load* reactance, leaving only equal resistor values for the source and the load terminations.

The primary objective in any impedance *matching* scheme then, is to force a load impedance to "look like" the complex conjugate of the source impedance so that maximum power may be transferred to the load. This is shown in **fig. 3** where a load impedance of $2 - j6$ ohms is transformed by the impedance

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matching network to a value of $5 + j10$ ohms. Therefore, the source "sees" a load impedance of $5 + j10$ ohms, which just happens to be its complex conjugate. It should be noted here that because we are dealing with reactances, which are frequency dependent, the perfect impedance match can occur at only one frequency: that is, the frequency at which the $+jX$ component exactly equals the $-jX$ component and thus cancellation or resonance occurs. At all other frequencies removed from the matching fre-

quency, the impedance match becomes progressively worse and eventually non-existent. This can be a problem in broadband circuits where we would ideally like to provide a perfect match everywhere within the broad passband.

There are an infinite number of possible networks which could be used to perform the impedance matching function of **fig. 3**. Something as simple as a 2-element L-C network or as elaborate as a 7-element filter, depending on the application, would work equally well.

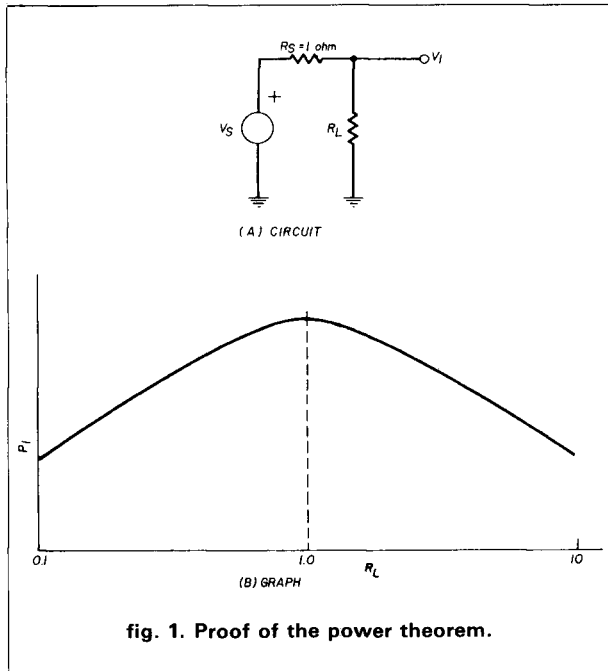


fig. 1. Proof of the power theorem.

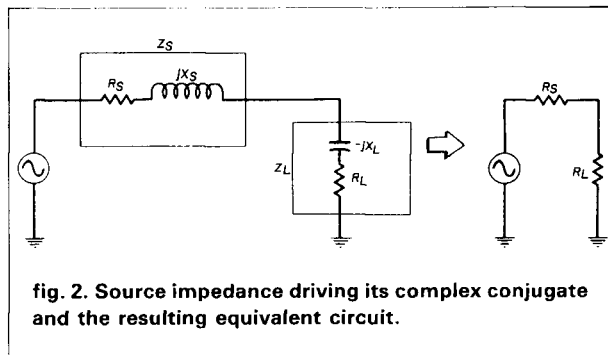


fig. 2. Source impedance driving its complex conjugate and the resulting equivalent circuit.

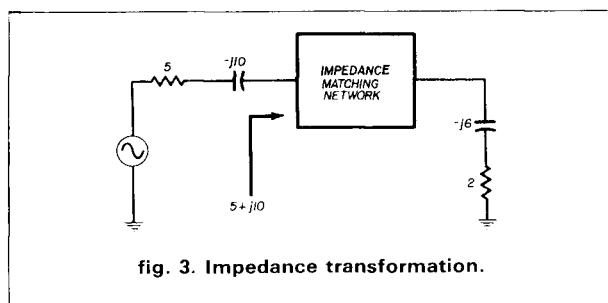


fig. 3. Impedance transformation.

the L-network: why it works

Probably the simplest and most widely used matching circuit is the L-network shown in **fig. 4**. This circuit receives its name from its component orientation, which resembles the shape of an L. As shown in the figure, there are four possible arrangements of the two components. Two of the arrangements, A and B, are in a lowpass filter configuration, while the other two, C and D, are in a highpass filter configuration.

Before we introduce equations that can be used to design the matching networks of **fig. 4**, let's first analyze an existing matching network so that we can understand exactly how the impedance match occurs. Once this analysis is made, impedance matching should seem less mysterious.

Figure 5 shows a simple L-network impedance match between a 100-ohm source and a 1000-ohm load. Without the impedance matching network installed, and with the 100-ohm source driving the 1000-ohm load directly, one-third of the signal available from the source is gone before we even get started. The impedance matching network eliminates this loss

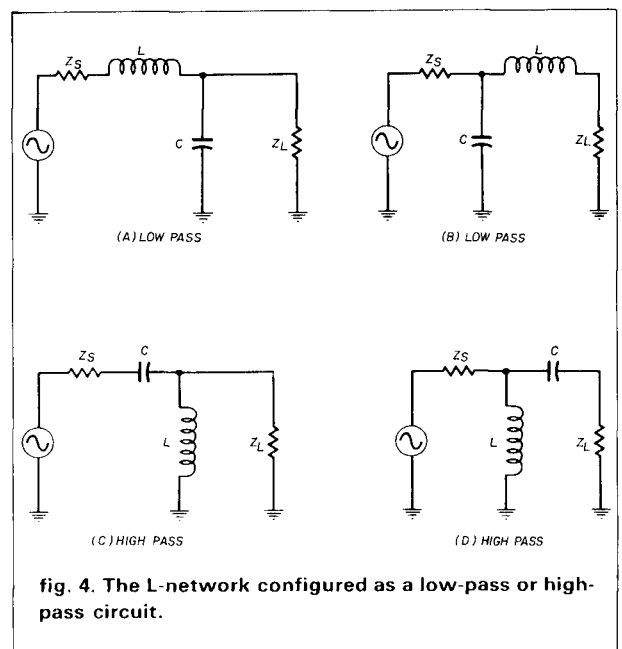


fig. 4. The L-network configured as a low-pass or high-pass circuit.

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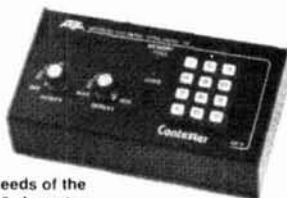
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4410G	440	100	10	265
4412	440	100	30	199
4412G	440	100	30	239

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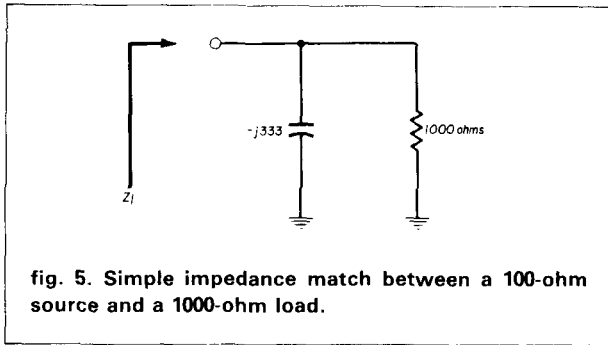


fig. 5. Simple impedance match between a 100-ohm source and a 1000-ohm load.

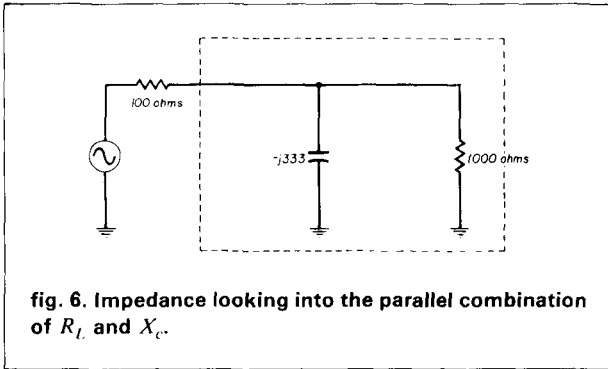


fig. 6. Impedance looking into the parallel combination of R_L and X_C .

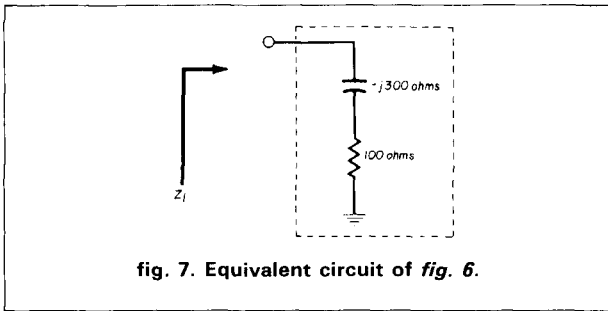


fig. 7. Equivalent circuit of fig. 6.

and allows for maximum power transfer to the load. This is done by forcing the 100-ohm source to see 100 ohms when it looks into the impedance matching network. But how?

If you analyze fig. 5, the simplicity of how the match occurs will amaze you. Take a look at fig. 6. The first step in the analysis is to determine what the load impedance actually looks like when the $-j333$ ohm capacitor is placed across the 1000-ohm load resistor. This is easily calculated by:

$$Z = \frac{X_C R_L}{X_C + R_L} = \frac{-j333(1000)}{-j333 + 1000}$$

$$= 100 - j300 \text{ ohms}$$

Thus, the parallel combination of the $-j333$ ohm capacitor and the 1000-ohm resistor *appears* to be an impedance of $100 - j300$ ohms. This is a *series* combination of a 100-ohm resistor and a $-j300$ ohm capacitor as shown in fig. 7. Indeed, if you hooked

a signal generator up to circuits similar to figs. 6 and 7 you would not be able to tell the difference between the two as they would exhibit the same characteristics (except at DC, obviously).

Now that we have an *apparent* series 100-j300 ohm impedance for a load, all we have to do to complete the impedance match to the 100-ohm source is to add an equal and opposite ($+j300$ ohm) reactance in series with the network of fig. 7. The addition of the $+j300$ -ohm inductor causes cancellation of the $-j300$ ohm capacitor, leaving only an *apparent* 100-ohm load resistor. This is shown in fig. 8. Keep in mind here that the actual network topology of fig. 5 has not changed. All we have done is to analyze small portions of the network so that we can understand the function of each component.

To summarize then, the function of the *shunt* component of the impedance matching network is to transform a larger impedance down to a smaller value with a real part equal to the real part of the other terminating impedance (in our case, the 100-ohm source). The *series* impedance matching element then resonates with or cancels any reactive component present, thus leaving the source driving an apparently equal load for optimum power transfer. So you see, the impedance match isn't mysterious at all; it can be completely explained every step of the way.

Now back to the design of the impedance matching networks of fig. 4. These circuits can be very easily designed using the following equations:

$$Q_s = Q_p = \sqrt{\frac{R_p}{R_s} - 1} \quad (1)$$

$$Q_s = \frac{X_s}{R_s} \quad (2)$$

$$Q_p = \frac{R_p}{X_p} \quad (3)$$

where, referring to fig. 9:

$Q_s = Q$ of the series leg

$Q_p = Q$ of the shunt leg

R_p = shunt resistance

X_p = shunt reactance

R_s = series resistance

X_s = series reactance

X_p and X_s may be either capacitive or inductive reactance, but each must be of the opposite type. Once X_p is chosen as a capacitor, for example, X_s must be an inductor and vice-versa.

example 1

Design a circuit to match a 100-ohm source to a 1000-ohm load at 100 MHz. Assume that a DC voltage must also be transferred from the source to the load.

Solution: The need for a DC path between the source and load dictates the need for an inductor in the series leg as in fig. 4A.

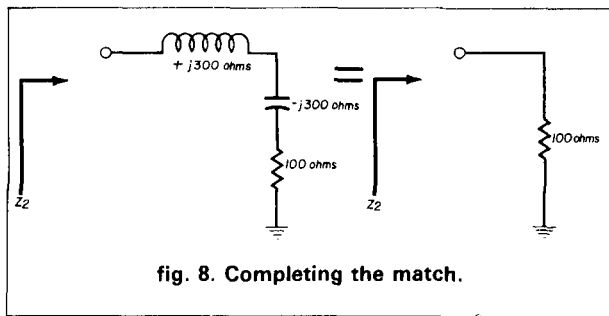


fig. 8. Completing the match.

From eq. 1 we have:

$$Q_s = Q_p = \sqrt{\frac{1000}{100} - 1} = \sqrt{9} = 3$$

From eq. 2:

$$X_s = Q_s R_s = (3)(100) = 300 \text{ ohms (inductive)}$$

From eq. 3:

$$X_p = \frac{R_p}{Q_p} = \frac{1000}{3} = 333 \text{ ohms (capacitive)}$$

The component values at 100 MHz are:

$$L = \frac{X_s}{2\pi f} = \frac{300}{2\pi(100 \times 10^6)} = 477 \text{ nH}$$

$$C = \frac{1}{\omega X_p} = \frac{1}{2\pi(100 \times 10^6)(333)} = 4.8 \text{ pF}$$

This yields the circuit of fig. 10. Notice that what you have done is to design the circuit which was previously given in fig. 5 and analyzed.

dealing with complex loads

The design of example 1 was for the simple case of matching two *real* impedances (pure resistances). It is very rare when such an occurrence actually exists in the real world. Transistor input and output impedances are almost always *complex*; that is, they contain both *resistive* and *reactive* components ($R \pm jX$). Transmission lines, mixers, antennas, and most other sources and loads are no different in that respect. Most will always have some reactive component which must be dealt with. It is, therefore, necessary to know how to handle these stray reactances, and in some instances, to actually put them to work for you.

There are two basic approaches in handling complex impedances as outlined below:

Absorption. It is possible to actually absorb any stray reactances into the impedance matching network itself. This can be done through prudent placement of each matching element such that element capacitors are placed in parallel with stray capacitances, and element inductors are placed in series with any stray inductances. The *stray* component values are then subtracted from the *calculated* element values, leaving new element values, C', L' , which are smaller than the calculated element values.

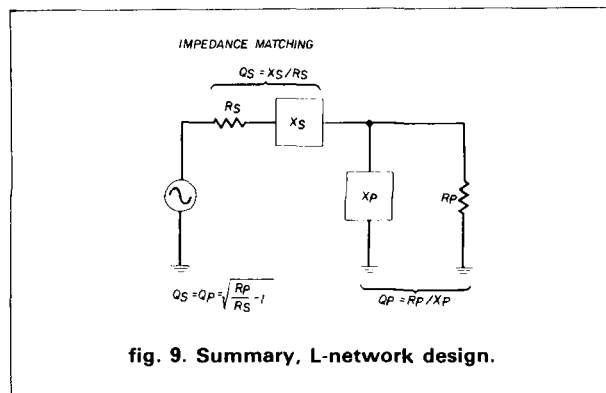


fig. 9. Summary, L-network design.

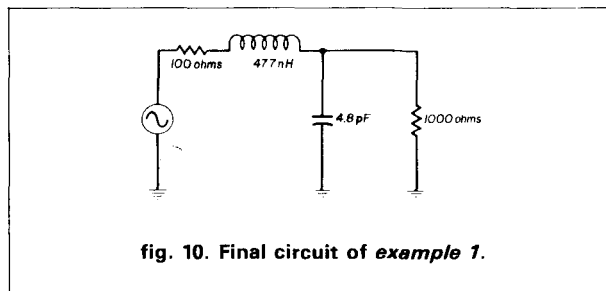


fig. 10. Final circuit of example 1.

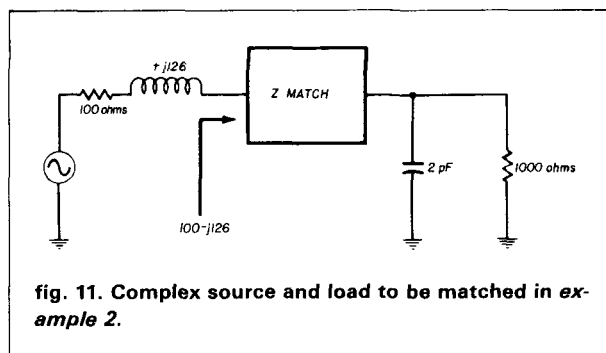


fig. 11. Complex source and load to be matched in example 2.

Resonance. Resonate any stray reactance with an equal and opposite reactance at the frequency of interest. Once this is done, the matching network design can proceed as in example 1 for two pure resistances.

Of course, it is possible to use both of the approaches outlined above at the same time. In fact, the majority of impedance matching designs probably do utilize a little of both. Let's take a look at two simple examples to help clarify matters.

example 2

Use the absorption approach to match the source and load of fig. 11 at 100 MHz.

Solution: The first step in the design process is to totally ignore the reactances and simply match the 100-ohm real part of the source to the 1000-ohm real part of the load at 100 MHz. Keep in mind that you would like to use a matching network that will place element inductances in series with stray inductance and element capacitances in parallel with stray capacitances. Conveniently, the network of fig. 4A is

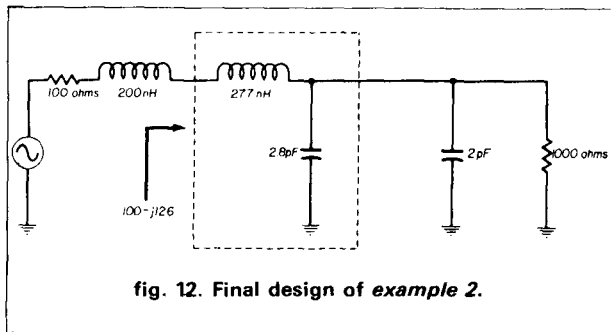


fig. 12. Final design of example 2.

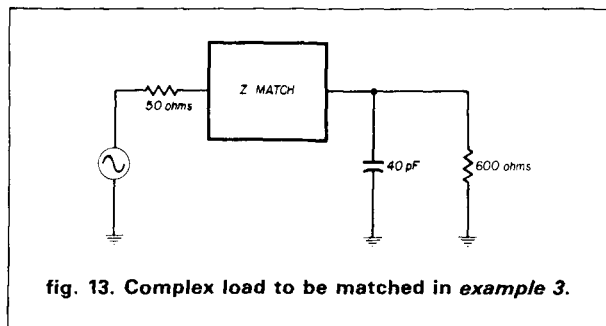


fig. 13. Complex load to be matched in example 3.

again chosen for the design, and again **example 1** provides the details. Thus, the calculated values for the network, if we ignore stray reactances, are shown back in **fig. 10**. But since the stray reactances really do exist, the design is not yet finished as we must now somehow absorb the strays into the matching network. This is done as follows. At the load end we need 4.8 pF for the matching network. We already have a stray 2 pF available at the load, so why not use it? If we use a 2.8 pF element capacitor, the total shunt capacitance becomes 4.8 pF, the design value. Similarly, at the source, the matching network calls for a series 477 nH inductor. We already have a +j126 ohm, or 200 nH inductor available in the source. If we use an actual element inductance of $477 \text{ nH} - 200 \text{ nH} = 277 \text{ nH}$, then the total series inductance will be 477 nH, which is the calculated design value. The final design is shown in **fig. 12**.

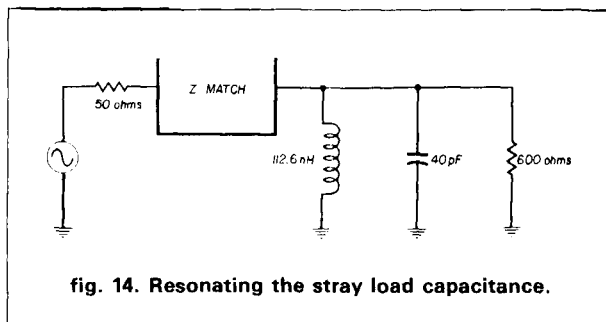


fig. 14. Resonating the stray load capacitance.

Notice that nowhere in the example was a conjugate match even mentioned. However, you can rest assured that if you perform the simple analysis outlined in the previous section of this article, the impedance looking into the matching network, as seen by the source, will be $100 - j126$ ohms which is indeed the complex conjugate of $100 + j126$ ohms.

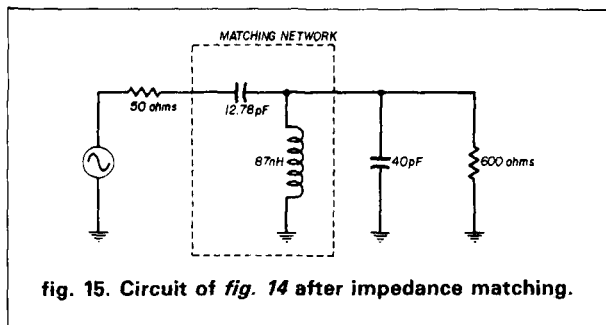


fig. 15. Circuit of fig. 14 after impedance matching.

Obviously, if the stray element values are larger than the calculated element values, absorption cannot take place. If, for instance, the stray capacitance of **fig. 11** were 20 pF, we could not have added a shunt element capacitor to give us a total-needed shunt capacitance of 4.8 pF. In a situation such as this, when absorption is not possible, the concept of resonance coupled with absorption will often do the trick.

example 3

Design an impedance matching network which will block the flow of DC from the source to load of **fig. 13**. The frequency of operation is 75 MHz. Try the resonant approach. **Solution:** The need to block the flow of DC from the source to the load dictates the use of the matching network of **fig. 4C**. But first let's get rid of the stray 40 pF capacitor by resonating it with a shunt inductor at 75 MHz.

$$L = \frac{1}{\omega^2 C_{stray}}$$

$$= \frac{1}{[2\pi(75 \times 10^6)]^2 (40 \times 10^{-12})}$$

$$= 112.6 \text{ nH}$$

This leaves us with the circuit of **fig. 14**. Now that we have eliminated the stray capacitance, we can proceed with the

matching network between the 50-ohm load and the apparent 600-ohm load.

Thus:

$$Q_s = Q_p = \sqrt{\frac{R_p}{R_s} - 1} = \sqrt{\frac{600}{50} - 1} = 3.32$$

$$X_s = Q_s R_s = (3.32)(50) = 166 \text{ ohms}$$

$$X_p = \frac{R_p}{Q_p} = \frac{600}{3.32} = 181 \text{ ohms}$$

Therefore, the element values are:

$$C = \frac{1}{\omega X_s} = \frac{1}{2\pi(75 \times 10^6)(166)} = 12.78 \text{ pF}$$

$$L = \frac{X_p}{\omega} = \frac{181}{2\pi(75 \times 10^6)} = 384 \text{ nH}$$

These values then, yield the circuit of **fig. 15**. But notice that this circuit can be further simplified by simply replacing the two shunt inductors by a single inductor.

Therefore:

$$L_{new} = \frac{L_1 L_2}{L_1 + L_2} = \frac{(384)(112.6)}{384 + 112.6} = 87 \text{ nH}$$

The final design appears in **fig. 16**.

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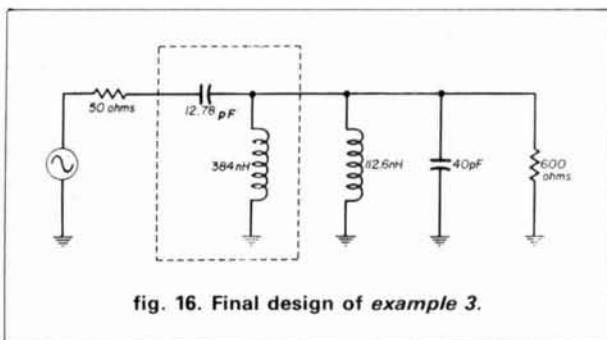


fig. 16. Final design of example 3.

conclusion

Examples 2 and 3 detail some very important concepts in the design of impedance matching networks. With a little planning and preparation, the design of simple impedance matching networks between complex loads becomes a simple number-crunching task using elementary algebra. Any stray reactances present in the source and load can usually be absorbed into the matching network, (example 2) or can be resonated with an equal and opposite reactance which is then absorbed into the network instead (example 3).

Impedance matching isn't really magic at all, is it?

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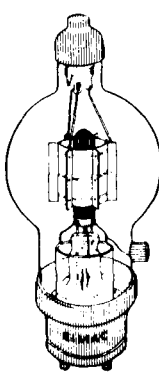
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fig. 1. This modest ad started it all in 1934. W6UF and W6CHE couldn't buy the tube they wanted, so they built their own.

It was the beginning of a long journey, still in progress. In 1934, I had little inkling of where the future would lead me.

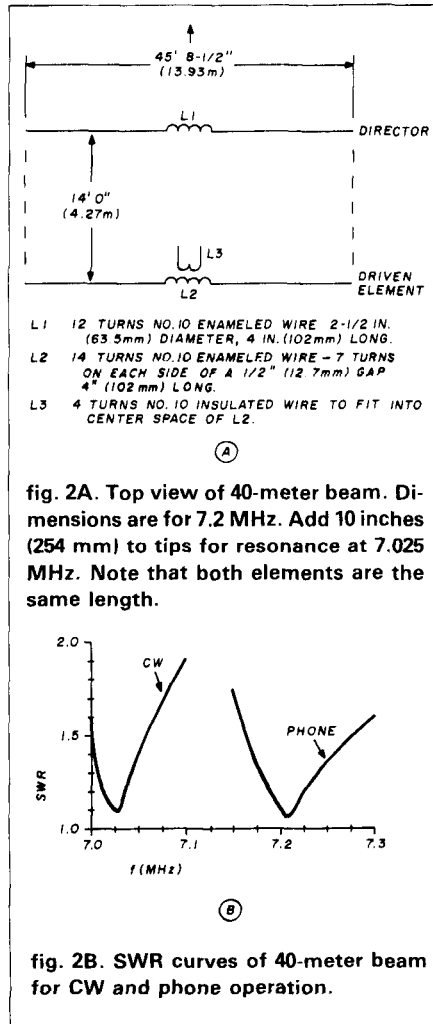
Across the continent, in San Bruno, California, two young Radio Amateurs were betting their future on a new tube development. Bill Eitel, W6UF, and Jack McCullough, W6CHE, combined their brains, talent, and their thin pocketbooks to start manufacturing a precedent-setting transmitting tube. Little did they realize they would revolutionize the world's tube industry and quickly assume a dominant role in the communications industry. And little did I realize, as I read the first EIMAC ad in November, 1934s *QST* (fig. 1), that these two pioneers would become my close friends and colleagues in years to come. Yes, 1934 was a very good year.

more on video disc RFI

In last month's column I commented on the severe RFI problems encountered with the video disc player which has active circuits that function in the 900-925 MHz range. No sooner had I written the column than I received the ARRL Letter which said, in part, that the FCC "had been informed by RCA Corporation that there is a potential interference problem resulting from the new 902-928 MHz secondary status allocation to the Amateur Radio service under Part 2 of the Rules."

RCA went on to state that the FCC should "seek recognition of the need for balancing a possible continuing experimental use of the 902-928 MHz band against the beneficial influence of the video disc player in the lives of millions of U.S. consumers, now, and for years to come."

Amazing! RCA, which has known of the potential incompatibility of its video disc player (as discussed in this column last month), could have chosen to redesign the unit to be immune to RF pickup, but instead chose to lay a "guilt trip" on the Radio Amateur and the FCC. The ARRL promises strong opposition to this move. I'll keep you informed!



tween 20 and 40 kHz, but at least one type operates in the ISM (Industrial-Scientific-Medical) band at 13.56 MHz.

The general theory of operation is that rectified AC is applied to an inverter whose output is RF energy at a frequency above 20 kHz. The RF energy is then applied to a fluorescent tube to strike an arc that excites the fluorescent coating to emit light.

Some of the RF lamps require that the RF oscillator be on continuously while the lamp is lit, while others require a burst of RF energy only when the lamp is turned on.

Compared to an incandescent lamp, the RF lamp is supposed to be more energy-efficient, using only 25 percent as much energy to produce the same lumen output as a conventional bulb.

A powerful argument exists, then, for the marketing of the RF lamp, if only as an energy conserver. The unanswered question is, how much RF interference do these lamps generate? And what will be the effect upon radio communications when hundreds of thousands (or millions) of these lamps are in daily use?

Last fall the FCC granted a limited waiver to various companies to manufacture and market 10,000 electronic ballast units and 100,000 RF light bulbs to be used in field testing and evaluations. The companies will study the cumulative effect of a large number of devices (installed in one plant and all connected to a single wiring system) on the amount of RF interference created, and how this correlates with the RFI level of a single device.

All well and good, but this operation reminds me of a student grading his or her own exam paper! I'm sure these noise generators will soon be on the market; the question is how much control will be exerted by the FCC over the noise radiated by these new RF lamps?

a compact 40-meter beam

As the sunspot cycle continues on its downward trend, activity picks up on the lower frequency bands that are

... and on RF lamps

Since the late 1970's several companies (General Electric, North American Phillips, International Energy Conservation System, and Soli-Tronics — among others) have been developing and manufacturing limited numbers of RF lighting devices. In general, these are fluorescent tubes that have electronic ballasting instead of an electromagnetic ballast.

One form of RF light is a self-contained lamp that screws into a standard bulb socket; a second type is an external solid-state RF ballast package that will replace the conventional ballast device in existing fluorescent lamps; and a third type of lamp makes use of RF energy delivered to it over the wires.

Most electronic ballasts operate be-

less affected by the rise and fall of the MUF (Maximum Usable Frequency). Forty meters is *really* coming into its own as a DX band! Some very effective beams are being used on this band, making it very hard for the average ham with a dipole or groundplane to enjoy contacts with exotic DX stations. One answer to this vexing problem is the miniature beam antenna. Despised by those who own full-size beams, the "mini-beam" can give a good account of itself provided it is well designed and properly built. Even a 40-meter mini-beam is quite large, and it's difficult to build one that won't fall apart in heavy wind. Shown in **fig. 2A** is a practical and rugged mini-beam design that has stood the test of time. Used by various California DXers for a decade, it can hold its own in a pile-up and also endure buffeting by heavy winds.

Center-loaded elements are used even though loading coils placed near the element tips are theoretically more efficient. The elements are made of 1 1/4-inch (31.75 mm) OD aluminum tubing with telescoping tips. Twelve foot (3.66 meters) long tubes are used.

The parasitic element is a director, and for CW operation at the low end of the band, is resonant at about 6.7 MHz. The driven element is resonant at 7.025 MHz. The elements are adjusted to resonance with the aid of a dip-oscillator before the beam is assembled. The coils are fixed and frequency adjustments are made to the tip sections.

Loading coils are wound on a 2 1/2 inch (6.35 mm) OD phenolic rod and are given a coat of epoxy after completion. RF current in the coils is quite high, so solid connections must be made between the coil and the elements with 1/2-inch (12.7 mm) wide copper strap.

The elements are supported on a 15-foot (4.57 m) long boom of 2 1/2-inch (63.5 mm) diameter, heavy wall aluminum tubing. Mounting plates and U-bolts hold the elements to the boom. Insulating sleeves are used between the U-bolts and the element sections, as illustrated.

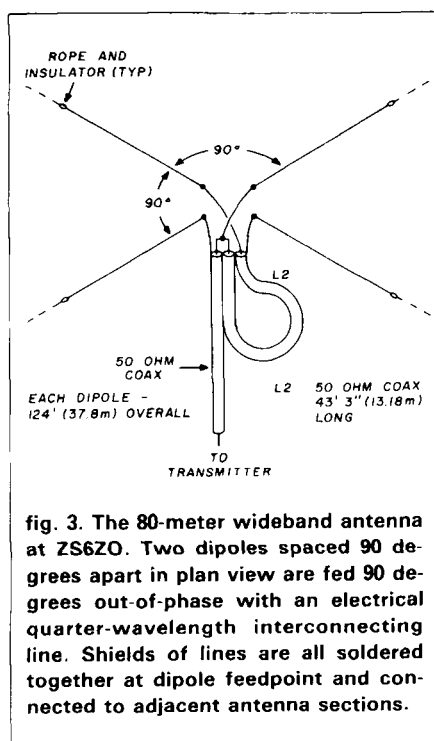


fig. 3. The 80-meter wideband antenna at ZS6ZO. Two dipoles spaced 90 degrees apart in plan view are fed 90 degrees out-of-phase with an electrical quarter-wavelength interconnecting line. Shields of lines are all soldered together at dipole feedpoint and connected to adjacent antenna sections.

SWR curves for the mini-beam are shown in **fig. 2B**, for the CW and SSB band segments. The SWR curve is affected by the director length, primarily, and by the adjustment of the coupling coil at the center of the driven element. Changing the director length by a few inches should drop the SWR curve down to a reasonable value at the design frequency.

Proper operation requires that the beam be well up in the air; a half-wavelength above ground is suggested as a minimum height. That means about 65 feet! Good results have been achieved with the beam as low as 35 feet, but the advantages of low angle radiation are lost when the beam is placed at a low elevation.

the ZS6ZO wideband 80-meter antenna

Dave, ZS6ZO, has had good luck on 80 meters with the Turnstyle-type antenna shown in **fig. 3**. He uses two dipoles cut to the middle of the band and spaced 90 degrees apart. He feeds them 90 degrees out-of-phase with a quarter-wave length of coaxial line between the dipoles. This provides circu-

lar polarization to the zenith and omnidirectional horizontal polarization to the horizon.

As one dipole increases in electrical length with respect to the design frequency, the other, via the quarter-wave line, appears shorter. This results in doubling the bandwidth over just two dipoles fed in parallel at the center points.

the forgotten RG-58 cable

Save money on your feedline? That's always an attractive proposition. It's not always necessary to use the expensive RG-8A/U or RG-213/U coax, especially for a lower frequency antenna when moderate power levels are used. This is where the RG-58 family of cable comes into use. As with other cables, there are several forms of RG-58 on the market: RG-58/U, RG-58/U type, RG-58A/U, RG-58A/U type and RG-58C/U type. The first two are older style cables with an impedance of 53.5 ohms. Stay away from these, because modern SWR meters are designed for 50-ohm line (the RG-58/U type may also be an inferior cable). The newer, 50-ohm cables are the RG-58A/U and the RG-58C/U. Of the two, the C/U is the better choice because of a non-contaminating (longlife) outer jacket. (The RG-58A/U and the RG-58A/U type both have the lower cost, PVC outer jacket which has a much shorter life.)

The RG-58C/U, when used below approximately 10 MHz, has only about 1 dB loss per one hundred feet, with the loss dropping as the frequency goes down. While the cable is not rated in terms of power carrying ability, I have used it with no problems at 1 kW PEP and CW input. Indeed for short runs of up to 25 or 30 feet, it can be used with success up to 30 MHz. At 28.6 MHz a 30 foot section runs slightly warm with 1 kW PEP input working into a load SWR of 1.5:1.

In order to use the cable with the popular PL-259 style of plug an adapter is required. The military number of this part is UG-175/U (Amphenol No. 83-185). The adapter fits inside the

PL-259 and allows the user to make a tight connection between plug and cable.

using the cable adapter

It is tempting to use the cable/plug assembly drawings shown in most handbooks, but I've found a simpler process that allows you to use the plug and adapter more than once. In other words, this method is easier to use and to disassemble than the process outlined in the handbook.

Strip the cable jacket back by 3/4 inch. (I use a sharp nail scissors to do this to prevent nicking the braid.) Trim the end of the jacket square; then, using the scissors, cut the braid back so that only 1/4 inch projects out from under the jacket. At this point (or before) the adapter and PL-259 outer coupling ring are slid over the cable, leaving just the short braid projecting from the rim of the adapter.

Spread the braid out evenly over the rim of the adapter and with the scissors, trim it back to the outer edge of the adapter. Only a fraction of an inch of the braid covers the lip of the adapter now. Next, solder the braid to the lip of the adapter all around the rim. (Use only a small soldering iron to avoid overheating the center insulation of the cable.) When the adapter has cooled, file the rough edges of the braid and solder down to a smooth surface. Thread the adapter and cable into the PL-259 plug and twist the plug/adapter combination tight with the aid of two pliers. Solder the inner conductor of the cable to the end of the center pin of the plug.

It actually takes longer to describe the operation than to do it. The connection has never worked loose in my experience, and it is very easy to unsolder the adapter and reuse it.

Remember that the PL-259 series of plugs are not waterproof; they should be protected against moisture regardless of the assembly technique used. I wrap mine with several layers of electrical tape and that seems to do the job.

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MRF433	13W	14.50	32.00
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MRF449	30W	12.00	27.00
MRF449A	30W	11.00	25.00
MRF450	50W	12.00	27.00
MRF450A	50W	12.00	27.00
MRF453	60W	15.00	33.00
MRF453A	60W	15.00	33.00
MRF454	80W	16.00	35.00
MRF454A	80W	16.00	35.00
MRF455	60W	12.00	27.00
MRF455A	60W	12.00	27.00
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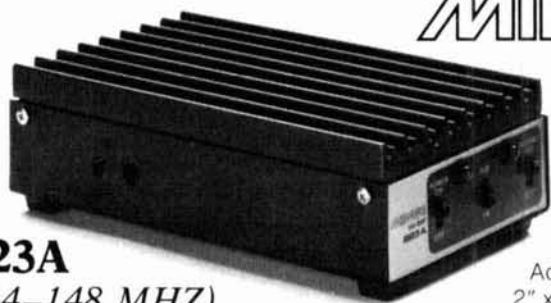
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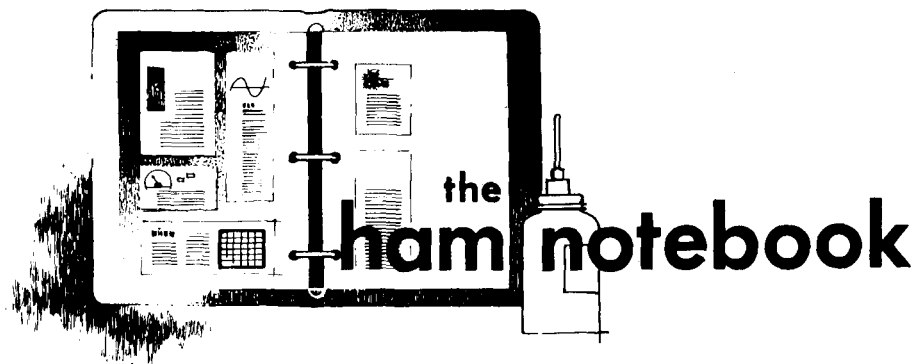
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limited space inverted "L"

During the past two years I have been assigned to Great Lakes Naval Training Center and have lived in a townhouse at Grayslake, Illinois. Needless to say, I never thought that I would be able to get on the air from this location at all — let alone on 160, 80, and 40 meters. How did I do it? With a good earth reference and some short inverted "L"s.

The ground reference for the antennas is a "window-well" retaining wall.

The dimensions are 4 × 5 feet with 2 feet on each side, leaving a total of 80 square feet of visible ground contact.

The antennas, all "shunt-fed," measure 14 feet in the vertical dimension. I spaced them across the front of the window-well 18 inches from the side of the house. Switching is made possible with a Heathkit antenna switcher. A single line trails into the basement via the air-conditioner pipe hole-through.

Figure 1 illustrates the three-band antenna configuration. Coil taps may

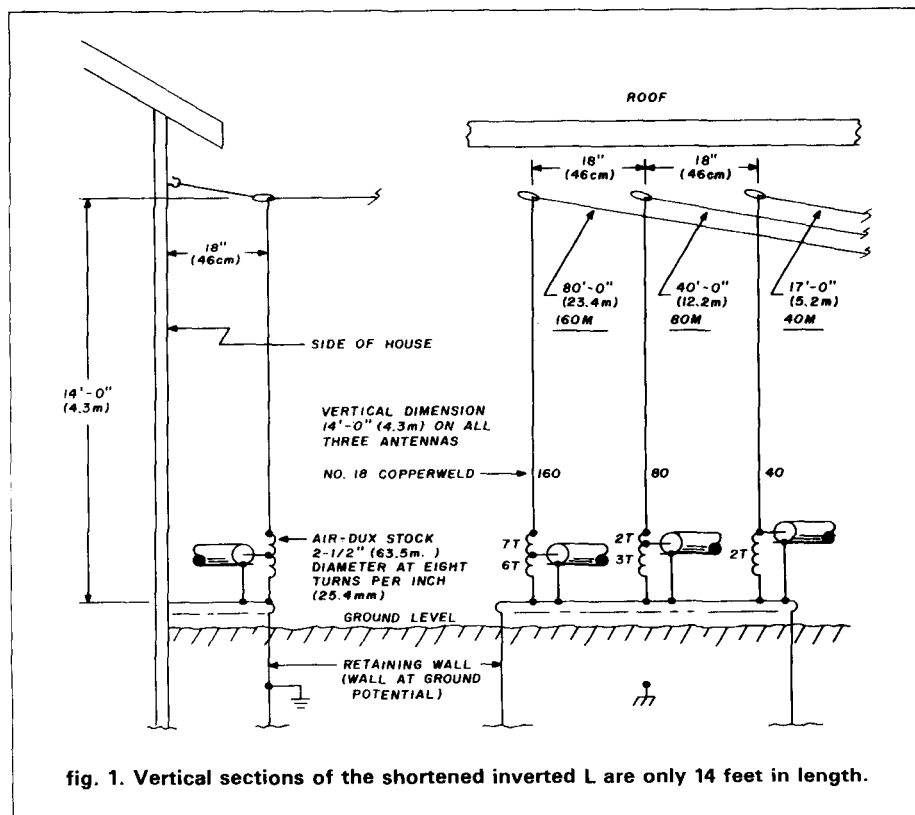


fig. 1. Vertical sections of the shortened inverted L are only 14 feet in length.

vary because your ground situation is unique to your QTH. However, the given coil information should be close. My successes have been "WAS" on 80/40 and 42 on 160 so far. I have worked 66 countries on top band and 74 on 80/40 this year, and also worked four JA stations for WAC on 160 again (last year I worked only one JA). I hope you can install the same kind of system I have had so much success with while "confined" to a townhouse.

Fred C. Race, W8FR

neutralizing 572B final at 1500 watts output

The recent FCC ruling setting 1 1/2 kW as the maximum power output prompted me to rework one of my home-made amplifiers, a pair of 572Bs, grounded grid, to grounded cathode for more output.

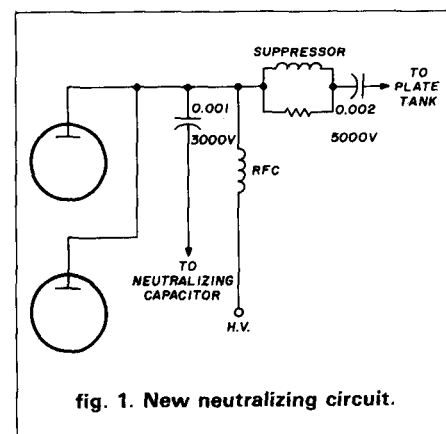


fig. 1. New neutralizing circuit.

The two tubes, fan cooled, would put out 550 watts in grounded grid before showing any color. Grid driven in Class C, they put out a nice 1425 watts. But there was a problem with the frequency-sensitive neutralizing settings. I could adjust the neutralization for stability on any one band, but it would sometimes take off on some other band. In the past I solved this problem by using a form of negative feedback in the filament circuit. However, this requires more drive power on the higher bands, and Class C is hard enough to drive as is.

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parasitic coils, I decided to take the parasitic coils out of the neutralizing path. I wired the two tubes directly to the hot end of the RF plate choke. From the same point I connected a 0.001 μ F 5000 volt mica capacitor to the neutralizing capacitor. Also from the same point I wired in one of the parasitic suppressors to the regular plate coupling capacitor. (See fig. 1.) This cured any tendency towards instability. Now with zero bias on the tubes and a full 2750 volts on the plates, no amount of band switching or knob twisting will show the tiniest twitch on the meters.

The parasitic choke is a self-supported coil consisting of seven turns of No. 14 wire, 5/16 inch (8 mm) diameter and 3/4 inch (19 mm) long. The swamping resistor is a Globar with a cold resistance of 400 ohms.

John Labaj, W2YU

high-frequency dummy load

This 52-ohm dummy load consists of twelve 620 ohm, 2-watt resistors housed in a salve can. The load is useful to 175 MHz.

It is capable of dissipating 30 watts on a 50 percent cycle and 50 watts on a shorter duty cycle.

Start construction by filing the outboard shoulder of a UG-176/UHF sleeve to a 3/32 inch (2.5 mm) height. Tin the inner shoulder of the sleeve and outboard end of the PL-259 fitting. The tinned areas are indicated as "solder" in the drawing.

Next, drill and ream a hole in the center of the bottom salve can to accommodate the UG-176/UHF sleeve. Then drill twelve No. 50 drill holes around the periphery of the can. They are on a line half way up the can. Tin area inside and out around each hole, mount the coax connector on the bottom and sweat solder in place.

Solder a 2-3/4 inch (70 mm) length of No. 14 wire center of PL-259 connector extending into the salve can. Fit each 620 ohm 2-watt resistor in place between the center conductor and hole drilled in the rim of the can. Clip

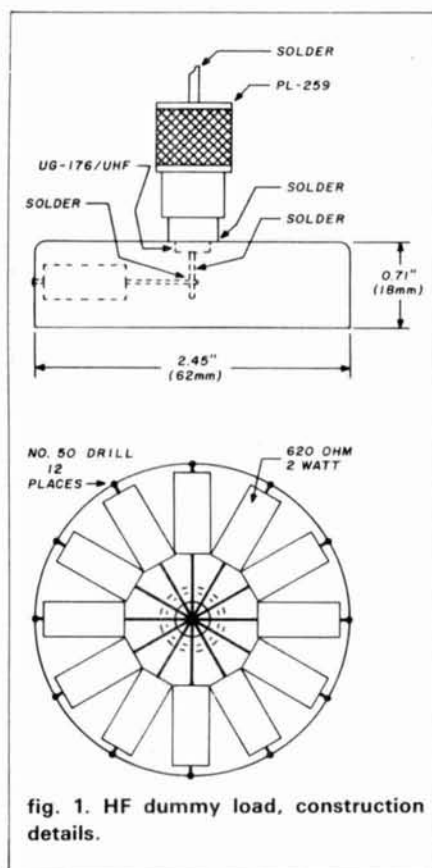


fig. 1. HF dummy load, construction details.

outer end about 1/32 inch (1 mm) beyond can and solder. Form resistor wire approximately half way around the No. 14 wire. After 12 resistors are mounted, consolidate their other ends about the No. 14 wire and solder.

Clip excess from No. 14 wire. Fit on the cover and you have a shielded dummy load.

William J. Goodwin, W1KWE

(Reprinted with permission from *Air Force MARS Communicator*.)

antenna support

I have been using nylon rope to hold up my vertical antennas. Nylon rope, however, tends to stretch and come apart, and it needs constant attention.

A better method is to use nylon fishing line. For small vertical antennas, a 300 to 600 pound-test line is okay. For larger antennas ask for cod line, which is almost 1/16-inch thick and very tough. Look in your fishing book for the right knots.

Ed Marriner, W6XM

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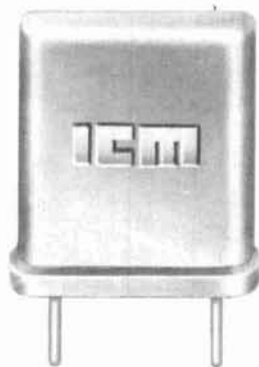
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TS-930S Optional Accessories:

AT-930 automatic antenna tuner, SP-930 external speaker, with selectable audio filters, YG-455C-1 (500 Hz), YG-455CN-1 (250 Hz), YK-88C-1 (500 Hz) CW filter, YK-88A-1 (6 kHz) AM filter, all plug-in type. SO-1 commercial stability TCXO, MC-60A deluxe desk microphone, MC-80 and MC-85 communications microphones, MC-42S mobile hand microphone, TL-922A linear amplifier (not for CW QSK), SM-220 station monitor, PC-1A phone patch, SW-2000 SWR/power meter, 160 ~ 6 meter, SW100A SWR/power/volt meter 160-2m HS-4, HS-5, HS-6, and HS-7 headphones.

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More information on the TS-930S is available from authorized dealers of Trio-Kenwood Communications, 1111 West Walnut Street, Compton, California 90220.



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TM-201A/TM-401A

TM-201A/TM-401A
"comp-ACT"... tough act to follow.

The word "compact" best describes the TM-201A VHF (a big 25 watts!) or the TM-401A 70-cm (12 watts) mobiles. Measures 5.6Wx1.6Hx7.2D inches (the TM-201A and TM-401A are the most compact rigs available). Ideal in size,

their performances are superlative. Each features a HI/LO power switch, dual digital VFO's built-in, 5 memories plus a "COM" channel with lithium battery back-up, memory scan, programmable band scan, priority alert scan, and GaAs FET RF (front end) amplifiers. They have a highly visible yellow LED digital display, a repeater offset switch, a reverse switch,

and a "beeper" to confirm operation of various switches. For superior sound quality, the separate, external speaker, can be easily mounted to project the sound in the desired direction. A 16-key autopatch UP/DOWN mic. allows easy remote operation of major front panel functions. Thanks to KENWOOD, compact radios are now available for the popular VHF and UHF bands providing high performance and superior sound quality.

Other TM-201A/TM-401A Optional Accessories:

TU-3 Programmable two-frequency CTCSS encoder, KPS-7A fixed station power supply, MA-4000 dual-band mobile antenna with duplexer, SW-100A/B SWR/power meter, MC-55 mobile microphone with time-out timer.



Optional FC-10 Frequency Controller

Connects to the TM-201A or TM-401A. Convenient control keys for frequency UP/DOWN MHz shift, VFO A/B, and MR (memory recall or change memory channel). A green LCD display indicates transmit/receive frequencies, memory channel number, ALERT, and SCAN (with blinking MHz decimal).

TW-4000A

TW-4000A
FM "Dual-Bander"

KENWOOD'S TW-4000A FM "Dual-Bander" provides new versatility in VHF and UHF operations, uniquely combining 2-m and 70-cm FM functions in one compact package. It covers the 2-m band (142.000-148.995 MHz), including certain MARS and CAP frequencies, and the 70-cm band (440.000-449.995 MHz), all in a package

only 6-3/8 W x 2-3/8 H x 8-9/16 D inches. RF output power measures 25 watts on either band. The TW-4000A features a large, easy-to-read LCD display, front panel illumination for night operations, 10 memories with OFFSET recall and lithium battery backup, programmable memory scan, band scan in selected 1-MHz segments, priority watch function, common channel scan, dual digital VFO's, repeater reverse switch, GaAs FET front ends, rugged die-cast chassis,

"beeper" through speaker, a mobile mount, and a 16-key autopatch UP/DOWN mic.

The new optional VS-1 voice synthesizer has everyone talking! A voice announces the frequency, band, VFO A or B, repeater offset, and memory channel number when these functions are selected.

Other TW-4000A optional accessories:

VS-1 voice synthesizer, TU-4C programmable two-frequency CTCSS encoder, KPS-7A fixed

station power supply, SP-40 compact mobile speaker, SP-50 compact mobile speaker, MA-4000 dual-band mobile antenna with duplexer, MC-55 mobile microphone with time-out timer, and a SW-100B SWR/power meter.

More information on the TM-201A/TM-401A and TW-4000A is available from authorized dealers of Trio-Kenwood Communications 1111 West Walnut Street Compton, California 90220.

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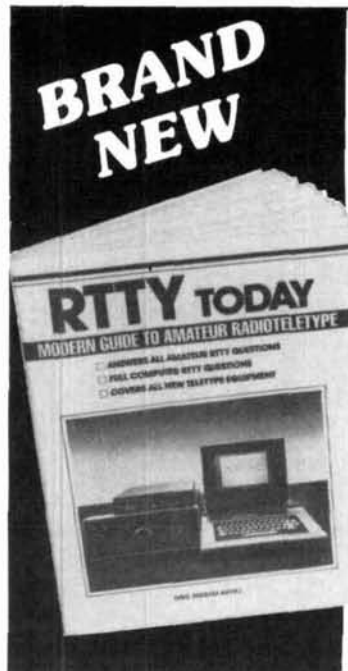
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NEW BT-1



The **BT-1 Basic Trainer** is a hand-held computerized unit which teaches the code one character at a time at 18 or 20 words per minute. The BT-1 contains a self-paced training program that allows serious students the possibility of learning Morse to 20 wpm in as little as one month! Each character represents a separate practice session in which the character is first introduced by itself, and then presented 50% of the time along with all previously learned characters. There are no tapes to memorize, wear out, or break. No programming skills are necessary; the BT-1 is very easy to use. The tone oscillator can also be keyed for sending practice. An earphone jack is provided for private listening. The BT-1 will go as high as 99 WPM in 1 WPM increments. A battery operated version, the BT-1P, is available with wall charger and internal NICAD batteries.

The **KT-3 Keyer-Trainer** unit uses the teaching program used in the BT-1 trainer. In addition, the KT-3 features a full function Morse automatic keyer for keying any modern transceiver, or for sending practice. Speed range is 18-99 wpm for transmitting and 1-99 wpm for training.

The **KT-2 Keyer-Trainer** is a computerized keyer with all the features shown above, plus a Morse proficiency trainer. It is designed to increase your existing code as quickly as possible. The unit can be set for beginning practice speed, ending practice speed, and duration of practice. The microcomputer does all the rest by gradually increasing the speed during the practice time selected. You can even select between fast code (Farnsworth) or slow code methods. The characters are sent in 5 letter groups, or random word lengths. Two levels of difficulty can be selected; common Morse characters or all English Morse characters. A 24,000 character answer book is provided for the 10 separate starting positions. There is also random practice mode for which no answers are available.



The **CK-2 Contester™ Keyer** is the lowest cost automatic keyer available featuring an automatic serial number generator for contesting. The CK-2 keyer features a large 500 character message memory that can be soft-partitioned into as many as 10 sections. An exclusive AEA edit mode makes it possible to correct mistakes made while entering messages or to insert words into previously established messages. Two different speeds can be set for fast recall in addition to a stepped variable speed control. The CK-2 features an automatic message repeat mode with variable delay-before-repeat for automatic CQ transmissions or TVI testing.

MM-2 MorseMatic™



The **MM-2 Morsematic Keyer** represents the most sophisticated paddle keyer ever designed and features two powerful microcomputers. The Morsematic incorporates virtually all the features (except the preset and stepped variable speeds) of both the CK-2 and KT-2 shown above. In addition, the MM-2 offers an exclusive automatic beacon mode which is invaluable for meteor scatter, moonbounce scheduling, or beacon operation.

NEW KT-3



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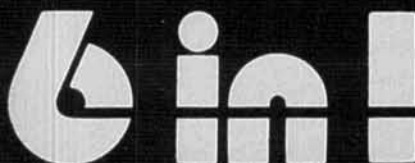
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NEW! % Soft Orange background Liquid Crystal Display (LCD) for direct sunlight viewing plus lighting for night viewing.

NEW! % Offset (+, -) stored in memory along with the frequency information.

NEW! % Frequency coverage of 142,000 to 149,995 MHz for M.A.R.S. and C.A.P. usage.

NEW! % Chrome front panel with accent knobs and lighter color on case to match today's auto decor.

NEW! % Scan for signal now has 3-second delay before resume after loss of signal.

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.
- Tone unit switch on front panel to prevent "humming" on the wrong channel.
- Repeater input monitor capability with the push of a single momentary switch.
- Solid-state level meter for both output level and input level monitoring.
- User programmable initial characteristics for band limits, channel step size, etc.
- Odd repeater splits can be handled with the memory in the AxB mode.
- Programmable band-scan limits are stored in protected RAM.
- 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 memo-

ry, 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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microphone calibration

Don't guess —
here's how to determine
your microphone's
frequency response
with or without
a computer

A look around the serious ham's shack will often reveal many pieces of test equipment used to monitor the performance of commercial gear and run tests during the construction of homebrew gear. This equipment is also invaluable for "checking" items obtained during those innumerable scrounging trips that legend says soon become part of every Amateur's life.

Yet, the same serious Amateur who wouldn't dream of trying out a new antenna without first pulling out a trusty VSWR meter may think nothing of sticking a loudspeaker in a box without testing to see whether there are any nasty resonances, and will mount a microphone element in a holder other than the one for which it was designed without doing any tests at all. This lack of quantitative measurement in the performance of acoustic equipment is apparent in the poor audio quality of many stations you hear on the air. In light of the fact that many hams also consider themselves audio buffs, it's surprising that more testing isn't done and that discussions often include such inaccurate descriptions of sound quality as "wide-range," "boomy," "vibrant."

One reason more testing isn't done is that a calibrated microphone is necessary for truly accurate results. Calibrated microphones are expensive and

their purchase difficult to justify, considering the few times that they are needed. This article describes a method of calibrating *any* microphone for use as a standard. You don't need an expensive microphone; in fact, instead of a microphone, a small loudspeaker will be sufficient. Any irregularities in the frequency response are not important. The calibration curve will reveal their location and magnitude, thereby enabling the proper allowances to be made.

Those of us who like to use only the latest technology may be disappointed to learn that the method used, the Reciprocity Principle, was described in a book entitled *Theory of Sound* written by Lord Rayleigh in 1877. It apparently wasn't new even at that time.

In applying the principle to microphone calibration, two loudspeakers, (one of which must be reversible), and the microphone under test are employed. When we say that one of the loudspeakers must be reversible, we mean simply that it must be capable of functioning as both a loudspeaker and a microphone. Common cone-type speakers with voice coils meet this requirement.

The first step consists of setting up the equipment shown in **fig. 1**. Loudspeaker SP1, and amplifier A serve simply as a sound source and do not need any special features. The loudspeaker of your stereo system, already connected to an amplifier, can be used as a convenient SP1.

Loudspeaker SP2, which must be reversible, and microphone M, whose calibration we seek, are placed side by side at distance d in front of SP1. (Distance d should be the same as the distance you intend to use for future tests because the low-frequency response of many microphones varies slightly with distance from the sound source.) The distance selected will depend upon the nature of the information desired; a microphone-to-speaker spacing of less than two feet greatly excludes the acoustic effects of

By Daniel Peters, NY6U, Falcon Communications, P.O. Box 620625, Woodside, California 94062

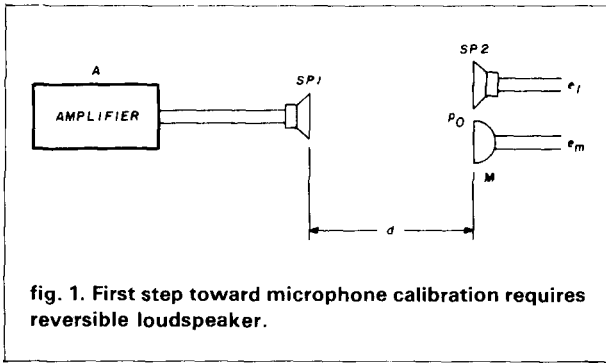


fig. 1. First step toward microphone calibration requires reversible loudspeaker.

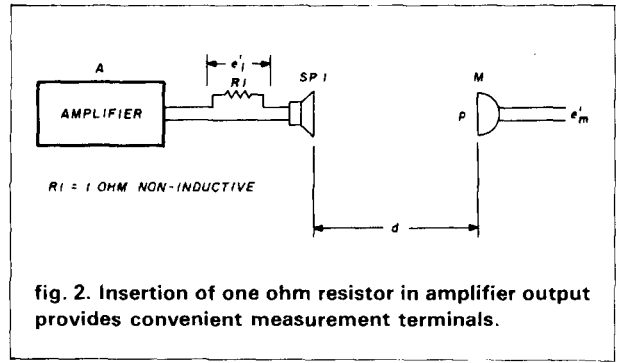


fig. 2. Insertion of one ohm resistor in amplifier output provides convenient measurement terminals.

the room, while larger spacings provide a measure of the effect of room acoustics. If you are calibrating your usual station microphone, it would be well to set distance d the same as your normal mouth-to-microphone distance.

Because the high frequency response of most microphones changes for different angles of incidence, position M and SP2 so that they point directly at SP1. For the same reason, place M and SP2 close to each other and aim SP1 squarely at them.

Feeding an audio tone into SP1 results in a sound pressure P_0 at M and SP2, which generates an open circuit voltage e_m and e_1 , respectively. Measure and record these voltages at each frequency of interest, using either a millivoltmeter or an audio amplifier followed by an AC voltmeter. As long as you use the same meter to make all measurements, the frequency response of the measuring instrument will not affect the results. Likewise, it is not necessary that SP1, or the audio signal driving it, have a flat, or even known amplitude. If you do not have a variable frequency audio generator to drive the amplifier connected to SP1, a tape with recorded audio tones will serve. Again, frequency response is not important; all you need is a source of known frequency.

Use a signal into SP1 sufficient to mask any background noise. However, keep the amplitude low enough to prevent overloading; otherwise the harmonics generated will give erroneous results.

Next, connect the equipment as shown in fig. 2. Note that we have replaced SP1 with SP2 and have added a 1-ohm resistor in series with the amplifier output. Distance d should remain unchanged. Supply audio power and measure voltages e'_m and e'_1 at the same frequencies and with the same meter as used in the preceding steps. Actually the current in SP2 is the quantity of interest; the 1-ohm resistor, R1, provides a 1-volt drop for every ampere of current, thereby allowing the use of the same voltmeter used in our other measurements.

After measuring e'_m and e'_1 at the same frequencies at which e_m and e_1 were measured, you should end up with a set of data such as shown in table 1.

table 1. Sample microphone calibration data.

f(MHz)	e_1^*	e_m	e'_1	e'_m
20	0.50	0.40	190	3.6
30	0.50	0.70	250	6.0
40	0.60	1.50	320	4.8
60	0.40	2.30	320	1.6
80	0.62	2.60	320	5.2
100	2.40	1.40	320	1.8
150	0.65	0.50	320	5.2
200	0.36	1.40	320	5.1
300	0.36	2.70	320	8.8
500	0.74	5.40	320	25.5
700	1.90	7.80	320	170.0
1000	1.50	36.00	320	30.0
1500	2.20	12.00	320	37.0
2000	2.90	14.00	320	84.0
3000	0.70	0.16	320	34.0
4000	0.28	8.20	320	110.0
5000	0.14	6.80	320	54.0
7000	0.08	1.60	320	52.0

*All voltages in millivolts.

The formula for calculating the microphone sensitivity, S_m , is:

$$S_m = K \sqrt{\frac{e_m e'_m}{e_1 e'_1 f}} \quad (1)$$

The derivation of the above formula, including the value of k , is provided in the appendix. However, since a relative response curve is all that is generally required, the value of k is not important and can be left out of the formula, resulting in:

$$S_{mr} = \sqrt{\frac{e_m e'_m}{e_1 e'_1 f}} \quad (2)$$

In the above formula, S_{mr} is the relative microphone sensitivity, and f is the frequency in Hz; voltages are expressed in volts. If you took your readings in mV, you can use mV, if you use mV for all four entries.

Substitute the values recorded for each frequency in the formula and calculate the relative sensitivities. After finding the relative sensitivity for frequencies of interest, select a value considered an average and calculate all other points in reference to the selected one,

table 2. Sample relative microphone sensitivity calibration chart.

f(MHz)	e_1^*	e_m	e_1'	e_m'	S_{mr}	% S_{mr}^{**}
20	0.50	0.40	190	3.6	0.0275	99.21
30	0.50	0.70	250	6.0	0.0334	120.60
40	0.60	1.50	320	4.8	0.0306	110.30
60	0.40	2.30	320	1.6	0.0218	78.89
80	0.62	2.60	320	5.2	0.0291	105.10
100	2.40	1.40	320	1.8	0.0057	20.64
150	0.65	0.50	320	5.2	0.0091	32.89
200	0.36	1.40	320	5.1	0.0176	63.44
300	0.36	2.70	320	8.8	0.0262	94.49
500	0.74	5.40	320	25.5	0.0341	122.90
700	1.90	7.80	320	170.0	0.0558	201.10
1000	1.50	36.00	320	30.0	0.0474	170.90
1500	2.20	12.00	320	37.0	0.0205	73.89
2000	2.90	14.00	320	84.0	0.0251	90.71
3000	0.70	0.16	320	34.0	0.0028	10.25
4000	0.28	8.20	320	110.0	0.0501	180.80
5000	0.14	6.80	320	54.0	0.0404	145.90
7000	0.08	1.60	320	52.0	0.0215	77.65

average sum
0.0277

*All voltages in millivolts.

$$^{**}\% S_{mr} = \frac{S_{mr}}{S_{mr}(\text{average})} \times 100\%$$

where S_{mr} average = sum of all S_{mr} readings
divided by 18 (number of lines of data)

either as a percentage or in dB, using the selected value as 0 dB. (See **table 2.**) (Results may be plotted in the form of a graph.)

You are now ready to use your newly calibrated microphone. One word of caution: when you use the calibrated microphone to test a favorite loudspeaker or microphone that you thought to be "flat," don't be surprised if the response curve resembles a Rocky Mountain skyline.

Individually tuning the ports seen on many microphone cases and loudspeaker enclosures by partially covering or otherwise impeding the air flow with various fabrics can often do much to improve their response. However, even when you've adjusted the system for optimum performance the curve is still going to look pretty rough, and it's better not to mention it to your uninitiated friends because they'll inevitably insist that their similar component is "flat." It isn't — and you know it — but why lose friends?

appendix

derivation of formula

Referring to **fig. 1**:

$$e_l = S_l P_o \quad (1)$$

$$e_m = S_m P_o \quad (2)$$

where: S_l = sensitivity of SP2 (in abvolts per dyne per square centimeter)

S_m = sensitivity of M

If we assume SP2 is a conventional loudspeaker, we know that e_l is produced by a conductor moving in a magnetic field, or:

$$e_l = blv \quad (3)$$

where: b = flux density in speaker gap, in Gauss

l = length of wire in the voice coil, in cm

v = velocity of the coil, in cm per second

From the "Ohms law" of mechanical circuits:

$$V = \frac{P_o A}{Z_m} \quad (4)$$

where: A = diaphragm area in square centimeters

Z_m = mechanical impedance of the vibrating system in mechanical ohms

Combining **eqs. 1, 3, and 4**:

$$S_l = \frac{e_l}{P_o} = \frac{blA}{Z_m} \quad (5)$$

Referring now to **fig. 2**, the pressure p at M, caused by SP2 located d centimeters away, is given by:

$$P = \frac{r_a V}{2\lambda d} \quad (6)$$

where: r_a = acoustic impedance of the atmosphere in mechanical ohms (41.5 for standard air at sea level)

λ = wavelength of sound, in cm

The velocity v for a current of i amperes in SP2 is given by:

$$v = \frac{bli}{Z_m} \quad (7)$$

Combining **eqs. 6 and 7**:

$$P = \frac{rblAi}{2\lambda d Z_m} \quad (8)$$

From **eqs. 8 and 5**:

$$P = \frac{riSl}{2d\lambda} \quad (9)$$

The pressure p on M produces a voltage e_m' given by:

$$e_m' = S_m P \quad (10)$$

Combining this with eq. 9:

$$S_m = \frac{2d\lambda e_m'}{S_j r i} \quad (11)$$

Combining eqs. 1 and 2 to eliminate P_o and then substituting for S_1 :

$$S_m = \sqrt{\frac{2d\lambda e_m e_m'}{e_j r i}} \quad (12)$$

However, since $i = e_j'$, by virtue of the 1-ohm resistor:

$$S_m = \sqrt{\frac{2d\lambda}{r} \cdot \frac{e_m e_m'}{e_j e_j'}} \quad (13)$$

Finally, remembering that $\lambda = v/f$, where $v =$ velocity of sound in cm/sec:

$$\begin{aligned} S_m &= \sqrt{\frac{2dv}{r}} \cdot \sqrt{\frac{e_m e_m'}{e_j e_j' f}} \\ &= k \sqrt{\frac{e_m e_m'}{e_j e_j' f}} \end{aligned} \quad (14)$$

Thus, using only equipment likely to be found in any well equipped shack, an absolute calibration curve for the sensitivity of a microphone can be obtained without the use of a previously calibrated standard.

microphone calibration program

By Nick Corcodilos, 765 San Antonio Road #51, Palo Alto, California 94303

The program listing provided here has been designed to automate the number-crunching necessary in calibrating your microphone. Although developed for the Radio Shack TRS-80 Model 1[®] computer, the program should run on other TRS-80s, and, with a little modification, on most computers that have a BASIC interpreter. Even though BASIC is widely used, there is no standard version usable on all machines. So if you're using a Commodore or a Timex/Sinclair, for example, some of the code will have to be modified.

The version of BASIC used here is what Radio Shack calls Level II BASIC. It requires no disk drives. An Epson MX-80 dot matrix printer was used to test the program; other printers should work equally well.

Once you've typed the program into your computer, you'll want to save it for later use. You can do this using disks or a cassette storage device. Look up the "SAVE" command in your computer manual for instructions. The "LOAD" and "RUN" commands will also be useful.

The TRS-80 Model 1 CRT Monitor, (16 lines \times 60 characters) can display fourteen calibration samples before it scrolls. The program takes these limits into account. If you have a TRS-80 with a 24 line by 80 character screen, you'll have to modify the program to take full advantage of your monitor.

To start, begin typing in the program. Type in the lines of code exactly as they are listed. The spaces between words are as critical as characters; count the spaces carefully and put them in the right places. There are important differences between commas (,), semicolons (;), and colons (:). Type patiently and check and recheck your typing.

Because the program was written to be understandable, plenty of "Remark" statements are included. These remarks are preceded by a single quote (') either after a line number or at the end of a line of code, and are not executed during a program run. They are included to break up the code and help you see which sections of code do what. When you type these, be sure to include the leading (').

When you run the program, it will prompt you to enter five data values for each sample: the frequency (Hz) of the sample, loudspeaker voltages E(L) and E(L)1 where 1 signifies "prime," and microphone voltages E(M) and E(M)1. (These correspond to $e_l, e_l', e_m,$ and e' in the tables.) Since all values for one sample are to be entered together, you'll have to record your original data on paper while you're taking measurements with L2 in its two different positions. (Note L1 = SP1, L2 = SP2.)

The program will produce three tables at the end of its run. Together, these tables will be roughly equivalent to table 2 in the article. When each table appears on the screen, you'll be asked if you want to print that table. When responding to the "<P> to print to printer?" prompt, be sure to use a capital "P." Lower case won't work.

The main values you'll be interested in are the Relative Microphone Sensitivities (S_{mr} 's) for each sample frequency. Also provided is the Average S_{mr} , which you may or may not be interested in. Keep in mind that the Average S_{mr} is just an intermediate value; it is provided in case you should want to do something with it.

In the interest of simplicity, the program has limited error-recovery capability. BASIC does not allow dividing a number by zero. Because some of the calculations the program performs are divisions (in lines 510 and 598), you may experience this problem. If you enter a zero data value, you'll get a "divide by 0" or "/0" error on the screen and your results will be invalidated; the program will "crash." If you enter a character instead of a number (the program accepts numerical data only), you'll get a "?redo from start" error message. Just retype your data value, using a number this time.

If you enter a value incorrectly (for example, 125 instead of 12.5), you will have an opportunity to correct your error after all values for that one sample have been entered (you cannot correct a zero entry). In other words, you can cancel a sample and re-enter it if you do so before going on to the next sample. You cannot change a sample after all samples have been entered. When responding to the prompt "<X> to correct this sample" be sure to use a capital, not lower case, "X."

Be sure your printer is on before you request the printing of a table. Programs run on the Model 1 computer have been known to "crash" if a printer wasn't ready and waiting when needed.

To cancel the program at any point, press <BREAK>. Type "run" followed by a carriage return to start the program again. When the last table has been displayed on the screen, the program will recycle to its beginning, with all data wiped out. You'll know you're there when you see "MICROPHONE CALIBRATION - NEW DATA" at the top of the screen. New data must then be typed in.

Those who need more than fourteen samples in your calibration efforts can either run the program more than once with the additional samples, or tweak the program a bit; with tweaking, your tables will scroll off the screen because they'll be too big, but if you have a printer, the full tables can be printed there with no losses. To tweak the program, change every "14" in lines 220, 350, and 355 to the number of samples you wish to use. That's it. (If your program crashes after these modifications, it's probably because your computer doesn't have enough memory to handle the new number of samples.)

Note: This program is also available in a version designed for use on the IBM PC. For a copy of that program, send a business-sized SASE to N.A. Corcodilos, 765 San Antonio Road #51, Palo Alto, California 94303. — Editor

```

50 '          PROGRAM BY N A CORCODILOS 2/25/84
55 '          DEVELOPED AROUND AN IDEA BY D PETERS
60 '
100 '          MICROPHONE CALIBRATION PROGRAM - TRS80 MODEL 1
110 '                                     LEVEL II BASIC
150 '
200 '-----DEFINITION OF VARIABLES
210 '
220 DIM M(14), M1(14), L(14), L1(14), F(14), SMR(14)
250 '
300 '-----DATA ENTRY
310 '
320 CLS
330 PRINT "MICROPHONE CALIBRATION DATA - NEW DATA"
340 PRINT
350 INPUT "HOW MANY SAMPLES WILL YOU ENTER (14 MAX)      ";S
355 IF S<1 OR S>14 THEN 300 'CHECKS FOR TOO MANY OR FEW SAMPLES
400 CLS
430 '
440 FOR J=1 TO S
445 PRINT "MICROPHONE CALIBRATION DATA      ";S;" SAMPLES"
446 PRINT
450 PRINT "SAMPLE # ";J
460 INPUT "F(HZ)          ";F(J)
470 INPUT "E(L)           ";L(J)
480 INPUT "E(M)           ";M(J)
490 INPUT "E(L)1          ";L1(J)
500 INPUT "E(M)1          ";M1(J)
510 I=((M(J)*M1(J))/(L(J)*L1(J)*F(J))) 'INTERMEDIATE VALUE
520 SMR(J)=SQR(I) 'SQR IS A BASIC FUNCTION WHICH TAKES SQ ROOT
530 PRINT
540 PRINT "SMR FOR ";F(J);"HZ = ";:PRINT USING "##.####";SMR(J)
550 PRINT
560 INPUT "<X> TO CORRECT THIS SAMPLE, <ENTER> TO CONTINUE ";Q$
570 IF Q$="X" THEN CLS:PRINT "MICROPHONE CALIBRATION DATA      ";S;" SAMPLES"
575 IF Q$="X" THEN PRINT:Q$="":GOTO 450
580 IF Q$<>"" THEN Q$="":GOTO 560
585 Q$="":CLS
590 NEXT J
591 '
592 '-----SUM & AVERAGE SMR'S
593 '
594 FOR J=1 TO S
595 H=H+SMR(J) 'H IS A HOLDING VARIABLE
596 NEXT J
597 '

```

```

598 AVGSMR=(H/S)
600 '
610 '-----PRINT CALIB TABLE 1 TO SCREEN
620 '
630 PRINT "F(HZ)","E(L)","E(M)","      TABLE 1"
640 FOR J=1 TO S
650   PRINT F(J),L(J),M(J)
660   NEXT J
675 INPUT "<P> TO PRINT TABLE TO PRINTER, <ENTER> TO CONTINUE INSTEAD ";Q$
676 IF Q$="P" THEN GOSUB 2000 ELSE IF Q$<>"" THEN 675
678 '
680 '-----PRINT CALIB TABLE 2 TO SCREEN
681 '
682 CLS:PRINT "F(HZ)","E(L)1","E(M)1"
684 FOR J=1 TO S
685   PRINT F(J),L1(J),M1(J)
686   NEXT J
688 INPUT "<P> TO PRINT TABLE TO PRINTER, <ENTER> TO CONTINUE INSTEAD ";Q$
689 IF Q$="P" THEN GOSUB 3000 ELSE IF Q$<>"" THEN 688
690 '
900 '-----PRINT CALIB TABLE 3 TO SCREEN
910 '
920 CLS
970 PRINT "F(HZ)","SMR","AVERAGE SMR = ";:PRINT USING "##.###";AVGSMR
990 FOR J=1 TO S
1000  PRINT F(J),
1010  PRINT USING "##.###";SMR(J)
1050  NEXT J
1110 INPUT "<P> TO PRINT TO PRINTER, <ENTER> TO RESTART PROGRAM ";Q$
1115 IF Q$="P" THEN GOSUB 4000 ELSE IF Q$<>"" THEN 1110
1200 RUN      'RESTART PROGRAM AFTER FINISH PROCESSING
1900 '
2000 '-----LPRINT ROUTINE TABLE 1
2020 '
2100 CLS:INPUT "TURN PRINTER ON & ALIGN PAPER - PRESS <ENTER> ";Q$
2110 LPRINT:LPRINT "MICROPHONE CALIBRATION TABLE 1"
2120 LPRINT:LPRINT
2130 LPRINT "F(HZ)","E(L)","E(M)"
2140 LPRINT
2150 FOR J=1 TO S
2160   LPRINT F(J),L(J),M(J)
2170   NEXT J
2175 LPRINT:LPRINT:LPRINT:LPRINT
2178 Q$=""
2180 RETURN
2190 '
3000 '-----LPRINT ROUTINE TABLE 2
3020 '
3100 CLS:INPUT "TURN PRINTER ON & ALIGN PAPER - PRESS <ENTER> ";Q$
3110 LPRINT:LPRINT "MICROPHONE CALIBRATION TABLE 2"
3120 LPRINT:LPRINT
3130 LPRINT "F(HZ)","E(L)1","E(M)1"
3140 LPRINT
3150 FOR J=1 TO S
3160   LPRINT F(J),L1(J),M1(J)
3170   NEXT J
3175 LPRINT:LPRINT:LPRINT:LPRINT
3178 Q$=""
3180 RETURN
3190 '
4000 '-----LPRINT ROUTINE TABLE 3
4010 '
4100 CLS:INPUT "TURN PRINTER ON & ALIGN PAPER - PRESS <ENTER> ";Q$
4110 LPRINT:LPRINT "MICROPHONE CALIBRATION TABLE 3"
4120 LPRINT:LPRINT
4130 LPRINT "F(HZ)","SMR","AVERAGE SMR = ";:LPRINT USING "##.###";AVGSMR
4140 LPRINT
4150 FOR J=1 TO S
4160   LPRINT F(J),:LPRINT USING "##.###";SMR(J)
4170   NEXT J
4175 LPRINT:LPRINT:LPRINT:LPRINT
4178 Q$=""
4180 RETURN

```

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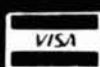


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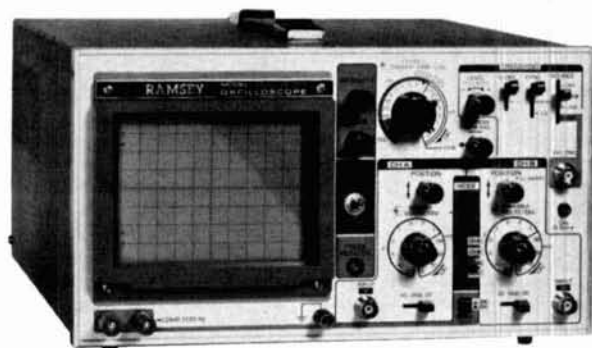
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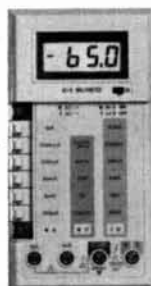


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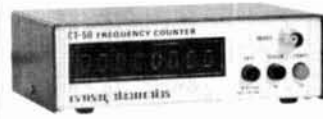
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<p>CMOS</p> <p>4011 50 4013 50 4046 \$1.85 4049 50 4059 \$9.00 4511 \$2.00 4518 \$1.35 5639 \$1.75</p>	<p>SPECIAL</p> <p>11C90 \$15.00 10116 \$17.50 7208 \$17.50 7207A \$5.50 7216D \$21.00 7107C \$12.50 5314 \$2.95 5375AB/G \$2.95</p>	<p>Switches</p> <p>Mini toggle SPDT \$1.00 Red Pushbuttons N/O 3/\$1.00</p>	<p>AC Adapters</p> <p>Good for electronic chargers, all 110 VAC, plug one end.</p> <p>8.5 vdc @ 20 mA \$1.00 16 vdc @ 160mA \$2.50 12 vdc @ 250mA \$2.00</p>																		
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<p>READOUTS</p> <p>FND 359 4" C.C. \$1.00 FND 507/510 5" C.C. 1.00 MAN 72/HP7730 33 C.A. 1.00 HP 7651 43 C.A. 2.00</p>	<p>DC-DC Converter</p> <p>+5 vdc input prod. -9 vdc @ 30ma +9 vdc produces -15 vdc @ 35ma \$1.25</p>	<p>Capacitors</p> <table border="1"> <tr> <th>TANTALUM</th> <th>ALUMINUM</th> <th>DISK CERAMIC</th> </tr> <tr> <td>Dipped Epoxy</td> <td>Electrolytic</td> <td>01 16V disk 20/\$1.00</td> </tr> <tr> <td>1.5 uF 25V 3/\$1.00</td> <td>1000 uF 15V Radial \$5.00</td> <td>1 16V 15/\$1.00</td> </tr> <tr> <td>1.8 uF 25V 3/\$1.00</td> <td>500 uF 20V Axial \$5.00</td> <td>100 16V 20/\$1.00</td> </tr> <tr> <td>2.2 uF 25V 3/\$1.00</td> <td>150 uF 16V Axial 5/\$1.00</td> <td>100 pF 20/\$1.00</td> </tr> <tr> <td></td> <td>10 uF 15V Radial 10/\$1.00</td> <td>100 16V 20/\$1.00</td> </tr> </table>	TANTALUM	ALUMINUM	DISK CERAMIC	Dipped Epoxy	Electrolytic	01 16V disk 20/\$1.00	1.5 uF 25V 3/\$1.00	1000 uF 15V Radial \$5.00	1 16V 15/\$1.00	1.8 uF 25V 3/\$1.00	500 uF 20V Axial \$5.00	100 16V 20/\$1.00	2.2 uF 25V 3/\$1.00	150 uF 16V Axial 5/\$1.00	100 pF 20/\$1.00		10 uF 15V Radial 10/\$1.00	100 16V 20/\$1.00	<p>OP-AMP Special</p> <p>BI-FET LF 13741 - Direct pin for pin 741 chip, but 500,000 MEG input z, super low 50 pa input current, power drain</p> <p>50 for only \$9.00 10 for \$2.00</p>
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<p>TRANSISTORS</p> <p>2N3904 NPN C-F 15/\$1.00 2N3906 PNP C-F 15/\$1.00 2N4403 PNP C-F 15/\$1.00 2N4410 NPN C-F 15/\$1.00 2N4916 FET C-F 4/\$1.00 2N5401 PNP C-F 5/\$1.00 2N6028 C-F 4/\$1.00 2N3771 NPN Silicon \$1.50 2N5179 UHF NPN 3/\$2.00 Power Tab NPN 40W 3/\$1.00 Power Tab PNP 40W 3/\$1.00 NPN 102/2N5484 \$1.50 NPN 3904 Type T-R 50/\$2.50 PNP 3906 Type T-R 50/\$2.50 2N3055 4.00 2N2646 UJT 3/\$2.00</p>	<p>Crystal Microphone</p> <p>Small 1" diameter 1/4" thick crystal mike cartridge .75</p>	<p>Parts Bag</p> <p>Ass't of chokes, disc caps, tantal resistors, transistors, diodes, MICAs, caps, etc. sm bag 100 pcs \$1.00 / 300 pcs \$2.50</p>	<p>9 Volt Battery Clips</p> <p>Nice quality clips 5 for \$1.00 1/4" Rubber Grommets 10 for \$1.00</p>																		
<p>25 AMP 100V Bridge \$1.75 each</p> <p>Mini-Bridge 50V 1 AMP 2 for \$1.00</p>	<p>Coax Connector</p> <p>Chassis mount BNC type \$1.00</p>	<p>Trimmer Caps</p> <p>Sprague 3-40 pf Stable Polypropylene 50 ea.</p>	<p>Shrink Tubing Nubs</p> <p>Nice pre-cut pieces of shrink size 1" x 1/4" shrink to 1/8" Great for splices 50/\$1.00</p>																		
<p>25 AMP 100V Bridge \$1.75 each</p> <p>Mini-Bridge 50V 1 AMP 2 for \$1.00</p>	<p>LEDs - your choice, please specify</p> <p>Mini Red, Jumbo Red, High Intensity Red, Illuminator Red 8/\$1 Mini Yellow, Jumbo Yellow, Jumbo Green 8/\$1</p>	<p>Connectors</p> <p>6 pin type gold contacts for mA-1003 car clock module price .75 ea.</p>	<p>Regulators</p> <p>7812 \$1.00 7815 \$1.00 7905 \$1.25 7912 \$1.25 7915 \$1.25</p>																		
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improving meteor scatter communications

It has been estimated that each day 50 to 100 million particles orbiting in space enter the Earth's gravitational field and are literally swept into the ionosphere. These particles, or meteors, as they are often called, are usually quite small — even as small as a grain of sand — and may leave a bright trail as they burn up by frictional heating when entering the atmosphere.

As meteors burn they produce ionization in the "E" layer (typically 50 to 150 km above the Earth). For many years VHF/UHFers have been using this ionization as one of the primary modes of propagation for working DX on 6 and 2 meters. A form of forward scatter, this is usually referred to as "meteor scatter."

During the late 1950s the race for the first 2-meter WAS began, and meteor scatter became one of the prime propagation modes. It soon became obvious that it was very difficult to work new states, especially when they were over 1200 miles (1930 km) distant. Predicting the best time and day were mainly based on luck or past experience.

When the competition for the first 220 MHz and 70 cm (432 MHz) meteor scatter QSOs began, the difficulty increased even further.¹ In fact, as of to-

day, only about a half-dozen 70 cm QSOs have been claimed since the original one on August 12, 1972.²

Over the past ten years I have been gathering information on meteor scatter communications and developing techniques, some already known, and some that are perhaps new to Amateurs. This information may assist you in pinpointing meteor scatter maximums, choosing the optimum dates and the best time to schedule, optimizing your equipment, and learning how to listen for meteors. Understanding this material should increase your success rate and possibly add to the data base that will be presented here. Since the prime meteor scatter season is just around the corner, I thought this would be a good time to present this material.

background information

There are two basic types of meteors: sporadic and shower. The sporadic meteors have random orbits in space and are drawn in by the gravitational force of the Earth as it passes them in its orbit around the sun. However, they are for the most part concentrated toward the ecliptic plane (the plane of the Earth's orbit) and move around the sun in the same direction as the Earth. Because of the geometry involved, these sporadic meteors tend to peak for east-west paths every day around 0600 and are at a minimum at 1800 local time with approximately 4:1

ratio.³ North-south paths tend to peak around 0200 and 1000 local time with a similar minimum. Sporadic meteors are not uniformly distributed and tend to be random in speed (more on this later) as well as difficult to predict. There is a further seasonal variation because of the tilting of the Earth's axis relative to the ecliptic plane. Sporadic meteors tend to peak with a broad maximum occurrence in July and a broad minimum in February.

Shower meteors, on the other hand, are more spectacular, but account for only a small fraction (less than 5 percent) of the total incidence of meteors. They are believed to be the remnants of old or extinct comets which have specific orbits and velocities around the sun. When the Earth intersects one of these orbits, there is a dramatic increase in the quantity and size of the meteors entering the ionosphere. Hence the name "meteor shower" has been coined to describe this phenomenon. The most observed meteor showers have been given astronomical names corresponding to the constellations in the sky from which they appear to originate. Because of their distinct orbit (in comparison to the sporadic types), they can peak at any time of the day or night. The duration of the shower may last anywhere from a few hours to as long as a week or two. Since they are so concentrated (compared to the sporadic types), they considerably enhance the possibility of a completed QSO.

table 1. Data for major meteor showers.

shower name	E.L.*	best dates	duration	accuracy	hourly rate**	velocity (km/sec)	local*** rise/set
Quadrantids	282.83	Jan 1 - 4	10 hours	± 15 min	50	43	2300-1800
April Lyrids	31.40	April 20 - 23	2 days	± 12 hrs	12	51	2100-1100
Eta Aquarids	44.00	May 2 - 6	5 days	± 12 hrs	15	64	0300-1200
Arietids	75.00	June 1 - 15	8 days	± 12 hrs	66	39	0330-1530
June Lyrids	84.00	June 10 - 21	2 days	± 12 hrs	10	51	2100-1100
Delta Aquarids	125.00	July 26 - 30	2 days	± 12 hrs	20	43	2200-0600
Perseids	139.30	Aug 10 - 14	4 days	± 75 min	49	60	(note 1)
Orionids	207.00	Oct 18 - 23	2 days	± 12 hrs	18	67	2230-0930
Taurids	220.00	Oct 30 - Nov 10	20 days	± 12 hrs	10	31	1900-0630
Leonids	234.70	Nov 14 - 19	3 hours	± 12 hrs	10	72	0000-1230
Geminids	261.20	Dec 10 - 15	3 days	± 12 hrs	60	37	1900-0900
Ursids	270.00	Dec 21 - 24	12 hours	± 12 hrs	15	35	(note 2)

* Ecliptic longitude in 1950 coordinates.

** Estimated meteors per hour at maximum. Can vary greatly from year to year depending on shower.

***For northern mid-latitudes.

Note 1. Never sets. Minimum at 1730.

Note 2. Never sets. Minimum at 2030.

Sporadic meteors will continue to be used by VHFers on 6 and 2 meters. The best times for use will be in the morning hours and during the summer months as stated earlier. However, long haul 2-meter DX and especially operation on 220 MHz and above would best be served by concentrating on specific meteor showers.

pinpointing meteor shower peaks

Although many articles have been written on meteor showers, there has been very little information on pinpointing exactly when these meteor showers peak. Most of the available information lists only the approximate dates of the expected peak.^{4,5,6} Some of these showers are of extremely short duration (one to four hours). Considering operation on only one particular day, or even during any six to ten hours off peak on a short duration shower will probably prove to be a waste of time.

Often you hear someone say, "Oh, that shower always peaks at 8 AM on August 12," only to hear conflicting stories about the same shower from someone else. The reasons for contradiction are many. Often overlooked is the basic fact that *the Earth takes 365¼ days to complete one orbit around the sun.* (This is the reason we need one leap year every four years in

order to get the calendar back in synchronization.) Therefore the shower we encounter today will typically peak six hours later next year, allowing, of course, for leap year when it occurs. Astronomers have a way to predict the time that the meteor showers are expected to peak.⁷ This method uses celestial information to predict the time the Earth intersects the orbit of the meteor stream based on data that has been generated by long-term visual observation of the more well known showers. Some information has also been generated from radar observations. I gave a talk on this prediction method at the Central States VHF Conference in Sioux Falls, South Dakota in July, 1981 and have been continuously updating the handout information that accompanied that presentation. (Each month I use this method to forecast the various meteor shower peaks and list them in the "Important VHF/UHF Events" at the end of the column.)

Let's see how to use this method. First you have to know the ecliptic (sometimes called solar) longitude of the various showers. This is listed each year in various publications⁸ and I believe *Sky and Telescope Magazine* uses the same information for its monthly meteor shower predictions. However, *beware of meteor shower peak predictions in astronomy maga-*

zines; their interest is primarily visual. If, for instance, the peak of the shower is during the day or on an evening near full moon, astronomy magazines may not provide sufficient information to determine the real peak. Most astronomers couldn't care less about the use of meteor showers for radio communications!

I have generated **table 1** to show the ecliptic longitude in 1950 (astronomical) coordinates for the peak of the meteor showers, the range of dates and times, the duration of the shower, the approximate accuracy of the predictions, and the hourly rate and velocity. To predict the time of the actual meteor shower peak, you need to acquire a table showing "Ecliptic Longitude at 0000 UTC" for the year of interest⁹ or calculate this data yourself (more on this later). Because four years of data are required, this would be an extensive table. Therefore, using reference 9, I have calculated and listed in **table 2** the ecliptic longitude for just the principal dates surrounding the major meteor showers. Days on either side of those listed could be estimated if desired. Because the Earth returns to approximately the same place in its orbit every four years (as described earlier) all you have to do is repeat the proper year. For example, the 1984 table is also good for 1976, 1980, 1988, and so on.

The equation for calculating the ecliptic longitude daily is found in reference 9. W4WD has taken this equation and some of the data shown in table 1 and written a computer program for the TRS-80 computer.¹⁰ Jim Reisert, AD1C, has revised the program and data. A copy of his program is shown in fig. 1.

using the tables

A few examples of how to use tables 1 and 2 should clarify the method.

Find the date and peak time for the Perseids meteor shower in 1984.

Table 1 shows the peak at ecliptic longitude 139.3. Scan through the ecliptic longitudes listed on table 2 for 1984 and find the day before and the day after the 139.3 peak, noting the date and ecliptic longitude shown for 0000 UTC. The day before is August 11 at ecliptic longitude 138.51, and the day after is August 12 at 139.47. Therefore, the shower will peak on August 11. To find the peak shower time, insert this ecliptic longitude data into the following equation:

$$T = 24 \cdot \frac{(E.L. - E.L.1)}{(E.L.2 - E.L.1)}$$

$$= 24 \cdot \frac{(139.30 - 138.51)}{(139.47 - 138.51)}$$

$$= 24 \cdot (0.823) = 19.75$$

or 1945 hours

where T is time in UTC, $E.L.$ is ecliptic longitude from table 1 for the shower of interest, $E.L.1$ is from table 2 for the day before and $E.L.2$ is from table 2 for the day after peak for the proper year. Therefore, the next peak of the Perseids meteor shower should be August 11, 1984, at approximately 1945 UTC.

Find the peak for the great Leonids shower of 1966. Table 1 shows the peak at ecliptic longitude 234.7. Looking through table 2 for 1982 (same as 1966 table, as explained earlier) we find the data for the day before and after as November 17 at 234.28 and November 18 at 235.39. Inserting these eclip-

fig. 1. Meteor shower peak prediction time program. Though written for TRS-80™, BASIC program can be adapted to any personal computer.

```


100 REM: PROGRAM BY JAMES REISERT, AD1C - 12 FEBRUARY 1984
105 REM: BASED ON PROGRAM BY RUSS WICKER, W4WD
110 K=57.29577951308
115 PRINT
120 PRINT TAB(5);"METEOR SHOWER PEAK TIME PREDICTION"
125 PRINT TAB(5);"-----"
130 PRINT
135 PRINT "WHAT IS THE YEAR (VVVV) ";
140 INPUT V
145 PRINT
150 PRINT TAB(15);"METEOR SHOWER"
155 PRINT TAB(15);"-----"
160 PRINT
165 PRINT " 1) QUADRANTIDS";TAB(33);"1-4 JAN."
170 PRINT " 2) APRIL LYRIDS";TAB(33);"20-23 APR."
175 PRINT " 3) ETA AQUARIDS";TAB(33);"2-6 MAY"
180 PRINT " 4) ARIETIDS";TAB(33);"1-15 JUNE"
185 PRINT " 5) JUNE LYRIDS";TAB(33);"10-14 JUNE"
190 PRINT " 6) DELTA AQUARIDS";TAB(33);"26-30 JULY"
195 PRINT " 7) PERSEIDS";TAB(33);"10-14 AUG."
200 PRINT " 8) ORIONIDS";TAB(33);"18-23 OCT."
205 PRINT " 9) TAURIDS";TAB(33);"30 OCT.-10 NOV."
210 PRINT "10) LEONIDS";TAB(33);"14-19 NOV."
215 PRINT "11) SEMINIDS";TAB(33);"10-15 DEC."
220 PRINT "12) URSID";TAB(33);"21-24 DEC."
225 PRINT
230 PRINT "TYPE IN THE NUMBER OF THE DESIRED SHOWER (1-12) ";
235 INPUT N
240 IF N<1 OR N>12 THEN 230
245 RESTORE
250 FOR I=1 TO N
255 READ S#,E,D#,A#,M,D
260 NEXT I
265 REM: CALCULATE THE JULIAN DATE
270 J=365*(V-1981)+INT((V-1)/4)-INT((V-1)/100)+(INT((V-1)/400)+1)
275 J=J+INT(36.55*(M-1)-1.4)+2*INT((12-N)/10)+D
280 IF N<2 OR (V/4)<<INT(V/4) THEN 290
285 J=J+1
290 GOSUB 435
295 IF E1>E THEN 320
300 J=J+1
305 D=D+1
310 GOSUB 435
315 GOTO 295
320 IF E1<E THEN 350
325 E2=E1
330 J=J-1
335 D=D-1
340 GOSUB 435
345 REM: CALCULATE SHOWER PEAK TIME IN GMT
350 T=24*((E-E1)/(E2-E1))
355 H0=INT(T)
360 M1=INT(60*(T-H0)+.5)
365 G=100+H0+M1
370 IF D<=31 THEN 385
375 D=D-31
380 M=M+1
385 PRINT
390 PRINT "THE ";S#;" METEOR SHOWER WILL PEAK ON";M#;"/"#D#;"/"#V-1980
395 PRINT "AT ";G#;" GMT. THIS SHOWER LASTS ";D#;" AND"
400 PRINT "THIS PREDICTION HAS AN ACCURACY OF ";A#
405 PRINT
410 PRINT"DO YOU WANT ANOTHER RUN (Y/N) ";
415 INPUT A#
420 IF A#="Y" THEN 115
425 GOTO 555
430 REM: SUBROUTINE TO CALCULATE ECLIPTIC LONGITUDES
435 T1=(J-270)/36525
440 C0=0.016717-0.00004*T1
445 M2=(0.935699*(J-117.821)-0.3227*T1)/K
450 C2=M2+C0*SIN(M2)
455 M0=C2-C0/SIN(C2)
460 D0=(M2-M0)/(1-C0+C05(C2))
465 C2=C2+D0
470 IF ABS(D0)>0.0001 THEN 455
475 T=K*(ATHN(SQR((1+C0)/(1-C0)))*SIN(C2/2)/COS(C2/2))
480 E1=T+1.7192+T1*77.396
485 IF E1<0 THEN E1=E1+360
490 RETURN
495 DATA QUADRANTIDS,282.03,10 HOURS,+/- 15 MINS.,1.4
500 DATA APRIL LYRIDS,31.4,2 DAYS,+/- 12 HOURS,4.21
505 DATA ETA AQUARIDS,44.0,5 DAYS,+/- 12 HOURS,5.4

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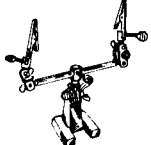
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


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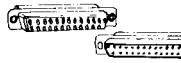
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100 FOR \$30.00

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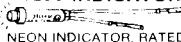
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5 KEY



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6 KEY




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MULTI-TURN POT



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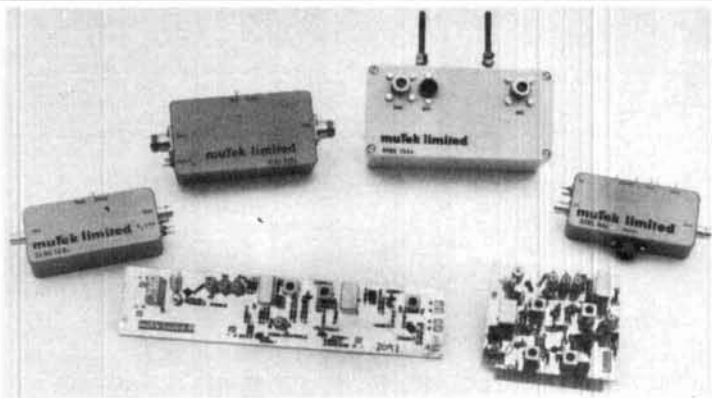
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510 DATA ARIETIDS,75.0,8 DAYS,+/- 12 HOURS,6.5
515 DATA JUNE LYRIDS,84.0,2 DAYS,+/- 12 HOURS,6.14
520 DATA DELTA AQUARIDS,125.0,2 DAYS,+/- 12 HOURS,7.26
525 DATA PERSEIDS,139.3,4 DAYS,+/- 75 MINS.,8.11
530 DATA ORIONIDS,207.0,2 DAYS,+/- 12 HOURS,10.20
535 DATA TAURIDS,220.0,20 DAYS,+/- 12 HOURS,10.31
540 DATA LEONIDS,234.7,3 HOURS,+/- 12 HOURS,11.16
545 DATA GEMINIDS,261.2,3 DAYS,+/- 12 HOURS,12.13
550 DATA URSIDS,270.0,12 HOURS,+/- 12 HOURS,12.21
555 END

```

READY

RUN

METEOR SHOWER PEAK TIME PREDICTION

WHAT IS THE YEAR (YYYY) ? 1984

METEOR SHOWER

- | | | |
|-----|----------------|-----------------|
| 1) | QUADRANTIDS | 1-4 JAN. |
| 2) | APRIL LYRIDS | 20-23 APR. |
| 3) | ETA AQUARIDS | 2-6 MAY |
| 4) | ARIETIDS | 1-15 JUNE |
| 5) | JUNE LYRIDS | 10-14 JUNE |
| 6) | DELTA AQUARIDS | 26-30 JULY |
| 7) | PERSEIDS | 10-14 AUG. |
| 8) | ORIONIDS | 18-23 OCT. |
| 9) | TAURIDS | 30 OCT.-10 NOV. |
| 10) | LEONIDS | 14-19 NOV. |
| 11) | GEMINIDS | 10-15 DEC. |
| 12) | URSID | 21-24 DEC. |

TYPE IN THE NUMBER OF THE DESIRED SHOWER (1-12) ? 7

THE PERSEIDS METEOR SHOWER WILL PEAK ON 8 / 11 / 84
AT 1939 GMT. THIS SHOWER LASTS 4 DAYS AND
THIS PREDICTION HAS AN ACCURACY OF +/- 75 MINS.

DO YOU WANT ANOTHER RUN (Y/N) ? N

READY

tic longitudes into the equation from above, we obtain:

$$\begin{aligned}
T &= 24 \cdot \frac{(E.L. - E.L.1)}{(E.L.2 - E.L.1)} \\
&= 24 \cdot \frac{(234.70 - 234.28)}{(235.29 - 234.28)} \\
&= 24 \cdot (0.416) = 9.98 \\
&= 0959 \text{ hours}
\end{aligned}$$

Checking back in history, we see that the peak indeed occurred on November 17, 1966, between 0900 and 1300 UTC.¹¹ Not bad for an estimate! Wait until the next Leonids peak in 1999; it will occur on November 17 at 1541 UTC. Check out the math yourself — and if I'm not around, remember that I told you so!

A few notes of caution are in order. As pointed out earlier, meteor shower peaks are based primarily on visual

sightings. Radio peaks may vary slightly because the ionization for radio reflection may not necessarily cause a bright visual display. However, the radio and visual peaks are probably not much different. Another factor is the orbits of the showers themselves. Sometimes an orbit may be deflected, especially if it passes near one of the major planets such as Jupiter. If this happens, the shower may peak at a different date and/or time or even completely disappear! Also, some showers such as the Leonids are believed to be much younger, astronomically speaking, and hence are more concentrated. Therefore, they may be good only during certain peak years. The astronomy magazines are good sources of information to determine when these peak years will occur. In the interest of brevity, I have not men-

tioned minor showers or those that have been dormant in recent years perhaps because of a shift in orbit. They are still worth investigating if you have the time and inclination! New showers may be discovered but will take time to pinpoint exactly.

getting the best reflection

Another reason why different persons may quote different shower peaks is that they may have overlooked the geometry factor that must be observed.^{4,6} In some cases there may be no optimum time for communications between two stations because a specific shower may not pass over the proper reflection point between the stations involved. However, when there is a usable meteor shower, there is an optimum time when the meteors will be in the proper location for the maximum signal reflection for the desired direction. W4LTU listed optimum times in his tables for scheduling between stations during meteor showers based on the direction of the path.⁶ This data is very important if you want to enhance your chance of a completed contact and not spend endless hours when the meteors are in the wrong position.

Some European VHF/UHFers have recently written computer programs to aid in selecting the best times to operate in any desired direction. They use the geometry specified by W4LTU in reference 4 with right ascension data for the meteor shower. Their program also adds data pertaining to effectiveness, thereby giving all times of the day with a quality factor of 0 to 100 percent for any desired path. Hopefully this program will soon be available here in the United States.

choosing the optimum shower

Another often overlooked fact is that each shower has its own specific characteristics. Time and space do not permit a long discussion here, but I will try to summarize some data I have collected to assist you in determining the best meteor shower to use for a specific frequency and path.

It is generally agreed that the opti-

table 2. Ecliptic longitude at 0000 UTC for selected days (from The American Ephemeris and Nautical Almanac for year of interest).^a

date	1984*	1985*	1986*	1987*
Jan 3	281.79	282.54	282.26	282.04
Jan 4	282.81	283.55	283.27	283.06
Jan 5	283.83	284.57	284.29	284.08
Apr 21	31.08	30.81	30.54	30.34
Apr 22	32.06	31.78	31.52	31.32
Apr 23	33.03	32.76	32.49	32.29
May 4	43.72	43.45	43.18	42.99
May 5	44.69	44.42	44.15	43.95
May 6	45.66	45.39	45.12	44.92
June 5	74.53	74.26	73.99	73.80
June 6	75.48	75.21	74.95	74.75
June 7	76.44	76.17	75.91	75.71
June 14	83.13	82.86	82.60	82.41
June 15	84.08	83.82	83.56	83.36
June 16	85.04	84.77	84.51	84.32
July 27	124.15	123.88	123.63	123.43
July 28	125.11	124.84	124.58	124.38
July 29	126.06	125.80	125.54	125.34
Aug 11	138.51	138.25	137.99	137.79
Aug 12	139.47	139.21	138.95	138.75
Aug 13	140.43	140.17	139.91	139.71
Oct 20	206.78	206.52	206.52	206.04
Oct 21	207.78	207.51	207.24	207.03
Nov 2	219.76	219.49	219.22	219.00
Nov 3	220.76	220.49	220.22	220.00
Nov 4	221.76	221.49	221.22	221.00
Nov 16	233.82	233.55	233.28	233.06
Nov 17	234.83	234.56	234.28	234.07
Nov 18	235.84	235.57	235.29	235.08
Dec 12	260.15	259.88	259.61	259.39
Dec 13	261.17	260.90	260.62	260.41
Dec 14	262.19	261.92	261.64	261.42
Dec 21	269.31	269.04	268.76	268.55
Dec 22	270.33	270.06	269.78	269.56
Dec 23	271.35	271.08	270.80	270.58

*Each table repeats itself every 4 years. Hence the table for 1984 will be usable in 1988, 1992, and so on. See text for further information.

mum path length for meteor scatter communications is between 700-1000 miles (1126-1609 km), but this is based mainly on an average meteor's ionizing at 100 km altitude. The slower velocity showers (11-40 km/sec., see velocity column on **table 1**) such as the Geminids can ionize as low as 60-80 km and hence are good for shorter distances, while the faster showers (40-72 km/sec.) such as the Perseids may ionize at as high an altitude as 150 km. Therefore, the faster showers will generally yield the best DX.

Likewise, the fast showers seem to be the best ones for 220 MHz and above. The duration and signal strength of the burst drops off rapidly with decreasing wavelength and therefore is considerably shorter and weaker

on 220 MHz than on 2 meters. Even on a fast shower, very few long bursts will be detected on 70 cm. The ideal shower for the most difficult paths and higher frequencies should have a good rate of meteors per hour because several bursts may be required to complete the exchange of information required for a QSO. Therefore, fast showers with few meteors, such as the Leonids of late, are not good prospects except during peak years in their cycle. The Orionids and Eta Aquarids meteor showers are believed to be associated with Halley's comet which is due to rendezvous with the sun in 1986. This could mean a big increase in the rate of these showers over the next few years. Stay tuned in!

In short, I feel the Perseids is the

ideal all-purpose shower, especially for 220 MHz and above. It has a long duration, high speed, lots of large particles, and is evenly distributed from year to year. Is it any wonder why all reported 70 cm meteor scatter completed contacts have taken place during this shower? The Geminids, even though slow in speed, are reliable year after year for paths up to 1000 miles (1609 km), with lots of meteors and good performance even on 220 MHz. The Quadrantids are great if you are lucky enough to catch the narrow peak. The Delta Aquarids can also be good, but it has been pointed out in recent years in astronomy magazines that this shower may be comprised of up to six or seven other showers, hence explaining its erratic nature from year to year.

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Photo shown MX-15, VX-15, PL-15, SP-15, MS-1 and PR-1



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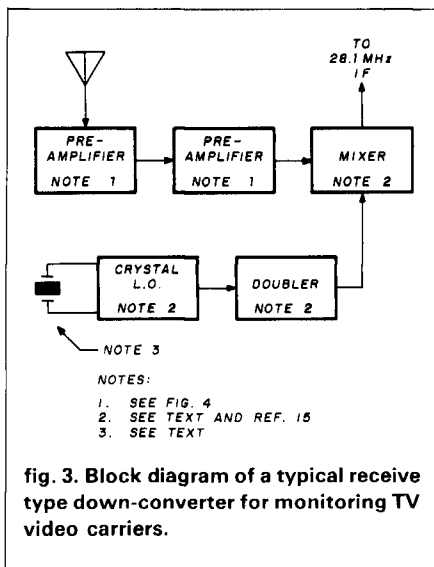


table 3. Selected TV video carrier frequencies for U.S.A., Canada, and most North American TV stations.

TV channel No.	frequency (MHz)*
2	55.250
3	61.250
4	67.250
5	77.250
6	83.250
7	175.250
8	181.250
9	187.250
10	193.250
11	199.250
12	205.250
13	211.250

*This is the zero-offset frequency. Channels may be on this frequency, ± 10 kHz of the same based on FCC frequency assignments (see text).

higher VHF channels since they are widespread; this gives plenty of opportunity to hear meteor bursts in different areas. The higher frequency channels also give a better indication when the meteors are really hot for DX, and when 220 MHz is possible. Channels 12 and 13 are ideal in this regard. Select a channel that isn't used locally (within 100 miles or 161 km), because strong channels could overload your receiver and may produce extraneous 15,750 kHz video birdies.

My converter is typical of those used on 2 meters or 220 MHz for weak signal work and is patterned according to the circuitry shown in my March, 1984 *ham radio* article.¹⁵ A block diagram of

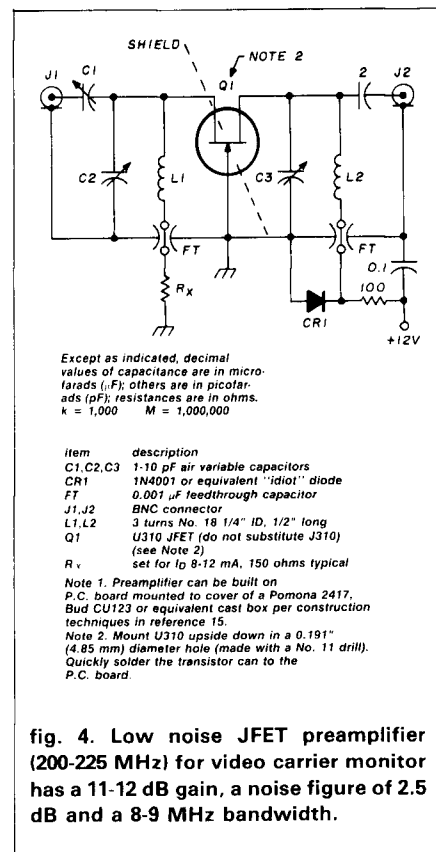
this converter is shown in **fig. 3**. I chose channel 13 (video carrier on 211.250 MHz from **table 3**) and use a local oscillator frequency of 183.150 MHz derived with the actual crystal oscillator operating at 91.575 MHz. My IF is 28.1 MHz for reasons specified in reference 15. For a preamplifier I used two U310 JFET stages as shown in **fig. 4** which will work from 200-225 MHz and over a wider frequency range if the inductors are scaled accordingly. This configuration is more than adequate to hear the weak TV video carriers out to 300 miles even on poor days with no propagation enhancements. Remember, these stations are radiating high power and usually at high elevations.

The choice of receiving antenna is very important. For best operation you should have a sharp and clean antenna pattern with low side lobes so that you can null out a loud station as well as be able to distinguish which direction the signals are coming from. I prefer the NBS 2.2 wavelength Yagi and have shown a suitable design in reference 16. I have recently changed to a T-match and would recommend same if you are making your own antenna.

A few final comments about monitoring TV video carriers: short meteor bursts on channel 12 or 13 will probably indicate that 2-meter scatter is good; 5 to 10 second bursts probably mean good DX as well as opportunities on 220 MHz and above. I have noticed that the burst starts first on the higher frequency. Hence, if you hear a good burst start in the desired direction, the lower frequency path will open shortly afterward. Conversely, a burst on 200 MHz may occur too late for you to catch a 70 cm path. Pings or rapid Doppler means that there are underdense bursts which aren't going to be of much help, but they do indicate that there are meteors present. Use of this type of monitor is not only helpful to see when, where, and if a meteor shower is in progress, *but can also be used to catch other VHF/UHF openings such as sporadic E, auroral or tropo.*

operating procedures

In the United States, meteor scat-



ter schedules are usually run for one hour with the station farthest south and/or west transmitting the first and third 15 seconds of each minute. CW used to be the prime mode, but now SSB is used almost exclusively. CW is best on weak signals (especially for long DX and 70 cm) and is easy to tune in, but has a low data rate. SSB is definitely faster — especially if the burst is long enough to complete the exchange — but is more difficult to tune in especially when signals are weak. Call signs must be exchanged by both stations although not necessarily in a single burst. Reports and "rogers" received by both parties complete the QSO. If a burst is long or falls at the end of a transmission, break-in procedures may be used to complete the contact on a single burst.

Until recently, Europeans had only two bands to use for meteor scatter, 2 meters, and 70 cm. In Europe, high speed (75-125 WPM!) CW is still in wide use. In contrast to the United States, where the contact takes place in real time, the Europeans usually run long (1 to 5 minutes) transmitting sequences and then record on tape. This

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method is less critical on timing (using 15 second sequencing can cause a 33 percent loss of information if one station is off 5 seconds in timing!). At the end of a receiving sequence, the tape is quickly replayed at reduced speed to pick off any information received. This procedure does favor short bursts because entire call sets and reports can be sent in seconds or less and replayed until the information is deciphered. SSB is now gaining popularity in Europe.

In some sense, the high-speed CW used in Europe is similar to the procedures being proposed by those interested in packet or computer-oriented communications.¹⁷ It's no secret that many of us still feel that communications must still be heard and deciphered by the operator rather than just appear as a letter or message on a video screen. However, such is progress! Reviewing the material in reference 17 should be very interesting to those with computer experience.

summary

I can't believe this article grew so long! Hopefully the material presented will be interesting and helpful. Let me point out that I am not advocating the use of only certain meteor showers. I presented this material to help you increase your success record — especially on the longer DX, 220 MHz and above. If the shower isn't materializing, why waste the kilowatts? However, using the material presented here, you may be able to discover other shower opportunities or input data to refine the peaks of existing showers.

Various methods have been presented to predict more accurately when the better meteor showers will peak. Remember, you can't use a short duration shower if it peaks when the radiant is not above your horizon! In addition to the information in table 1, refer back to W4LTU's table⁶ for best times for the path direction desired. Optimize your equipment especially if it is not up to the standards recommended; build up a monitor as described and you'll be amazed how helpful it will be, not only for meteor

scatter but for other propagation modes as well.

Finally, let me thank W4WD and AD1C for their help in determining the shower peaks by computer. Also, many thanks to Chip Brown, KR1P, for the material he helped me obtain on this subject as well as his helpful suggestions; to WTFDA for use of their map; and the people at *Sky and Telescope Magazine* for their help. Good luck on your next meteor scatter schedule and let me know if you can improve the data base in this article.

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- June 9-10: ARRL VHF QSO Party
- June 14: 2200 UTC, peak of June Lyrids
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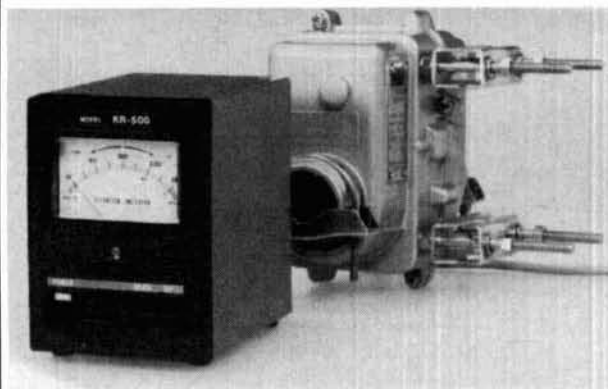
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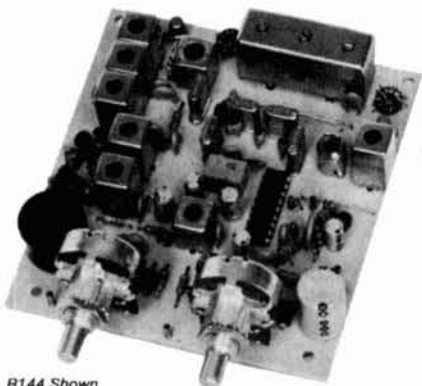
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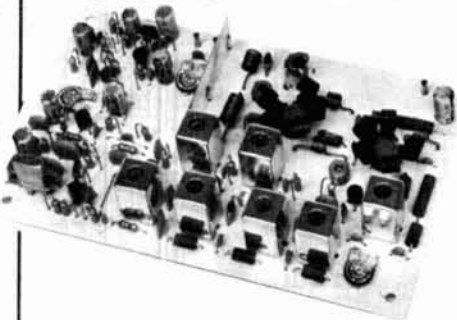
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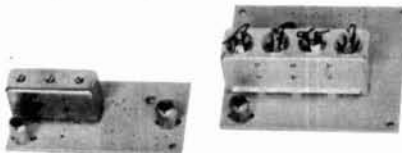


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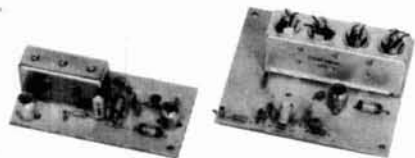
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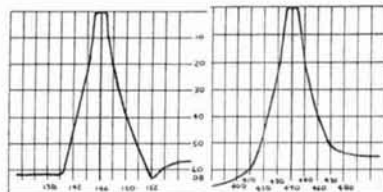


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the peaked lowpass: a look at the ultraspherical filter

Use a pocket calculator
for filter design,
analysis, experimentation

Much of the fundamental work done in filter design and analysis over the past twenty years has been the result of detailed computer studies done by researchers in industry and education. Now, with personal computers, even home hobbyists can perform the complex calculations necessary for thorough examination of existing filter types and understanding of new types, exceeding the current standards, as they become available.

The most obvious opportunity for Amateur exploration in this field is in design, using published equations for the generation of tables. For example, using modern network theory,¹ a computer program can easily generate the table for Chebyshev filters of any arbitrary ripple value.² This allows one to design using available standard components.³

An equally useful computer application is filter analysis. An analysis program allows the user to enter component values and examine the response of that filter. Both gain (transducer gain) and phase response are easily generated with a simple ladder analysis program. More refined programs provide details regarding the filter response to a nonsinusoidal input such as an impulse or step; each of these is of interest to the circuit theorist.⁴

A well-designed filter analysis program does more than confirm the traditional — and therefore expected — results. It allows practical details, such as the effects of loss in the elements (finite Q inductors and capacitors) and parasitic reactances, to be enumerated

and evaluated. One can also use a filter analysis program to study what happens when certain component values are changed.

It isn't even necessary to use a personal computer; for this study, a modest but powerful handheld calculator (an HP-41CV) was employed, using a previously published ladder analysis program.^{5,6} The program was applied to the ultraspherical filter, a polynomial filter whose utility in certain special applications outweighs its apparent lack of popularity. (The fundamental work on this type of filter was done by Johnson and Johnson;⁷ their work will be extended — and some practical details added — in this article.)

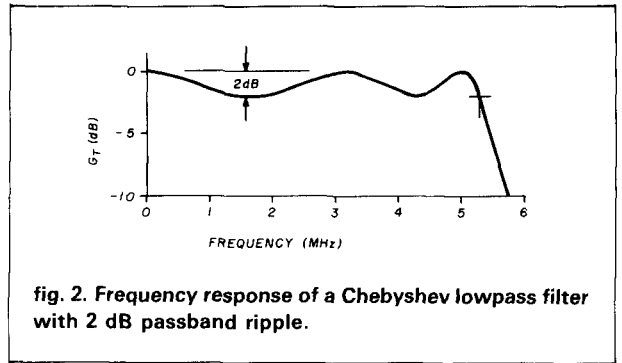
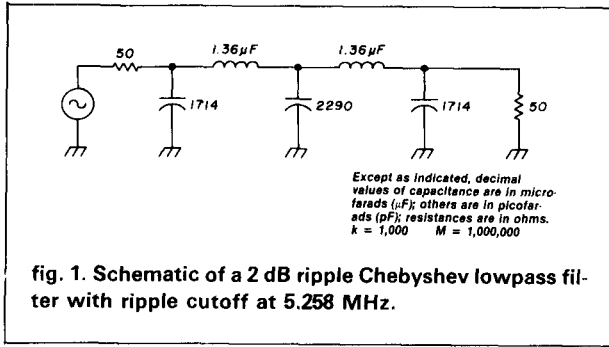
lowpass filters

To begin, let's examine a traditional lowpass filter. The filter chosen, a 5-pole Chebyshev with a 2-dB passband ripple, has been designed for a ripple cutoff frequency of 5.258 MHz. Its circuit appears in **fig. 1** with its frequency response shown in **fig. 2**. The usual Chebyshev characteristics are evident. There are five half-cycles of ripple in the passband. The response is down by 2 dB, the ripple value, at the 5.258 MHz ripple cutoff frequency.

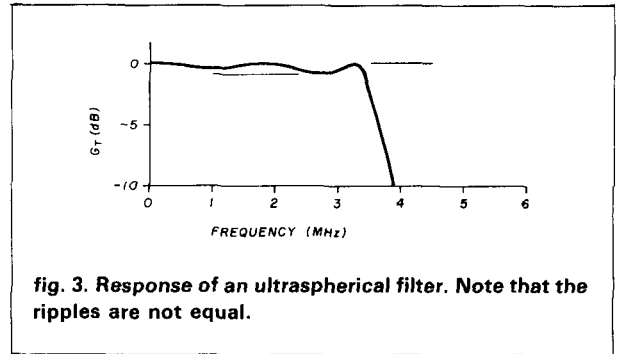
This filter also exhibits an interesting but rarely appreciated property of the Chebyshev: with a 5.258-MHz ripple cutoff, the filter has its final peak at 5 MHz. Further examination reveals that the relationship between the positions of the response peaks are related to the cutoff by constants that are *not* dependent on the ripple. That is, all doubly terminated 5-pole Chebyshev filters will have their final peak at a frequency that is below the ripple cutoff by a factor 0.9509 ($= 5.00/5.258$) for all ripple values. Further analysis provides the relationships for other filter orders and for the other peaks.

Having examined a classic filter, let's now consider the effect of changing, or perturbing, some of the

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component values. First, we'll increase the inductor values from those shown in fig. 1. We'll keep the filter symmetrical with equal inductors, but increase the value from 1.36 to 3 microhenries. With the larger inductors, we would expect the cutoff frequency to decrease; this is confirmed in the frequency response (fig. 3). Of greater interest, however, is a change in filter shape. The filter still has ripples in the passband, but they are no longer of equal value. The first (close to zero frequency) dip in the response is not as deep as the second one, closer to the cutoff. A further increase in inductor values will further emphasize this effect.



Next we examine the modified filter with the goal of moving the response peak back to 5 MHz. This can be realized in at least two ways. All component values can be reduced equally to produce a filter with an identical shape with the peak at 5 MHz. We could, alternatively, reduce only the center capacitor until the final peak is at 5 MHz. This occurs with the center capacitor reduced from 2290 to 812 pF, yielding the response shown in fig. 4. This result is especially interesting — the shape is an even more extreme departure from the original Chebyshev, with a drastic difference in the dips in the curve — the ripples. Indeed, the smaller ripple, shown in fig. 4, is labeled in order that it not be missed!

a reduction of inductor values. Allow the inductors to decrease from 1.36 to 1 microhenry; this will increase the peak frequency above the original 5 MHz. This increase is compensated for by increasing the center capacitor from 2290 to 4000 pF. The resulting response and circuit are shown in fig. 5. Again, the response has five half-cycles of ripple oscillation. The ripples are unequal, but the large dip in the passband is now the one close to zero frequency. This filter might be termed a "double peaked lowpass." This particular circuit, if properly scaled, would produce a lowpass response with good harmonic attenuation, and with a flat characteristic with only 0.15 dB ripple over the 3.1 to 4 MHz range.

This filter is so extreme that we might well ask whether it's worth considering for any practical application. The ripple has become large enough that the filter has taken on a bandpass-like filter characteristic. This wouldn't be very useful for an application in which a true lowpass shape was needed. However, this is *not* the way lowpass filters are used in most applications; in Amateur Radio, the most common application is in harmonic filtering, in which we wish to pass one frequency or narrow band while attenuating the harmonics of that frequency as much as possible. The filter with the response shown in fig. 4 will do just that. The harmonic attenuation is greater at 10 MHz than the original Chebyshev prototype. We'll term this circuit a "peaked lowpass filter," or PLPF.

insertion loss

The frequency response curves presented so far have assumed lossless components. (This is the common approach in analyzing lowpass filters.) While this can be a mistake, it is easily remedied with the computer or calculator. A more detailed examination will show that the main loss occurs in the inductors. Typically, the inductors have Q_u (unloaded Q) values of 250 or less (toroids at HF). In contrast, mica capacitors often show a Q_u value in excess of 700 at HF.

Returning to the original Chebyshev prototype of fig. 1, we can now consider an opposite perturbation,

If we assume a Q_u that is constant with frequency, we find that the greatest loss occurs at or near the lowpass filter cutoff. (Effects are minimal at lower frequencies.) This loss can be significant in a high-ripple Chebyshev. The effects are also significant in PLPF,

especially as the peak becomes sharper. Design then becomes a tradeoff between acceptable insertion loss and the desired selectivity characteristics. This tradeoff between loss and selectivity is a central theme in all filter design, and is especially significant with band-pass filters with a narrow fractional bandwidth.

the double pi-network: a design method for the PLPF

The circuit we have discussed is a familiar one if we consider only superficial details. It could be a lowpass designed from tables for one sort of polynomial or another. It is, however, a double pi-network, the cascade of two familiar impedance matching networks. The matching circuit is designed for a single specific frequency; our analysis of the PLPF has also focused on a single peak frequency. This similarity suggests a method for design.

First, we'll analyze the impedance characteristics of a pi-network. Our analysis will then form the basis for derivation of some special design equations for the PLPF. This method may be used for higher order versions of the PLPF, either with numerical methods on our computer or in closed mathematical form.

Analysis of the pi-network begins with the circuit of **fig. 6A**, an end resistance, R_o , paralleled with an end capacitor, C_e . The admittance of this combination is written directly, $Y_a = G + j\omega C_e$ where $G = 1/R_o$. This is converted to an impedance by taking the reciprocal of Y .

The impedance looking into plane "a" may now be combined with a series inductor, shown in **fig. 6B**. The resulting impedance is $Z_b = Z_a + j\omega L$. Keep in mind that both Z values are complex, with both real and imaginary parts. The admittance looking into plane "b" is obtained again by complex inversion, $Y_b = 1/Z_b$. This admittance consists of two parts, a real conductance, G_b , and an imaginary susceptance, jB_b . The imaginary term will be negative, indicating that the admittance is inductive. This may be cancelled, or tuned with a shunt capacitance, C_t , producing the traditional pi-network of **fig. 6C**. The capacitance required for tuning is:

$$C_t = \frac{-1}{\omega} \text{Im}(Y_b) \quad (1)$$

where $\omega = 2\pi f$ and f is in Hz. L and C values are in Henrys and Farads.

Thus we have formed a traditional pi-network. The input impedance looking in will be real (resistance only), with a value of $R_{in} = 1/G_b$. This circuit would most likely be mismatched if driven by a source resistance R_o . However, we can eliminate the mismatch, and the loss that would result from it, by transforming an R_o source to "look like" a source resistance of R_{in} . This is easily realized with another pi-network identical to the one we have just "de-

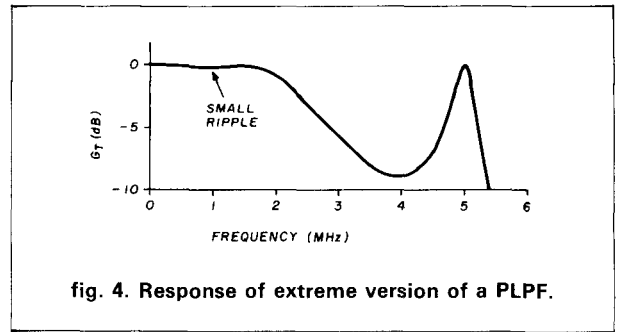


fig. 4. Response of extreme version of a PLPF.

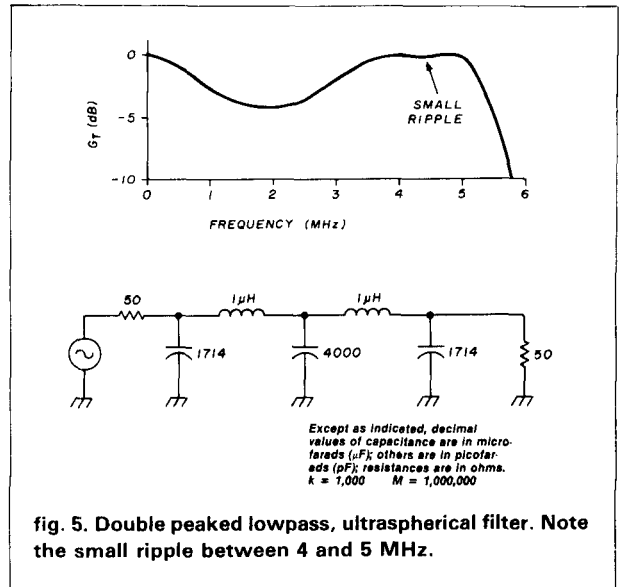


fig. 5. Double peaked lowpass, ultraspherical filter. Note the small ripple between 4 and 5 MHz.

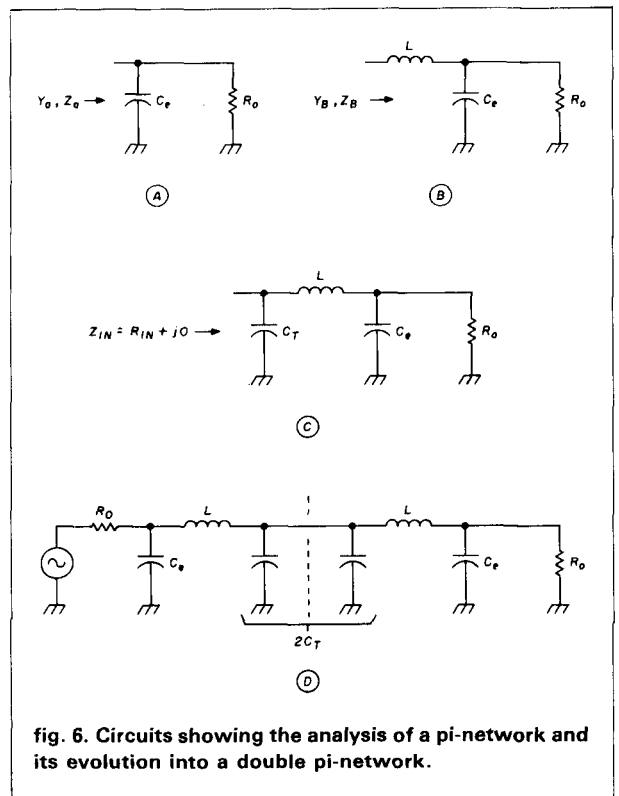


fig. 6. Circuits showing the analysis of a pi-network and its evolution into a double pi-network.

table 1. Normalized component values for 5th order ultraspherical lowpass filters. $Q_u = 200$ for inductors, capacitors are lossless. Also shown is the peak ripple in the passband, the insertion loss and the responses at the 2nd and 3rd harmonics.

g_1	g_2	g_3	ripple dB	IL, dB	$-G_t(2f_p)$ dB	$-G_t(3f_p)$ dB
1	1.0	2.0000	0.37	0.09	25.1	45.7
1	1.2	1.8919	0.16	0.10	29.0	48.8
1	1.4	1.6981	0.21	0.12	31.4	50.9
1	1.6	1.5068	0.47	0.14	33.2	52.3
1	1.8	1.3402	0.84	0.16	34.5	53.5
1	2.0	1.2000	1.29	0.17	35.6	54.5
1	2.5	0.9412	2.56	0.22	37.7	56.4
1	3.0	0.7692	3.83	0.26	39.4	57.9
1	3.5	0.6486	5.03	0.30	40.7	59.2
1	4.0	0.5600	6.13	0.34	41.9	60.3
1	5.0	0.4390	8.04	0.42	43.8	62.1
2	1.0	3.0000	1.15	0.22	42.2	61.8
2	1.2	2.3529	1.78	0.26	43.6	63.0
2	1.4	1.9231	2.82	0.30	44.7	64.0
2	1.6	1.6216	3.84	0.34	45.7	64.9
2	1.8	1.4000	4.81	0.38	46.5	65.8
2	2.0	1.2308	5.71	0.42	47.3	66.5
2	2.5	0.9438	7.70	0.53	49.1	68.1
2	3.0	0.7647	9.35	0.63	50.5	69.5
2	3.5	0.6425	10.76	0.73	51.7	70.7
2	4.0	0.5538	11.99	0.83	52.8	71.8
2	5.0	0.4340	14.02	1.02	54.6	73.5
3	1.6	1.5294	8.99	0.67	52.3	71.5
3	1.8	1.3274	10.11	0.75	53.1	72.3
3	2.0	1.1724	11.10	0.83	53.9	73.1
3	2.5	0.9072	13.20	1.02	55.7	74.8
3	3.0	0.7397	14.89	1.21	57.1	76.2
3	3.5	0.6244	16.31	1.40	58.4	77.4
3	4.0	0.5401	17.54	1.58	59.4	78.5
3	5.0	0.4253	19.57	1.94	61.3	80.3
4	1.6	1.4628	13.51	1.11	56.9	76.1
4	1.8	1.2764	14.63	1.24	57.8	77.0
4	2.0	1.1321	15.62	1.36	58.6	77.8
4	3.0	0.7231	19.39	1.97	61.9	81.0
4	4.0	0.5311	22.01	2.54	64.2	83.3
4	5.0	0.4197	24.02	3.08	66.1	85.2
5	1.6	1.4197	17.24	1.64	60.6	79.8
5	2.0	1.1059	19.33	2.01	62.3	81.5
5	3.0	0.7122	23.05	2.86	65.6	84.7
5	4.0	0.5252	25.65	3.64	68.0	87.1
5	5.0	0.4160	27.65	4.35	69.9	89.0

signed," but reversed. The final circuit is shown in fig. 6D.

We have done all our design and analysis at one frequency, one where we desire a response with no loss (assuming ideal components). This is not especially illuminating as far as filter properties are concerned. Still, it has provided a simple method for choosing the center capacitor in a filter so as to ensure minimum attenuation at one particular frequency.

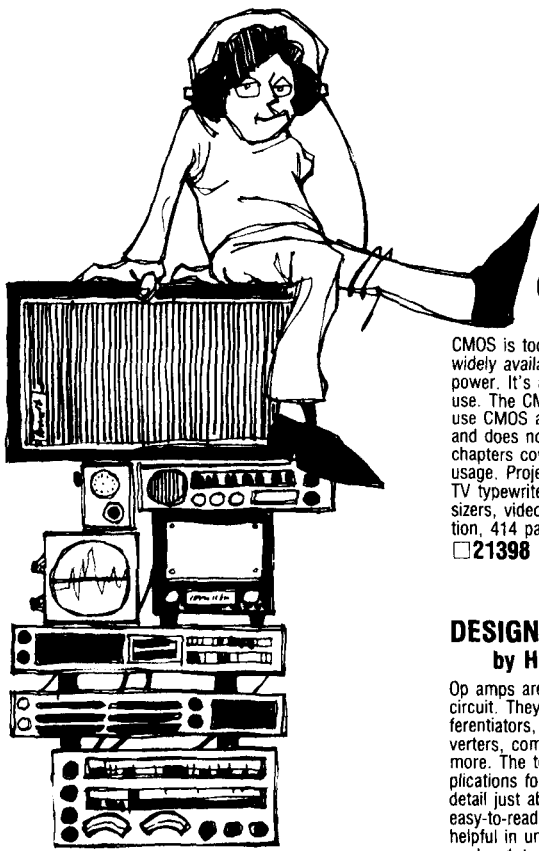
A direct extension of the previous analysis will lead to design equations for the 5th order PLPF. If the end capacitor chosen has reactance X_e at the peak frequency and the inductor has reactance X_L , with the end resistance R_o , the total center capacitance is:

$$C_t = \frac{1}{\pi f} \left[\frac{X_L - \frac{R_o^2}{X_e} (1 - X_L/X_e)}{R_o^2(1 - X_L/X_e)^2 + X_L^2} \right] \quad (2)$$

where f is the peak frequency in Hz

We have already mentioned the importance of considering insertion loss. Further manipulation of the equations (with the assumptions that capacitors are lossless, but that the inductors have a known unloaded Q), shows that the insertion loss is:

$$IL (dB) = 20 \log \left[1 + X_L \frac{X_e^2 + R_o^2}{X_e^2 R_o Q} \right] \quad (3)$$



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These equations may be used for the design of a practical PLPF if some restrictions are noted. The end capacitor should have a reactance $X_e \leq R_o$, while the inductors should have a reactance $X_L \geq R_o$. Both are evaluated at the peak frequency.

Filter design usually begins with standard-value end capacitors and inductors already on hand. The value of the tuning capacitor and level of insertion loss are calculated; if the loss is acceptable, construction

can proceed. If an appropriate program is used, analysis will provide the expected levels of harmonic attenuation.

The nature of the PLPFs possible is illustrated in **fig. 7**. Three filters have been designed for a peak at 7 MHz. One, shown as curve A, is the popular half-wave filter.⁹ While its peak is not very sharp, this is an easy filter to build. The insertion loss for inductors with $Q_u = 250$ is low, but the harmonic attenuation is poor at best. This filter may be designed with methods outlined, with $X_e = X_L = R_o$. Curves B and C of **fig. 7** are much more dramatic, showing significantly improved harmonic attenuation. The insertion loss is higher for these filters, however, but this is the price of increased selectivity.

normalized tables for the PLPF

Most of the more familiar lowpass filters are designed from tables. Extensive data is available for the Chebyshev and Butterworth polynomial filters, as well as many more.¹⁰ Manipulation of the equations above allows us to formulate tables for the PLPF, presented in **table 1** for only the 5-element filter. The g_k values shown are the values of capacitors or inductors for a filter with a peak frequency of 0.1592 Hz (one radian) and 1 ohm terminations at both ends. The possible circuits are shown in **fig. 8**. The form with capacitors at the ends is preferred. The first and second elements, g_1 and g_2 , were chosen arbitrarily. Then the required tuning element, g_3 , was calculated. **Eq. 2** was placed in normalized form for this evaluation,

$$g_3 = \frac{2(g_1^2 g_2 + g_2 - g_1)}{(1 - g_1 g_2)^2 + g_2^2} \quad (4)$$

Table 1 contains the normalized component values for several PLPF circuits. Also shown are the values of the largest ripple in the "passband," the insertion loss is based on an inductor Q of 200, and the attenuation values at the 2nd and 3rd harmonics. It's easy to use the table for designing a PLPF; simply study the insertion loss and harmonic attenuation columns to find a circuit that will meet the requirements for the application at hand. Then design the circuit using,

$$L = \frac{g_2 R_o}{\omega_p} \quad (5)$$

and

$$C_k = \frac{g_k}{R_o \omega_p} \quad (6)$$

where $\omega_p = 2\pi f_p$ with f_p being peak frequency in Hz. **Equation 6** provides both the end capacitors from g_1 and the tuning capacitor with g_3 .

Any filter designed directly from the table would probably not be the most practical one. A more realistic design method would use the table merely as a guide: a preliminary filter would be designed according to the table; end capacitors and inductors — with

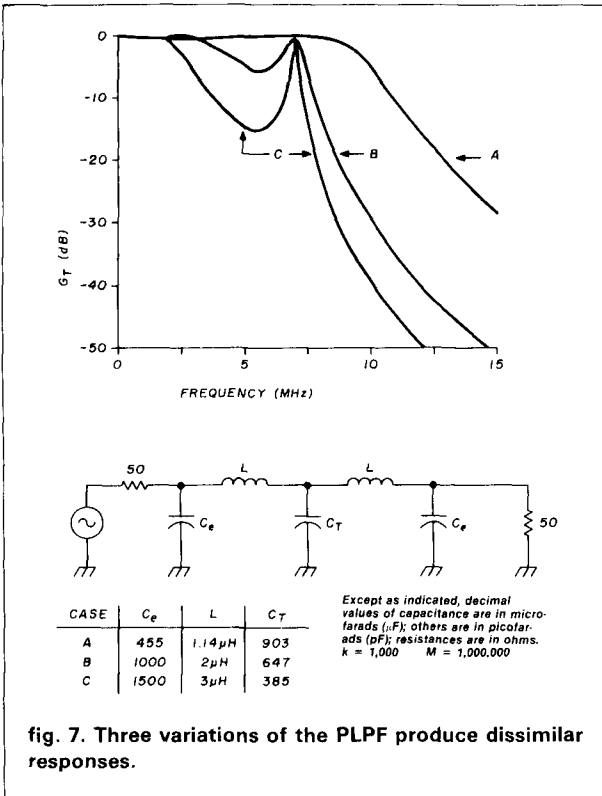


fig. 7. Three variations of the PLPF produce dissimilar responses.

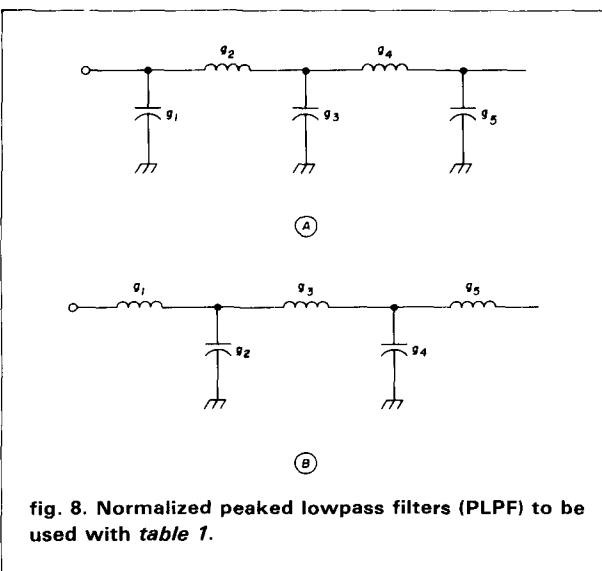


fig. 8. Normalized peaked lowpass filters (PLPF) to be used with **table 1**.

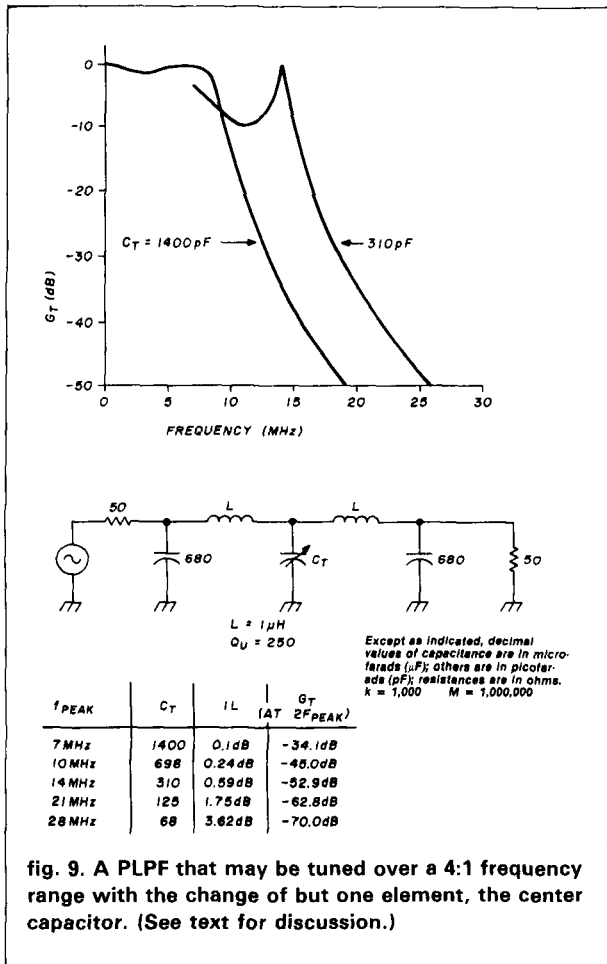


fig. 9. A PLPF that may be tuned over a 4:1 frequency range with the change of but one element, the center capacitor. (See text for discussion.)

values close to those calculated — would then be selected from the junk box. Equation 2 would be used to determine the final tuning capacitor value.

There is one practical complication associated with the PLPF, especially in the more extreme examples, in which g_1 and g_2 are large in comparison to unity. The peak frequency will change significantly with the tuning capacitor. Hence, a trimmer is usually required. This is a small price to pay for the improved harmonic attenuation that can result.

variations on the PLPF

Many things can be done with the PLPF. One problem mentioned in the previous section was the tuning sensitivity of the center capacitor. An adage used by engineers applies to this situation: "If you can't fix it, feature it." We find that a peaked lowpass filter may be tuned over a wide frequency range merely by changing the center capacitor. This is illustrated with the filter and response curves shown in fig. 9. A single filter is tuned over the range of 7 to 28 MHz with one variable element. The ripple depth and the insertion loss both grow as the filter is tuned to higher frequencies, limiting its practical application.

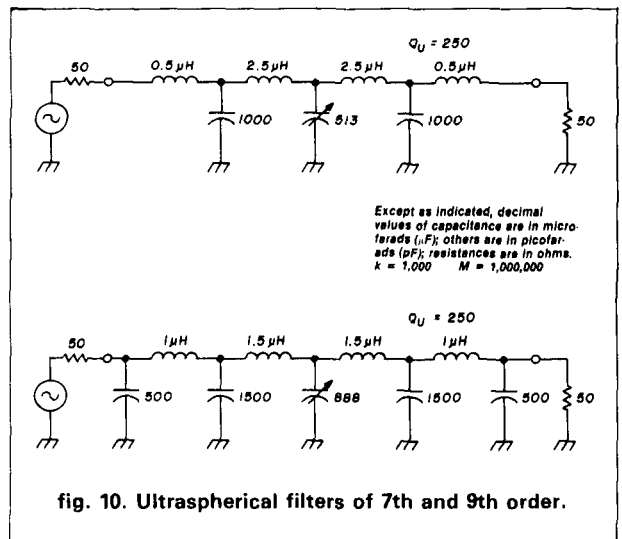


fig. 10. Ultraspherical filters of 7th and 9th order.

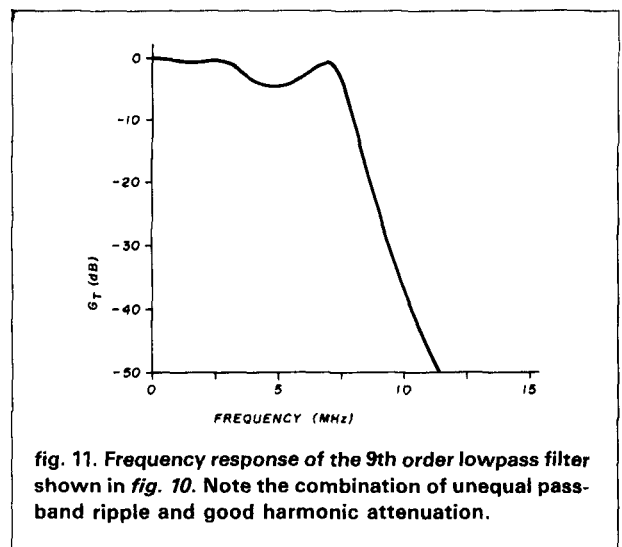


fig. 11. Frequency response of the 9th order lowpass filter shown in fig. 10. Note the combination of unequal pass-band ripple and good harmonic attenuation.

The ultraspherical filter is not limited to circuits with only five elements. Fig. 10 shows two circuits peaked at 7 MHz using 7 and 9 elements. Methods such as those used in analysis of the pi-network were applied to determine the value of the tuning capacitors in these circuits. The 7-element filter has an insertion loss of 0.38 dB and 2nd harmonic attenuation of 52.5 dB. The 9th order filter has an even lower IL of 0.30 dB and 2nd harmonic attenuation of 71.4 dB. The reduction in IL results from the improved impedance matching aided by the additional end elements. The matching is effective at the peak frequency, but continues to contribute to the filtering at harmonics. Fig. 11 shows the response of the 9-element filter of fig. 10.

An interesting traditional filter is the elliptic or Cauer-Chebyshev.¹¹ A lowpass of this type may have its inductors replaced by parallel resonant traps. We can perform the same modification on the PLPF. An ex-

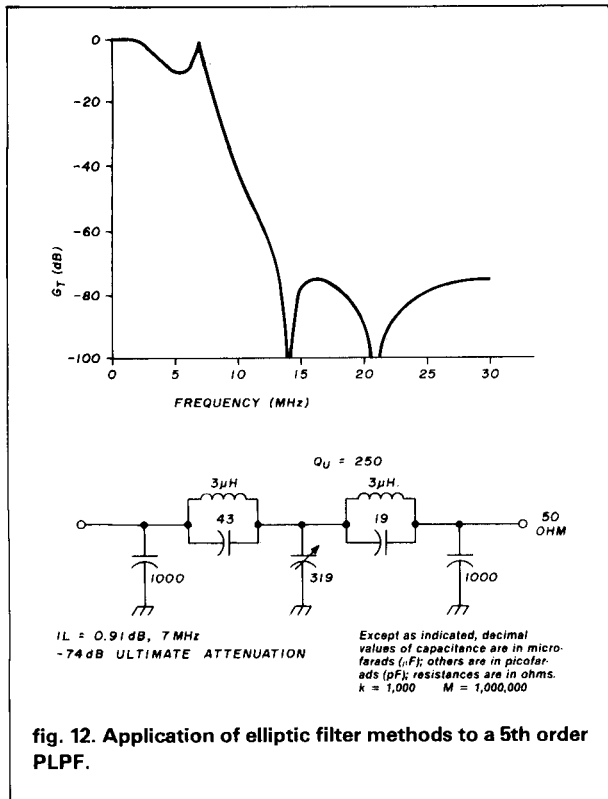


fig. 12. Application of elliptic filter methods to a 5th order PLPF.

ample is presented in fig. 12, peaked at 7 MHz. The traps are tuned to 14 and 21 MHz. The result is a filter similar to the ultraspherical in the passband with unequal ripples, but with deep notches at the harmonics. The main deficiency of this circuit is a limited ultimate attenuation at VHF of -74 dB. This limitation is typical of traditional elliptic circuits.

bandpass filters based upon the PLPF

A characteristic found with the peaked lowpass circuit was a bandpass-like response for the extreme cases. This characteristic can be used to advantage, especially when a filter must also have extremely good attenuation in the high frequency stopband.

Fig. 13 shows a filter that was designed as a preselector to precede an 80-meter receiver.¹² The receiver used a 9 MHz IF and a 5 MHz LO, so the image was at 14 MHz. High image rejection was required, and some "close-in" selectivity was required in the 3.5 to 4 MHz region. A 5th order PLPF was used for the basic filter. This was cascaded with a 7th order highpass circuit to eliminate the low frequency response. Fig. 13 gives the overall response as well as those of the lowpass and highpass sections alone. Note the bump in the bandpass response at the 3 MHz cutoff of the highpass. This was not a problem in practice. The overall filter yielded nearly 100 dB image rejection and was tunable over the 80-meter band with a single section variable capacitor.

The more interesting bandpass filters are those with a multiplicity of resonators, or tuned circuits. Hence, two of the previous PLPF circuits were cascaded (on the computer), producing the response and circuit shown in fig. 14. The response shows a double peaked response like that of an overcoupled double tuned circuit.¹³ The $0.01 \mu\text{F}$ coupling capacitor between PLPF sections was increased to $0.015 \mu\text{F}$, yielding a single peak with little change in bandwidth or insertion loss. This circuit will tune over a reasonable range with a dual section variable capacitor.

The filters of figs. 13 and 14 are still basically lowpass designs, even though they emphasize the bandpass characteristics. The shunt end capacitors, when viewed in light of the bandpass filtering, serve merely to transform the end load resistance to a different value. Similarly, the shunt coupling capacitor between PLPF sections (fig. 14) controls the energy in one resonator shared by the other. Similar results would occur if these elements were shunt inductors with reactances equal to the capacitors previously used. These changes were made, resulting in the circuits of fig. 15. These are true bandpass filters, showing infinite attenuation at zero frequency.

The circuits of fig. 15 have two very interesting properties. First, the response shapes are very symmetrical. This symmetry is maintained even if the two-resonator filter is redone for a wider bandwidth. The second feature is the wide tuning range available. Note

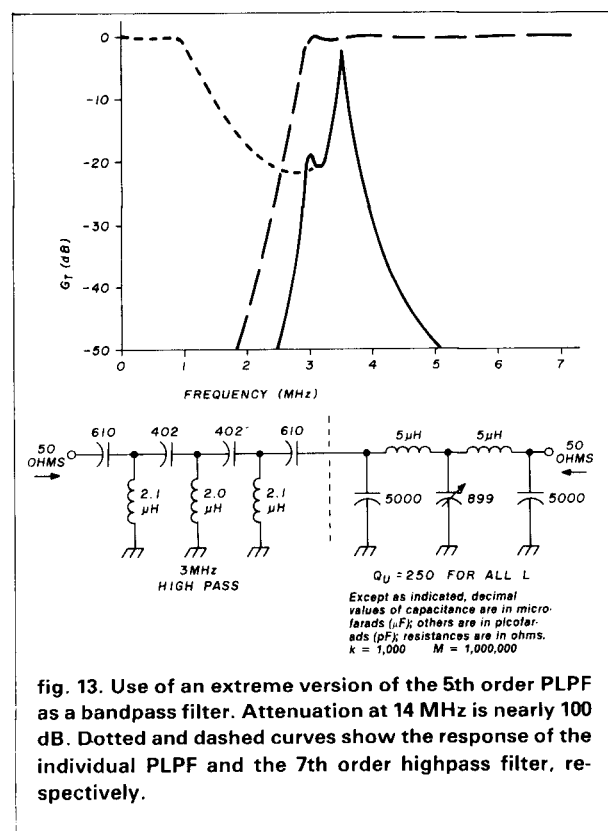


fig. 13. Use of an extreme version of the 5th order PLPF as a bandpass filter. Attenuation at 14 MHz is nearly 100 dB. Dotted and dashed curves show the response of the individual PLPF and the 7th order highpass filter, respectively.

that the only capacitors in the network are those used for tuning. All other elements are inductors. When the same concepts are applied to a more conventional double tuned circuit, the tuning range is expanded. The computer analysis showed that decreasing the two capacitors of fig. 15B from 766 to 95 pF produced a peak at 10 MHz, well above the original 3.5 MHz peak.

The double tuned circuit of fig. 15B was scaled to a slightly higher frequency and a model was built. Four 3-microhenry inductors were used with a dual section 400 pF variable capacitor. The main inductors were wound on T50-6 toroids, while smaller cores were used for the shunt elements. The circuit was tested with a spectrum analyzer and tracking generator (Tektronix 7L14 and TR-502) to confirm the calculations. This filter was especially easy to align and tuned 6 to 18 MHz. The circuit operates with an approximately constant loaded filter Q — that is, the bandwidth increases as the filter is tuned to higher frequency. Insertion loss varies little with tuning. Agreement with the computer modeling was excellent.

The work presented is restricted to doubly terminated designs. All circuits described have been built, confirming the computer results.

The first step in any filter design should be a careful evaluation of the requirements of the filter. The PLPF is well suited to some applications where a true low pass response is not really needed. The Chebyshev is not the only viable design for a low pass filter.

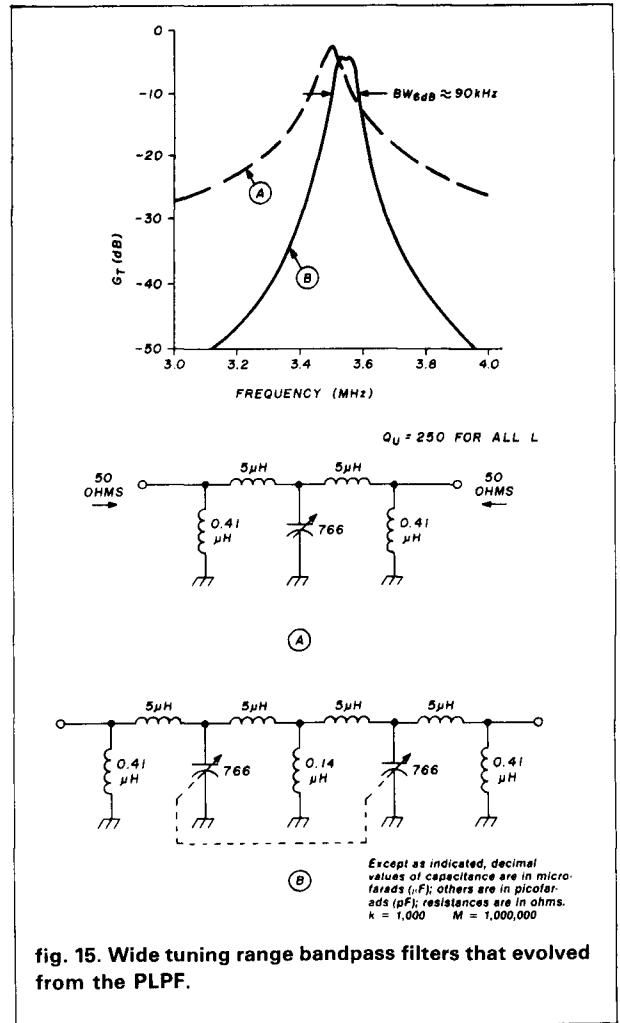


fig. 15. Wide tuning range bandpass filters that evolved from the PLPF.

Computer methods are very powerful, but are no substitute for formal analysis and synthesis. The best computer applications in electronics seem to be those that extend our intuition about circuit design.

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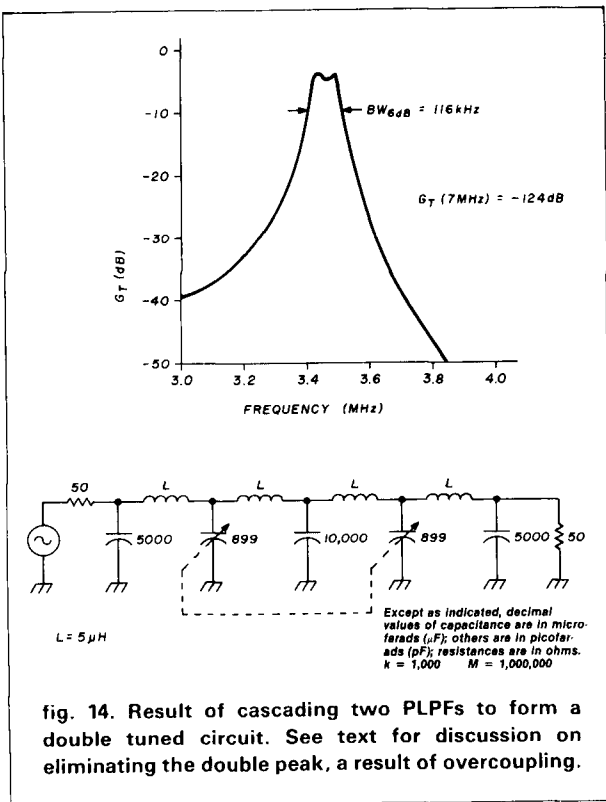
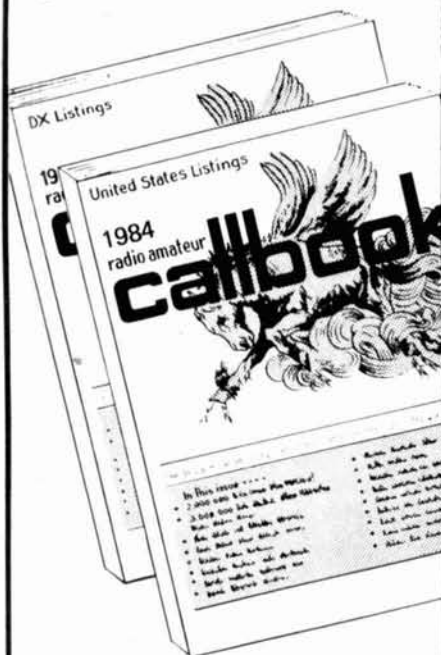


fig. 14. Result of cascading two PLPFs to form a double tuned circuit. See text for discussion on eliminating the double peak, a result of overcoupling.

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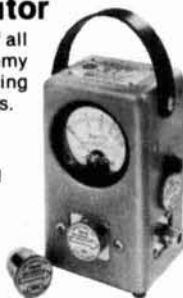


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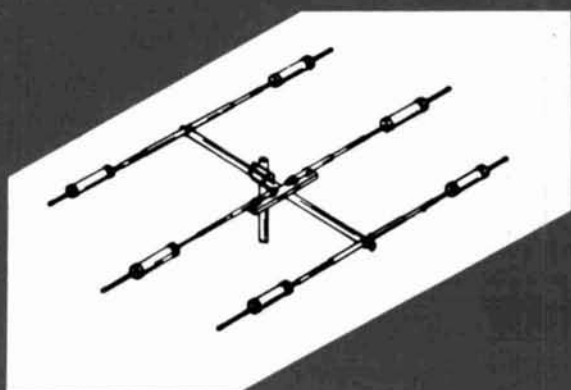
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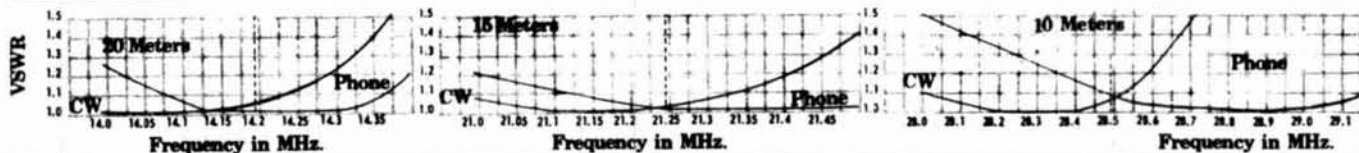
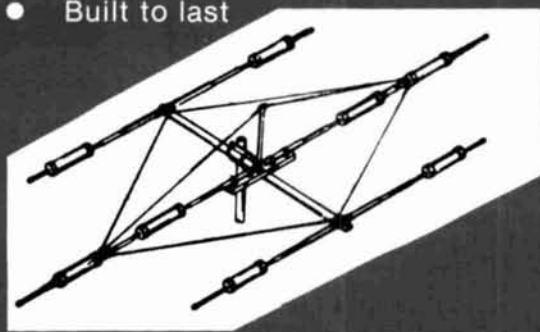
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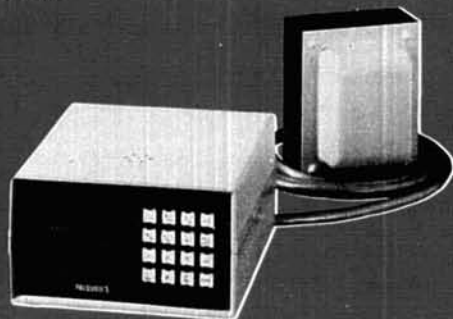


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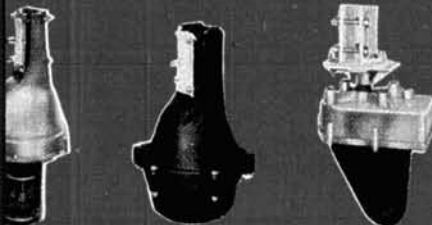
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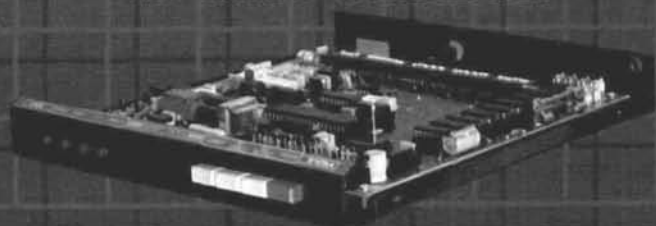
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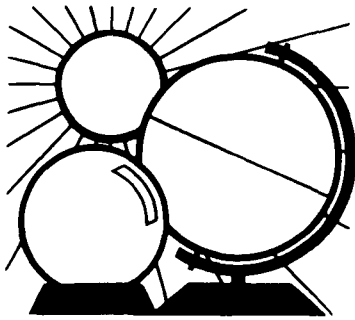


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DX FORECASTER

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sporadic E (E_s) DX

Last month the fundamentals of E_s and E_s propagation were reviewed. Now, before the E_s season gets further along, let's look at how E_s propagation can be used for DX. Because E_s propagation is short skip — i.e., 900 miles (1450 km) in hop length — the take-off angle needs to be low (5 to 10 degrees off the ground) in order to obtain the maximum length per hop. This keeps the number of hops (signal loss) to a minimum. For the higher frequency bands where horizontal beam (Yagi) antennas are used, this means tall towers with heights exceeding 60 feet — or even better, 100 feet or more. On the lower frequencies (below 10 MHz) vertical antennas in clear, treeless settings, situated over moist earth and equipped with sufficient ground systems are needed to obtain 5 to 10 degree take-off angles. (To obtain substantial energy at these angles, even at 7 MHz, ground systems should be measured in terms of wavelengths. — Editor).

To obtain the highest probability of "reflecting" from an E_s "cloud," a fairly wide beamwidth should be used. Because the beamwidth of Yagis (50 to 60 degrees) is better than the beamwidth of rhombics (20 to 30 degrees), Yagis are preferred for "hitting the clouds." E_s clouds usually measure about 10 by 100 km in length and about 0.6 km in depth. Their thin, dense configuration results in mirror-like reflections rather than the refractions that are characteristic of the F region. Reflection enhances signal strength by an average of 25 dB over refraction.

Another rule of thumb for E_s DX is to use the lowest frequency that isn't

absorbed too much. In other words, during daytime, don't use the 10-meter band when 20 is available. The probability of E_s occurrence is higher when the frequency is lower. You can expect an increase of at least 6 to 7 dB in E_s signal strength by using the lowest band that is open.

last-minute forecast

DX conditions are expected to be best for the higher frequency bands, 10 to 30 meters (daytime bands), from the 12th through 21st of the month, providing long and short skip openings. The lower frequency bands, 30 to 40 meters, are expected to be the best the first few days of the month and the last week of the month (the 25th and later), including some daytime openings when the solar flux is 80 units or below. The 80 to 160 meter bands will be poor because of noise, except for some sporadic E short-skip openings toward the end of the month.

The Aquarid meteor shower starts about the 18th, peaks about the 28th, and lasts until about August 7th. The maximum radio-echo rate will be 34 per hour. The full moon is on June 13th, lunar perigee the 7th, and solstice on the 21st at 0502 UT.

band-by-band summary

Six meters will provide occasional openings to South Africa and South America around local noontime by short-skip E_s .

Ten meters will be open to the south and southeast for a short period before local noon; to the south at noon and to the southwest in the afternoon. Openings will last longer when the

solar flux is at a maximum and improve (transequatorial one-long-hop) during periods of geomagnetic field-disturbances. Listen to WWV at 18 minutes after the hour for pertinent announcements.

Fifteen and twenty meters, almost always open to some part of the world, will be the main daytime DX bands. *Twenty meters* should stay open on long southern paths into the night, though 15 will drop out in the late afternoon. Operate on 15 first, then move down to 20 meters later. DX is 5,000 to 7,000 miles (8,000 to 11,300 km) on these bands. There may be some one-long-hop transequatorial propagation.

Thirty and forty meters are both daytime and nighttime bands. Intermediate distance operation, 1000-1500 miles (1600-2400 km), in any direction is considered daytime DX. Nighttime DX on these two bands may be expected to occur over greater distances than on 80 meters and, like 80, will follow the darkness path across the sky. Signal strength and distances covered are reduced on days of high solar flux values. In addition, no 30-meter openings will take place during the pre-dawn hours on the morning after these high radio flux values.

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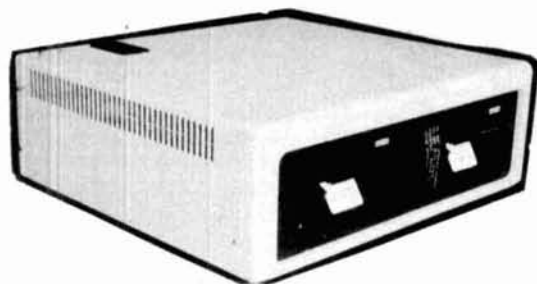
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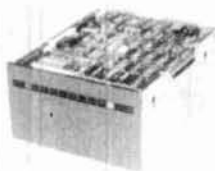
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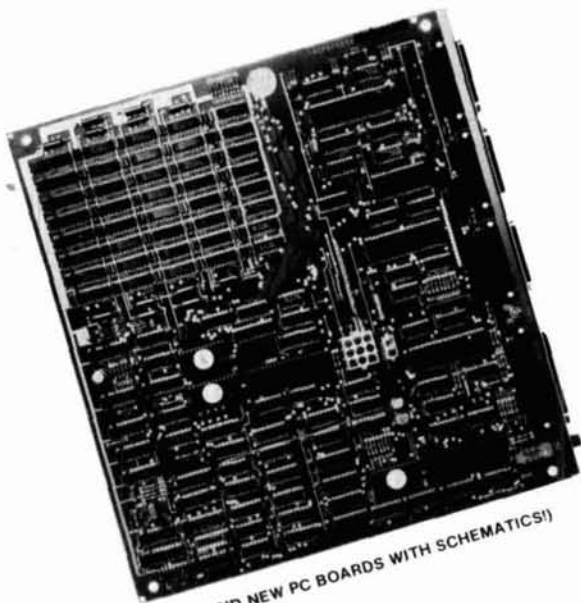
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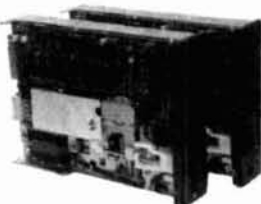
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product

REVIEW

ProSearch PSE-2N computerized antenna control

With all the advances in computer technology and applications, it was only a matter of time before someone designed a computer-controlled antenna rotator. The ProSearch PSE-2N is the first microprocessor controlled unit and features enunciated beam headings (with a computer generated voice). It will scan, is programmable for up to ten different beam headings, and has a computer actuated braking circuit. Like other ProSearch controllers, the PSE-2N is compatible with all commonly available rotators.

When I asked Gary Wurdack, President of ProSearch, for some background on the ProSearch Controller, he explained that the design came from his operating experience at K0VVUW, where he is actively involved in many contests, and that the ProSearch controller design evolved from his efforts to simplify and streamline the station. He explained his "wish list" of capabilities to a team of design engineers, and asked them to produce a computer controlled antenna rotator. The result is the ProSearch line of controllers.

Of particular interest to *ham radio* readers who have computer-integrated their stations, the PSE-2N can be hooked up to a master computer so that it can be controlled from a single source. This offers a number of exciting possibilities for complete computerization of ham shacks, and it will be interesting to see what results.

design

The heart of the ProSearch PSE 2 controller is a microprocessor that will process, store, and retrieve information and antenna headings and will control, in a manual mode, the operation of the rotator. Command entries are made through a 16-button keyboard on the front of the unit. Output commands from the microprocessor are fed to three driver amps that will activate the left and right movement of the rotator and the brake function. The microprocessor also controls the "talker" voice signals. When numbers are entered through the keyboard, they are read back for confirmation. The computer also controls the 80-Hz tone for CCW rotation and the 400-Hz tone for CW rotation.

As the rotator turns, a positive feedback potentiometer sends analog voltage signals back to the controller, indicating which direction the antenna is pointed. This signal is filtered and then converted into a digital signal to be compatible with the PSE microprocessor.

One admirable feature of the PSE-2N is its ten storable memory locations. Five of these mem-

ories have special buttons, keys 1-5, on the keypad for easy access. These areas are marked "Japan," "Europe," "Africa," "South America," and "New Zealand," respectively. Keys 6-0 can also be used to store beam headings for other areas of the world.

operation

Once you've connected all the rotator wires to the Cinch-Jones plugs and connected power to the unit, you are ready to go.

To turn the unit on, simply push the "SCAN & 7" button. All control instructions are entered from the keyboard and each key stroke is verbally confirmed.

The first order of business after installation is to calibrate the unit. This process is quite simple to accomplish using the step-by-step instructions provided and will take only a few minutes to accomplish. After the unit has been calibrated, it is ready to use in normal operations.

In order to demonstrate how the unit determines a specific heading, let's arbitrarily choose 45 degrees for Europe. Punch in a three-figured azimuth, (045 in this case), and push the "GO" button twice. Before the brake unlocks, the unit will say "0-4-5-GO-GO." The unit will unlock and begin to turn. Because of inaccuracies in rotor potentiometers, the computer will need to sample the analog input several times before stopping the unit in a desired direction, but when it stops, your antenna will be within ± 4 degrees of the desired direction.

ProSearch has built a protective circuit into the PSE-2N that will prevent accidental rotor damage from running the unit at full power into the stops: on north-centered units, inputs are within 15 degrees of the stops above 164 degrees or below 195 degrees; on south-centered units, the stops are between above 344 degrees and below 015 degrees. Should there be a heading you want in one of these areas, you can manually direct the antenna into these areas.

programming

To program the antenna for one of the ten memories, you first enter the beam heading. (Let's choose 045 degrees for Europe again.) Push the "STORE" button, then push the 2/EU (Europe). Memory position 2/EU is now programmed at 045 degrees and can be recalled by simply pushing the "GO" button once and then the 2/EU button. The antenna will automatically turn toward Europe at 045 degrees. Button 1/JA, 3/AFRICA, 4/SOUTH AMERICA and 5/NEW ZEALAND can now all be programmed with the appropriate information for your location. Memories 6-0 also can be programmed with any additional headings that you might desire or require.

Another useful feature is Scan. The PSE-2N has five "scan" functions. Scan-1 will have the rotator scan from 0-90 degrees; Scan-2, 90-180 degrees; Scan-3, 180-270 degrees; Scan-4, 270-360 degrees; and Scan-5, a full 360 degrees.

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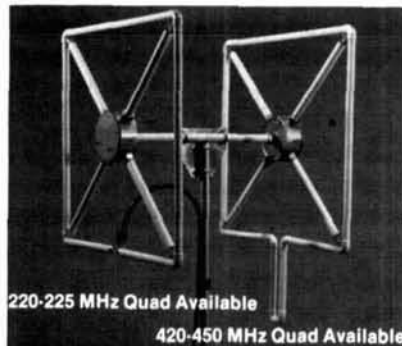
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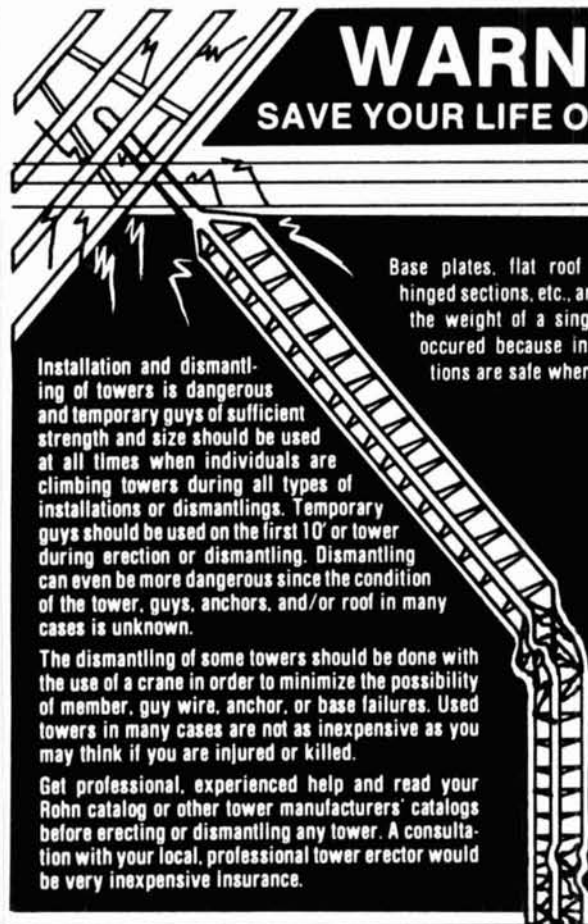
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Installation and dismantling of towers is dangerous and temporary guys of sufficient strength and size should be used at all times when individuals are climbing towers during all types of installations or dismantlings. Temporary guys should be used on the first 10' or tower during erection or dismantling. Dismantling can even be more dangerous since the condition of the tower, guys, anchors, and/or roof in many cases is unknown.

The dismantling of some towers should be done with the use of a crane in order to minimize the possibility of member, guy wire, anchor, or base failures. Used towers in many cases are not as inexpensive as you may think if you are injured or killed.

Get professional, experienced help and read your Rohn catalog or other tower manufacturers' catalogs before erecting or dismantling any tower. A consultation with your local, professional tower erector would be very inexpensive insurance.

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product
REVIEW

While scanning is a pleasurable activity, ProSearch does not recommend protracted amounts of scanning. They suggest that you don't scan for more than ten minutes without giving your rotator at least a few minutes' rest. This is required so that the brake solenoid will have sufficient time to cool.

The ProSearch PSE-2N isn't just a fully automatic unit. As you might expect, you can also turn the antenna manually with a clockwise or counter-clockwise rotation. This is helpful in fine tuning the direction of the beam to maximize signals.

computerization

Here's an area where you can really be at the forefront of current technology. When engineers designed the PSE-2N, they were able to provide an interface port that will facilitate connecting the controller to your home computer. The possibilities that this opens up are truly exciting. One thought is that you could design your station to be run completely by remote control. Why, you could even program a computer to work DX stations while you're at work or at home, sound asleep! You could store all the pertinent information about a particular station and your station could automatically turn on, aim the beam in the right direction, select the appropriate antenna and . . . well it is possible and may, in fact, already have been done. It is a fascinating thought; anyone who's actually done it is invited to drop us a note and tell us all about it.

summary

When I write a product review, I generally take the unit home to put it through its paces. In this case, because of the unique nature of the unit, I installed it into our club station WB1AHV so that all the hams here could try it out. It was interesting to hear the first impressions of the staff and station visitors to the PSE-2N; all were pleasantly surprised by the talk-back feature, and commented that it's a valuable asset. In casual operating, all who used the PSE-2N found it to be well engineered and easy to use, even with a minimum of instruction. One of the real benefits I found was its simplified operation. Instead of pushing and holding down both the brake and rotator control, insertion of desired heading plus the execute command left my hands free to do other things. In a contest this could free up valuable time for copying, logging, or checking QSO rate and multiplying counts. The ProSearch PSE-2N was a real "fun" piece of equipment to review.

The ProSearch line of rotator controllers uses high quality components throughout, and all double-sided glass board to ensure long, trouble-free service. The PSE-2N is priced at \$469. The PSE-1A "Contester," which sells for \$229.95, provides many of the same features, such as memory and digital input, but without "talk



Receive Only	Freq. Range (MHz)	N.F. (dB)	Gain (dB)	1 dB Comp. (dBm)	Device Type	Price
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P50VD	50-54	<1.3	15	0	DGFET	\$29.95
P50VDG	50-54	<0.5	24	+12	GaAsFET	\$79.95
P144VD	144-148	<1.5	15	0	DGFET	\$29.95
P144VDA	144-148	<1.0	15	0	DGFET	\$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	\$79.95
P220VD	220-225	<1.8	15	0	DGFET	\$29.95
P220VDA	220-225	<1.2	15	0	DGFET	\$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	\$79.95
P432VD	420-450	<1.8	15	-20	Bipolar	\$32.95
P432VDA	420-450	<1.1	17	-20	Bipolar	\$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	\$79.95
Inline (rf switched)						
SP28VD	28-30	<1.2	15	0	DGFET	\$59.95
SP50VD	50-54	<1.4	15	0	DGFET	\$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	\$109.95
SP144VD	144-148	<1.6	15	0	DGFET	\$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	\$67.95
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SP220VD	220-225	<1.9	15	0	DGFET	\$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	\$67.95
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back" and computer interface capability. Pro-Search is making a name for itself with these controllers — any one of which would be a valuable addition to any ham shack.

If you'd like more information, contact Pro-Search at 1344 Baur Boulevard, St. Louis, Missouri 63132.

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GaAs FET receiver preamp

Hamtronics, Inc. has just announced a new low-noise preamp that uses a new dual-gate GaAs FET recently designed especially for service in the VHF/UHF bands. Up until now, to get the low-noise figure of a GaAs FET, a designer had to adapt a transistor originally intended for microwave service; while such transistors work well, they are often costly and tend to oscillate because they have so much gain at the lower VHF and UHF frequencies. As single gate devices, they tend to have the characteristic high feedback capacitance associated with triodes, which makes them hard to tame under a wide variation in load impedances.

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The units operate on standard 12 to 14 VDC, are easy to tune, and may be mounted anywhere, including the tops of towers. LNG preamps are available for all Amateur bands, from 10 meters through 450 MHz.

For more information, including a free catalog on other Hamtronics® products, contact Hamtronics, Inc., 65 Moul Road, Hilton, New York 14468-9535.

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tool and instrument catalog

Contact East is offering a free copy of its 1984 Electronic Tool and Test Instrument catalog, featuring over 5,000 technical products for assembling, testing, and repairing electronic equipment. Products listed include precision hand tools, test instruments, tool kits, soldering supplies, plus a full selection of static control products. All products are fully illustrated with photographs accompanied by detailed descriptions, and prices.

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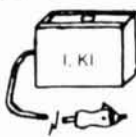
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2N5923	25.00	GMC290A	2.50	MRF453/A	18.40	PT8727	29.00
2N5941	23.00	HEP76	4.95	MRF454/A	20.12	PT8771	POR
2N5942	40.00	HEPS3002	11.40	MRF455/A	16.00	PT8742	19.10
2N5944	10.35	HEPS3003	30.00	MRF458	20.70	PT8787	POR
2N5945	11.50	HEPS3005	10.00	MRF463	25.00	PT9783	16.50
2N5946	14.40	HEPS3006	19.90	MRF472	1.00	PT9784	32.70
2N6080	10.35	HEPS3007	25.00	MRF475	3.10	PT9790	56.00
2N6081	12.07	HEPS3010	11.34	MRF476	2.00	PT31962	POR
2N6082	12.65	Hewlett Packard		MRF477	14.95	PT31963	POR
2N6083	13.25	HFET2204	112.00	MRF492	23.00	PT31083	POR
2N6084	15.00	35821E	38.00	MRF502	1.04	PTX6680	POR
2N6094	11.00	35826B	32.00	MRF503	6.00	RCA	
2N6095	12.00	35826E	32.00	MRF504	7.00	40081	5.00
2N6096	16.10	35831E-H31	30.00	MRF509	5.00	40279	10.00
2N6097	20.70	35831E	30.00	MRF511	10.69	40280	4.62
2N6105	21.00	35832E	50.00	MRF515	2.00	40281	10.00
2N6136	21.85	35833E	50.00	MRF517	2.00	40282	20.00
2N6166	40.24	35853E	71.50	MRF559	2.05	40290	2.80
2N6201	50.00	35854E	75.00	MRF605	20.00	40292	13.05
2N6304	1.50	35866E	44.00	MRF618	25.00	40294	2.50
2N6459	18.00	HXTR3101	7.00	MRF628	8.65	40341	21.00
2N6567	10.06	HXTR3102	8.75	MRF629	3.45	40608	2.48
2N6680	80.00	HXTR5104	30.00	MRF644	27.60	40894	1.00
2SC703	3.00	HXTR6104	68.00	MRF646	29.90	40977	10.00
2SC756A	7.50	HXTR6105	31.00	MRF816	15.00	62800A	60.00
2SC781	2.80	HXTR6106	33.00	MRF823	20.00	RE3754	25.00
2S11018	1.00	J310	.70	MRF901 (3) Lead	1.00	RE3789	25.00
2SC1042	12.00	TRW		MRF901 (4) Lead	2.00	RF110	25.00
2SC1070	2.50	JG2000	10.00	MRF904	2.30	S50-12	25.00
2S11239	2.50	JG2001	25.00	MRF911	3.00	S3006	5.00
2SC1251	12.00	JO4045	25.00	MRF961	2.30	S3031	5.00
2SC1306	2.90	Motorola Comm.		MRF8004	2.10	SCA3522	5.00
2SC1307	5.50	M1131	8.50	MS261F	POR	SCA3523	5.00
2SC1424	2.80	M1132	11.95	MSC1720-12	225.00	PRICE ON REQUEST = POR	

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GaAs, TUNNEL DIODES, ETC.

* R F TRANSISTORS *

TYPE	PRICE	TYPE	PRICE	TYPE	PRICE	TYPE	PRICE
THOMSON CSF							
SD345	\$ 5.00	SD1119	\$ 5.00	SD1278-5	\$18.00	SD1453-1	\$48.00
SD445	5.00	SD1124	50.00	SD1281-2	8.00	SD1454-1	48.00
SD1004	15.00	SD1127	3.50	SD1283	10.00	SD1477	48.00
SD1009	15.00	SD1133	14.00	SD1289-1	15.00	SD1478	21.00
SD1009-2	15.00	SD1133-1	14.00	SD1290-4	15.00	SD1480	60.00
SD1012	9.90	SD1134-1	3.00	SD1290-7	15.00	SD1484	1.50
SD1012-3	9.90	SD1135	8.00	SD1300	3.00	SD1484-5	1.50
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
SD1013-7	13.50	SD1143-1	12.00	SD1307	3.00	SD1488	39.00
SD1014	11.00	SD1143-3	17.00	SD1308	3.00	SD1488-1	28.00
SD1014-6	11.00	SD1144-1	3.00	SD1311	1.00	SD1488-7	27.00
SD1016	15.00	SD1146	15.00	SD1317	10.00	SD1488-8	28.00
SD1016-5	15.00	SD1147	15.00	SD1335	3.00	SD1499-1	39.00
SD1018-4	15.00	SD1188	10.00	SD1345-6	5.00	SD1520-2	18.00
SD1018-6	15.00	SD1189	24.00	SD1365-1	2.50	SD1522-4	33.00
SD1018-7	15.00	SD1200	1.50	SD1365-5	2.50	SD1528-1	24.00
SD1018-15	15.00	SD1201-2	10.00	SD1375	7.50	SD1528-3	34.00
SD1020-5	10.00	SD1202	10.00	SD1375-6	7.50	SD1530-2	38.00
SD1028	15.00	SD1212-11	4.00	SD1379	15.00	SD1536-1	41.00
SD1030-2	12.00	SD1212-12	4.00	SD1380-1	1.00	SD1545	34.00
SD1043	12.00	SD1212-16	4.00	SD1380-3	1.00	SD1561	79.00
SD1043-1	10.00	SD1214-7	5.00	SD1380-7	1.00	SF4557 Mot.	25.00
SD1045	3.75	SD1214-11	5.00	SD1405	40.00	SK3048 RCA	5.00
SD1049-1	2.00	SD1216	12.00	SD1409	18.00	SK3177 RCA	15.00
SD1053	4.00	SD1219-4	15.00	SD1410	22.00	SMS7714 Mot.	2.50
SD1065	4.75	SD1219-5	15.00	SD1410-3	21.00	SFR750 Mot.	36.00
SD1068	15.00	SD1219-8	15.00	SD1413-1	18.00	SFR1018 Mot.	5.00
SD1074-2	18.00	SD1220	8.00	SD1416	50.00	SFR2147 Mot.	22.00
SD1074-4	28.00	SD1220-9	8.00	SD1422-2	24.00	SFR2356 Mot.	38.00
SD1074-5	28.00	SD1222-8	16.00	SD1428	33.00	SFR2378 Mot.	16.00
SD1076	20.00	SD1222-11	7.50	SD1429-2	15.00	SFR2584 Mot.	40.00
SD1077-4	4.00	SD1224-10	18.00	SD1429-3	15.00	SFR2821 Mot.	25.00
SD1077-6	4.00	SD1225	18.00	SD1429-5	15.00	SFR2857 Mot.	20.00
SD1078-6	24.00	SD1228-8	POR	SD1430	12.00	TA8894 RCA	15.00
SD1080-8	6.00	SD1229-7	13.00	SD1430-2	18.00	TIS189/MRP966	3.55
SD1080-9	3.00	SD1229-16	13.00	SD1434-5	30.00	TP312	2.50
SD1084	8.00	SD1232	4.00	SD1434-9	30.00	TP1014 TRW	5.00
SD1087	15.00	SD1240-8	15.00	SD1438	26.00	TP1028 TRW	15.00
SD1089-5	15.00	SD1244-1	14.00	SD1441	91.00	01-80703T04/	
SD1095	15.00	SD1262	12.00	SD1442	15.00	458-949 Mot. Comm.	65.00
SD1100	5.00	SD1263	15.00	SD1444	6.00	TXVP2201 H.P.	450.00
SD1109	18.00	SD1263-1	15.00	SD1444-8	6.00	G2803 RCA	100.00
SD1115-2	8.00	SD1272	13.00	SD1450-1	28.00	TA7205/2N5921	80.00
SD1115-3	8.00	SD1272-2	15.00	SD1451	18.00	TA7487/2N5920	75.00
SD1115-7	2.50	SD1272-4	15.00	SD1451-2	18.00	TA7995/2N6267	150.00
SD1116	5.00	SD1278	20.00	SD1452	20.00	SFR2092 Mot.	18.00
SD1118	22.00	SD1278-1	18.00	SD1452-2	20.00	MRP479	8.05

We Can Cross Reference Most RF Transistors, Diodes, Hybrid Modules And Any Other Type Of Semiconductor.

* DIODES (HOT CARRIER, MICROWAVE, PIN, SCHOTTKY, TUNNEL, VARACTOR, GUNN) *

LN21	\$ 3.40	LN21B	\$ 3.40	LN21BR	\$ 3.40	LN21C	\$ 3.40
LN21D	4.00	LN21DR	4.00	LN21ER	6.00	LN21RF	5.00
LN21WE	5.80	LN21WG	5.80	LN22	5.00	LN23A	10.00
LN23B	3.40	LN23C	3.40	LN23CR	3.40	LN23D	4.95
LN23DR	4.00	LN23WE	5.00	LN25	7.50	LN25AR	18.00
LN28WE	10.00	LN29	10.00	LN42	20.00	LN53A	55.50
LN76	26.00	LN76R	28.00	LN78	26.00	LN78A	28.00
LN78B	26.00	LN78D	28.00	LN78DR	28.00	LN78R	20.00
LN149	6.00	LN150MR	18.00	LN415	4.00	LN415C	4.00
LN415G	15.00	LN416D	5.00	LN416E	6.00	LN446	10.00
LN831	10.00	LN833	10.00	LN950	4.00	LN1084	2.00
LN2930	15.00	LN2932	15.00	LN3540	15.00	LN3712	11.00
LN3713	18.00	LN3714	11.00	LN3715	16.00	LN3716	10.00
LN3717	14.00	LN3718	10.00	LN3721	14.00	LN3733	10.00
LN3747	21.00	LN4386	20.00	LN4396	15.00	LN4785	11.00
LN4812B	9.00	LN5139A/B	4.25	LN5140A/B	4.25	LN5141A/B	4.25
LN5142A/B	4.25	LN5143A/B	4.25	LN5144A/B	4.25	LN5145A/B	4.25
LN5146A/B	4.25	LN5147A/B	4.25	LN5148A/B	4.25	LN5167	5.50
LN5453	3.75	LN5465	7.65	LN5711	1.00	LN5711 JAN	2.00
LN5713	5.00	LN5767	2.00	LN6263	1.00	LS2199	15.00
LS2200	15.00	LS2208/9	1.00	8B1087/48R869558	65.00	SD3020	65.00
AZX116M Aertech	50.00	BB105B	1.00	BB105G	1.00	BD4/4JFBD4 G.E.	15.00
BL161 Bmmac	5.00	CMDS14AB C.M.	POR	D4060 Alpha	POR	D4159 Alpha	POR
D4233B Alpha	POR	D4900 Alpha	POR	D4959 Alpha	POR	D4987M Alpha	POR
D6047C Alpha	POR	D5147D Alpha	POR	D5503 Alpha	POR	D5506 Alpha	POR
DGB6158-98 Alpha	POR	DMD6022 Alpha	POR	DMD6460A Alpha	POR	DP20054 Crown	POR
GC1891-89 GHz	31.35	GC1602-89 GHz	31.35	GC1607-10 GHz	31.35	GC2531-88 GHz	37.40
GC2542-46 GHz	37.40	GC3208-40 GHz	37.40	GC17044 GHz	50.00	HP33644A-HD1	125.00
HP5082-0112	14.20	HP5082-0241	75.60	HP5082-0253	105.00	HP5082-0320	58.00
HP5082-0375	POR	HP5082-0386	POR	HP5082-0401	POR	HP5082-0438	POR
HP5082-1028	POR	HP5082-1332	POR	HP5082-2254	POR	HP5082-2302	10.70
HP5082-2303	5.20	HP5082-2696	POR	HP5082-2711	23.15	HP5082-2727	POR
HP5082-2800	1.00	HP5082-2805	4.45	HP5082-2835	1.00	HP5082-2884	POR
HP5082-3039	6.70	HP5082-3040	36.00	HP5082-3080	2.00	HP5082-3188	1.00
HP5082-3379	1.50	HP5082-6459	POR	HP5082-6462	POR	HP5082-6888	POR
HP5082-8016	POR	HP5082-8323	POR	K3A Kent ron	7.00	MA450A	POR
MA475	POR	MA40008	POR	MA11487	POR	MA41765	POR
MA41766	POR	MA43004	48.00	MA43589	POR	MA43622	POR
MA43636	POR	MA45104	27.00	MA47044	POR	MA47051	25.50
MA47100	3.05	MA47202	30.80	MA47771	POR	MA47838*	POR
MA47852	POR	MA49106	37.95	MA49558	POR	MA86731	125.00

* OUR STOCK CHANGES DAILY SO CALL IF THE PART YOU NEED IS NOT LISTED

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MHz electronics

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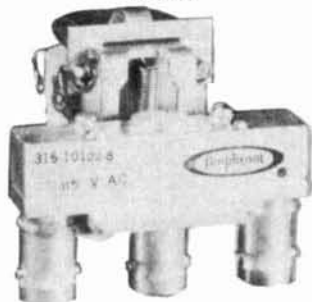
COAXIAL RELAY SWITCHES SPDT

Electronic Specialty Co./Raven Electronics FSN 5985-556-9683 \$49.00
 Part # 25N28 Part # SU-01
 26Vdc Type N Connector, DC to 1 GHz.



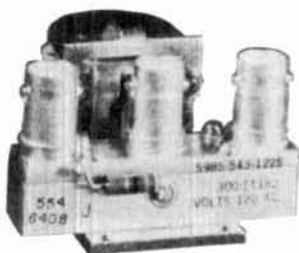
Amphenol
 Part # 316-10102-8
 115Vac Type BNC DC to 3 GHz.

\$29.99



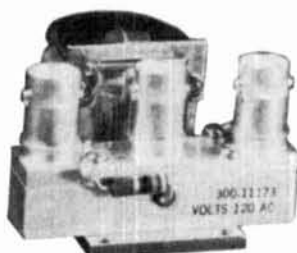
FXR
 Part # 300-11182
 120Vac Type BNC DC to 4 GHz.
 FSN 5985-543-1225

\$39.99



FXR
 Part # 300-11173
 120Vac Type BNC Same
 FSN 5985-543-1850

\$39.99



BNC To Banana Plug Coax Cable RG-58 36 inch or BNC to N Coax Cable RG-58 36 inch.

\$7.99 or 2 For \$13.99 or 10 For \$50.00

\$8.99 or 2 For \$15.99 or 10 For \$60.00



SOLID STATE RELAYS

P&B Model ECT1DB72 5vdc turn on
 PRICE EACH \$5.00

Digisig, Inc. Model ECS-215 5vdc turn on
 PRICE EACH \$7.50

Grigsby/Barton Model GB7400 5vdc turn on
 PRICE EACH \$7.50

120vac contact at 7amps or 20amps on a 10"x 10" x .124 aluminum. Heatsink with silicon grease.

240vac contact 14amps or 40amps on a 10"x 10" x .124 aluminum. Heatsink with silicon grease.

240vac contact at 15amps or 40amps on a 10"x 10" x .124 aluminum. Heatsink with silicon grease.

NOTE: *** Items may be substituted with other brands or equivalent model numbers. ***

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TUBES

TYPE	PRICE	TYPE	PRICE	TYPE	PRICE
2C39/7289	\$ 34.00	1182/4600A	\$500.00	ML7815AL	\$ 60.00
2E26	7.95	4600A	500.00	7843	107.00
2K28	200.00	4624	310.00	7854	130.00
3-500Z	102.00	4657	84.00	ML7855KAL	125.00
3-1000Z/8164	400.00	4662	100.00	7984	14.95
3B28/866A	9.50	4665	500.00	8072	84.00
3CX400U7/8961	255.00	4687	P.O.R.	8106	5.00
3CX1000A7/8283	526.00	5675	42.00	8117A	225.00
3CX3000F1/8239	567.00	5721	250.00	8121	110.00
3CW30000H7	1700.00	5768	125.00	8122	110.00
3X2500A3	473.00	5819	119.00	8134	470.00
3X3000F1	567.00	5836	232.50	8156	12.00
4-65A/8165	69.00	5837	232.50	8233	60.00
4-125A/4D21	79.00	5861	140.00	8236	35.00
4-250A/5D22	98.00	5867A	185.00	8295/PL172	500.00
4-400A/8438	98.00	5868/AX9902	270.00	8458	35.00
4-400B/7527	110.00	5876/A	42.00	8462	130.00
4-400C/6775	110.00	5881/6L6	8.00	8505A	95.00
4-1000A/8166	444.00	5893	60.00	8533W	136.00
4CX250B/7203	54.00	5894/A	54.00	8560/A	75.00
4CX250FG/8621	75.00	5894B/8737	54.00	8560AS	100.00
4CX250K/8245	125.00	5946	395.00	8608	38.00
4CX250R/7580W	90.00	6083/AZ9909	95.00	8624	100.00
4CX300A/8167	170.00	6146/6146A	8.50	8637	70.00
4CX350A/8321	110.00	6146B/8298	10.50	8643	83.00
4CX350F/8322	115.00	6146W/7212	17.95	8647	168.00
4CX350FJ/8904	140.00	6156	110.00	8683	95.00
4CX600J/8809	835.00	6159	13.85	8877	465.00
4CX1000A/8168	242.50*	6159B	23.50	8908	13.00
4CX1000A/8168	485.00	6161	325.00	8950	13.00
4CX1500B/8660	555.00	6280	42.50	8930	137.00
4CX5000A/8170	1100.00	6291	180.00	6L6 Metal	25.00
4CX10000D/8171	1255.00	6293	24.00	6L6GC	5.03
4CX15000A/8281	1500.00	6326	P.O.R.	6CA7/EL34	5.38
4CW800F	710.00	6360/A	5.75	6CL6	3.50
4D32	240.00	6399	540.00	6DJ8	2.50
4E27A/5-125B	240.00	6550A	10.00	6DQ5	6.58
4PR60A	200.00	6883B/8032A/8552	10.00	6GF5	5.85
4PR60B	345.00	6897	160.00	6GJ5A	6.20
4PR65A/8187	175.00	6907	79.00	6GK6	6.00
4PR1000A/8189	590.00	6922/6DJ8	5.00	6HB5	6.00
4X150A/7034	60.00	6939	22.00	6HF5	8.73
4X150D/7609	95.00	7094	250.00	6JG6A	6.28
4X250B	45.00	7117	38.50	6JM6	6.00
4X250F	45.00	7203	P.O.R.	6JN6	6.00
4X500A	412.00	7211	100.00	6JS6C	7.25
5CX1500A	660.00	7213	300.00*	6KN6	5.05
KT88	27.50	7214	300.00*	6KD6	8.25
416B	45.00	7271	135.00	6LF6	7.00
416C	62.50	7289/2C39	34.00	6LQ6 G.E.	7.00
572B/T160L	49.95	7325	P.O.R.	6LQ6/6MJ6 Sylvania	9.00
592/3-200A3	211.00	7360	13.50	6ME6	8.90
807	8.50	7377	85.00	12AT7	3.50
811A	15.00	7408	2.50	12AX7	3.00
812A	29.00	7609	95.00	12BY7	5.00
813	50.00	7735	36.00	12JB6A	6.50

NOTE * = USED TUBE

NOTE P.O.R. = PRICE ON REQUEST

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HEWLETT PACKARD SIGNAL GENERATORS

606A	50KHz to 65MHz in 6 bands $\pm 1\%$ Output level adjustable 0.1uV to 3V into 50 ohms. Built-in crystal calibrator. 400 - 1000Hz modulation.	\$ 650.00	616B	Same as above but later model.	\$ 600.00
606B	Same as above but has frequency control feature to allow operation with HP 8708A Synchronizer.	\$1100.00	618B	3.8 to 7.6GHz range, with calibrated output and selection of pulse-FM or square wave modulation.	\$ 600.00
608C	10MHz to 480MHz, 0.1uV-1V into 50 ohms, AM, CW, or pulse modulation, calibrated attenuator.	\$ 500.00	618C	Same as above but later model.	\$2200.00
608D/TS510	10MHz to 420MHz, 0.1uV-0.5V into 50 ohms, $\pm 0.5\%$ accuracy, built-in crystal calibrator, AM-CW or pulse output.	\$ 375.00	620A	7 to 11GHz range, with calibrated output and selection of pulse-FM or square wave modulation.	\$ 750.00
608E	Improved version of popular 608C. Up to 1V output. Improved stability, low residual FM.	\$1450.00	620B	Same as above but later model.	\$2200.00
608F	10MHz to 455MHz in 5 bands $\pm 1\%$ frequency accuracy with built-in crystal calibrator. Can be used with HP 8708A Synchronizer. Output continuously adjustable from .1uV to .5V into 50 ohms.	\$1100.00	626A	10 to 15GHz, 10mW output power with calibrated output and pulse-square wave or FM modulation.	\$4200.00
612A	450-1230MHz, 0.1uV-0.5V into 50 ohms, calibrated output.	\$ 750.00	8708A	Synchronizer used with 606B, 608F. The synchronizer is a phase-lock frequency stabilizer which provides crystal-oscillator frequency stability to 430MHz in the 608F signal generator. Phase locking eliminates microphonics and drift resulting in excellent frequency stability. The 8708A includes a varactor which can tune the reference oscillator over a range of $\pm 0.25\%$ permitting frequency stability to 2 parts in 10 to the seventh. Provides a very stable signal that satisfies many critical applications.	(With HP 606B or 608F) \$ 350.00 (Without) \$ 450.00
614A	900-2100MHz with many features including calibrated output and all modulation characteristics.	\$ 500.00	EMC-10	ELECTROMETRICS EMC-10 RFI/EMI RECEIVER Low frequency analyzer covering 20Hz to 50KHz frequency range. Extendable to 500 KHz in wideband mode.	\$2500.00
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Coming Events ACTIVITIES "Places to go..."

CALIFORNIA: The Satellite ARC's 1984 Santa Maria Swapfest and Barbecue on Father's Day, June 17 at the Union Oil Company Picnic Grounds south of Santa Maria. General Admission 9 AM. Barbecue served at 1 PM. For information, tickets or swap table reservations: Satellite ARC Swapfest, PO Box 5117, Vandenberg Air Force Base, CA 93437.

GEORGIA: The Atlanta Hamfestival 1984, sponsored by the Atlanta Radio Club, June 16 and 17, at the Atlanta Civic Center. 70,000 square feet of air-conditioned exhibitor space and over 800 outdoor flea market spaces will be available. Flea Market \$12.50 per space in advance; \$15.00 at the gate for both days. Hamfest registration \$5.00 in advance, \$6.00 at the door. To be pre-registered for the Flea Market or Hamfest, we must receive your application and check by June 8. Pre-registration applications received after June 8 will be returned. Hours 8 AM to 5 PM on Saturday, 8 AM to 2:30 PM on Sunday. Talk in on 3.97 MHz, 146.22/82 and 146.94 simplex. For pre-registration or other information write Atlanta Radio Club, PO Box 77171, Atlanta, GA 30357.

ILLINOIS: "RADIOFEST '84" a display and sale of antique and classic Amateur equipment as well as vintage radio memorabilia, June 21-23, Holiday Inn, I-90 and Illinois 31, Elgin. This event is sponsored by the Antique Radio Club of America and hosted by the Antique Radio Club of Illinois. Amateur radio participation is welcomed. Talk in on 146.52. For details write Joe Willis, Box 14732, Chicago, IL 60614.

INDIANA: State ARRL Convention and Indianapolis Hamfest, Saturday and Sunday, July 7 and 8, Marion County Fairgrounds, I-74 and 465. Flea Market setup 8 AM July 7. Free camping with hookups available on grounds. Nearby motels. Commercial building open to public 8 AM Sunday. Tech forums all day. Food service. Tickets \$4.00 includes free parking and all activities. For further information: Indianapolis Hamfest, Box 11086, Indianapolis, IN 46201.

INDIANA: The Lake County Amateur Radio Club will hold its 12th annual "Dad's Day" Hamfest, June 17, Industrial Arts Building, Lake County Fairgrounds, Crown Point. 8 AM to 2 PM. Tickets \$2.50. Plenty of parking and food. Talk in on

147.84/24 or 52. For further information: Bill De Geer, W9TY, Chairman, 3601 Tyler Street, Gary, IN 46408.

MARYLAND: The Frederick Amateur Radio Club's 7th annual Hamfest, June 17, Frederick Fairgrounds, 8 AM to 4 PM. Admission \$3.00. YL's and children free. Tailgaters \$2.00 additional. Exhibitors tables \$10.00 each; \$5.00 each additional table. Gates open for exhibitors 8 PM June 16. Overnight security. For additional information: Jim Devilbiss, WA3FUJ, 915 Pine Avenue Frederick, MD 21701. (301) 662-5784.

MICHIGAN: The Straits Area ARC's annual Swap-Shop and Computer demonstration at Emmet County Fairgrounds 4-H Building, Petoskey, July 21. 9 AM to 2 PM. Admission \$2.50. Tables \$3.00 with setup at 8 AM. RV camping nearby. Talk in on 146.67 and 52. For information: Irene Stein, KA8NKS, 4487 Robinson Rd., Pellston, MI 49769. (616) 539-8986.

MICHIGAN: The Independent Repeater Association of Grand Rapids will hold its annual Hamfest, Saturday, June 30, 8 AM to 4 PM, Wyoming National Guard Armory, 44th Street, west of US-131. Free table space to all sellers. Admission \$3.50. Satellite operation, packet radio, W5FLF space shuttle movie, Amtor forum, CW RX contest, Antenna forum and shack picture contest. Large swap area. Talk in on 147.165/147.765. For information: Linda Hurley, WD8OHW (616) 457-1253 or write I.R.A., 562 - 92nd Street SE, Byron Center, MI 49315.

NEVADA: The YL International SSB System's annual convention, June 21-24, Sahara Hotel, Las Vegas. Deluxe accommodations and RV parking at reasonable rates. Activities include a tour of Hoover Dam, Lake Mead cruise, gala stage show, cocktail party, banquet and breakfast buffet. DX forum and business meetings. YLRL ladies are invited to meet Thursday evening at 8 PM. A convention station will operate on 14.332 kHz. For complete details and registration packet send business SASE with 37¢ in stamps to: Jan Weaver, N7YL, 2195 East Camero Avenue, Las Vegas, NV 89123.

NEW JERSEY: The Raritan Valley Radio Club's 13th annual Hamfest, Saturday, June 16, Columbia Park, Dunellen. Gates open 8:30 AM. Lookers \$2.00. Sellers spots \$5.00 each, own tables. Refreshments available. Talk in on Club repeater, W2QW/R 146.025/625 and 146.52 simplex. Advance tickets may be purchased from any club member. For further information call Jack, W2IWK (201) 756-2546 or Ted, WB2TKU (201) 725-3481 between 10 AM and 10 PM.

NEW JERSEY: The Jersey Shore Chaverim is sponsoring the third annual Ham & Computerfest, June 10, 9 AM to 4 PM, Jewish Community Center, 100 Grant Avenue, Deal. 7300 sq. ft. of indoor space. Admission \$3 per person (children under 12 and YL's free). Refreshments available. Indoor table \$8 and tailgating \$3.50 per space. For reserved space SASE with advance payment to Jersey Shore Hamfest, PO Box 192, West Long Branch, NJ 07764 by June 1. Talk in on 147.045 + 6, 145.110 + 6 and 146.52 simplex. Deal, NJ is less than 50 miles from NYC and 70 miles from Philadelphia. For information call Arnold, W2GDS (201) 222-3009.

NEW YORK: The Putnam Emergency Amateur Repeater League (PEARL) will have its 3rd annual Hamfest, Saturday, July 7, 9 AM to 4 PM, St. John's School, Monsignor O'Brien Blvd., Mahopac. General admission \$1.00. Indoor tables \$5.00 each. Outdoor tailgating \$4.00. For advance registration and information: Frank Konecnik, WB2PTP, RD1, 244 C, Carmel, New York 10512. Talk in on 144.535/145.135 and 146.52.

NORTH DAKOTA/MANITOBA: The 21st annual international Hamfest, July 14 and 15, at the International Peace Garden between Dunseith, ND and Boissevain, Manitoba. Transmitter hunts, mobile judging, CW contest. Excellent camping. For more information: WD0EMY or WD0DAJ, Box H, Dickinson, ND 58601.

OHIO: The Tusco Amateur Radio Club, W8ZX, and the Canton Amateur Radio Club, W8AL, will hold the 10th annual Hall of Fame Hamfest, July 15, Nimishillen Grange, 6461 Easton Street, Louisville. Admission \$2.50 advance and \$3.00 at gate. Flea Market additional \$2.00 per vehicle. Reserved tables available. Mobile checkin on 146.52/52 and 147.72/12. Call W8ZX or W8AL. For reservations/information: WA8SHP, Butch Lebold, 10877 Hazelview Avenue, Alliance, Ohio 44601. (216) 821-8794.

OHIO: The 20th annual Wood County Ham-A-Rama, Sunday, July 8, Wood County Fairgrounds, Bowling Green. Gates open 8 AM. Free admission and parking. Trunk sales. Food available. Advance table rentals \$5.00 (dealers only). Saturday setup until 8 PM. K8THH talk in on 52. For information or dealer rentals SASE to: Wood Co. ARC, c/o Craig Henderson, Box 366, Luckey, OH 43443.

OREGON: The 9th annual Lane County Ham Fair, July 21 and 22, Oregon National Guard Armory, 2515 Centennial, Eugene. Doors open 8 AM both days. Computer demos, tech seminars, swap tables, kiddie korner, snack bar, free parking for RV's — no hookups. Saturday potluck supper. Tickets and swap tables \$5.00 each. FCC exams. Talk in 146.28/88, 147.86/26 and 52. For tickets/tables: Tom Tenby, Treas., 3227 Crocker Rd., Eugene, OR 97404. Make checks payable to Lane County Ham Fair.

PENNSYLVANIA: The 13th annual Hamfest sponsored by the Milton ARC, Sunday, June 10, rain or shine, Winfield Fire Co. grounds, Rt. 15, south of Lewisburg. 8 AM to 5 PM. Covered spaces available. Registration \$3.00. Spouse and kids free. Flea market, auction and contests. Talk in on 146.37/97 and 146.025/625. For further details: Jerry Williamson, WA3SQ, 10 Old Farm Lane, Milton, PA 17847. (717) 742-3027.

PENNSYLVANIA: The annual "Firecracker" Hamfest, Wednesday, July 4, sponsored by the Harrisburg Radio Amateur Club, Bressler F.C. picnic grounds, exit 1 off I-283. Admission \$3.00. YL and children free. Free tailgating. Nearby motels and restaurants. Plenty of parking. Shaded tables. For details/table reservations: Dave, KC3MG, 131 Livingston Street, Swatara, PA 17113 (717) 039-4957.

WEST VIRGINIA: Wheeling Hamfest, Sunday, July 22, Wheeling Park. Flea market, auction, dealers welcome. Under roof tables available. Admission \$3.00. For information/reservations: TSRA. Box 240, RD 1, Adena, OH 43901. (614) 546-3930

WISCONSIN: The South Milwaukee ARC's annual Swapfest, Saturday, July 7, American Legion Post #434, 9327 South Shepard Avenue, Oak Creek. 7 AM to 5 PM. Picnic area, refreshments available on grounds, free overnight camping. Admission \$3.00 per person includes "Happy Hour" with free beverages. Talk in on 146.94 MHz FM. For details the club at PO Box 102, South Milwaukee, WI 53172.

ONTARIO: The tenth annual Ontario Hamfest, July 14, 7 AM to 4 PM, Milton, Ontario, fairgrounds. Weekend camping, free parking, free flea market tables. Tickets \$2.50 advance, \$4.00 at gate. Commercial displays, refreshments. Talk in on Club repeater 21/81. For details and pre-registration: Burlington ARC, PO Box 836, Burlington, Ontario L7R 3Y7.

BRITISH COLUMBIA: The Maple Ridge ARC is hosting Hamfest '84, June 30 and July 1, Maple Ridge Fairgrounds 30 miles east of Vancouver. Registration: Hams \$5.00, non-Hams over 12 \$2.00. Swap and shop, commercial displays, bunny hunts, ladies' and children's programs and more. Camper space available with elec. Talk in on 146.20/80 and 146.34/94. For information an registration (20% off gate entrance) contact: Maple Ridge ARC, Box 292, Maple Ridge, BC V2X 7G2

OPERATING EVENTS "Things to do..."

JUNE 16: The Missouri Valley ARC's fifth annual Pony Express Day, 0900 to 1700 CST. and June 17, 1000 to 1300 CST to commemorate the original running of the Pony Express from St. Joseph, MO to Sacramento, CA. Listen for club station W0NH 10 kc's from bottom of General phone bands on 15, 20, 40 and 75 meters. 10 meters 28.575. CW 28.150 on 10; 21.150 on 15; and 7.125 on 40. Send one 1st class stamp and QSL to Missouri Valley ARC, 401 N. 12th Street, St. Joseph, MO 64501.

JULY 7-8 SSB and JULY 28-29 CW. Venezuelan Independence Worldwide Contest. 0000 GMT Saturday — 2400 GMT Sunday. All bands exchange RS(T) plus a three figure QSO number starting with 001. Logs must show date, hour (GMT only), station worked, reports exchanged and respective numerical order, multipliers and points. Each participant will accompany log with US \$2.00 or IRC equivalent post-marked no later than August 15, 1984 for SSB participant and September 15, 1984 for CW. Send logs to RCV, PO Box 2285, Caracas 1010-A, Venezuela.

NEW AMATEUR OPERATING CERTIFICATE now being offered by the Bartlesville (Oklahoma) ARC to focus attention on the "Green Country" region of northeast Oklahoma. This award is available to anyone making two-way Amateur radio contact with three hams in the Nowata, Osage and/or Washington Counties of Oklahoma. All bands/modes permitted. Applicants for the award should submit calls and pertinent details of three qualifying QSO's plus \$1.00 s&h to W5NS Awards Manager, 1800 Moonlight Drive, Bartlesville, OK 74006.

THE LINCOLN (NEBRASKA) COMMUNICATIONS SOCIETY has constructed a beacon transmitter to provide a signal for propagation studies and frequency reference. The beacon operates CW on 144.055 MHz and is located in the northeast corner of grid square EN-10. I.D. call sign is WB0IY/B. Reception reports should be sent to Lincoln Communications Society, Attn: KING, 1801 So. 48th Street, Lincoln, NE 68506.

MAY-SEPTEMBER: N.O.A.R.S. and the U.S.S. COD will be on the air again during the summer of 1984. NOARS members will operate from the COD starting Memorial Day weekend daily through Labor Day weekend. Look for operations in the lower portion of the General bands 10 through 80 meters. Special Novice operations on June 16, July 15 and August 18. Extra operations during Cleveland Hamfest, September 23. For a special 8 x 11 certificate picturing the U.S.S. COD send QSL confirming two-way contact and \$1.00 s&h to WD8RZG.

JUNE 11-17: The Henry County ARC will operate club station K8TII to commemorate the Napoleon, Ohio, Sesquicentennial. Frequencies: 3740, 3965, 7065, 14265, 21150 and 21365. Contact with club station or any club members' stations qualifies for certificate. SASE to Roger C. Jaqua, W8SMW, 17136 Mercer Rd., Bowling Green, Ohio 43402.

JUNE 8-10: The Macomb Emergency Communications Association will have its second special event. Operation commences at 2200Z Friday to 2200Z Sunday. Lower end of General class portion of each Amateur band. SSB and CW/RTTY of HF. FM phone on 146.07/67. QSL to MECA, Box 488, Ulica, MI 48087 with 9 x 12 SASE. DX stations need send only QSL.

JUNE 29-JULY 1: The Muscle Shoals ARC will operate W4JNB from 1600-2100Z from Spring Park, Tusculumbia, Alabama to celebrate Helen Keller Festival Days. Phone frequencies: 7270-7290 and 14,280-14,295. For certificate send 4 x 10 SASE to Box 2745, Muscle Shoals, AL 35662.

JUNE 30-JULY 1: The Hannibal ARC will issue a fourth annual special certificate from the National Tom Sawyer Days celebration in Mark Twain's boyhood home town, Hannibal, MO. 1500-2100Z UTC both days. Frequencies: Phone — 7.245, 14.290, 21.400, 28.770 and CW — 7.125 and 21.125. To receive the certificate send a large SASE and your QSL card confirming contact to Hannibal ARC, W0KEM, 2108 Orchard Avenue, Hannibal, MO 63401.

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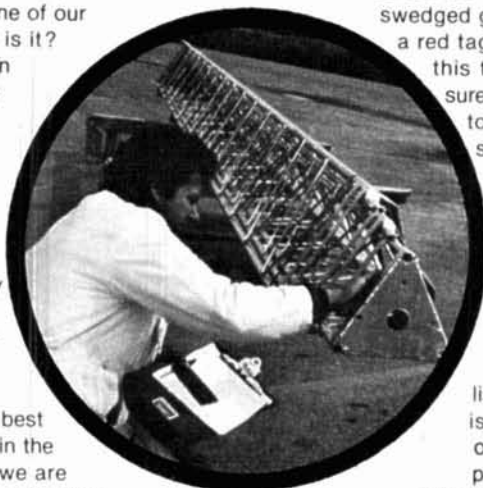
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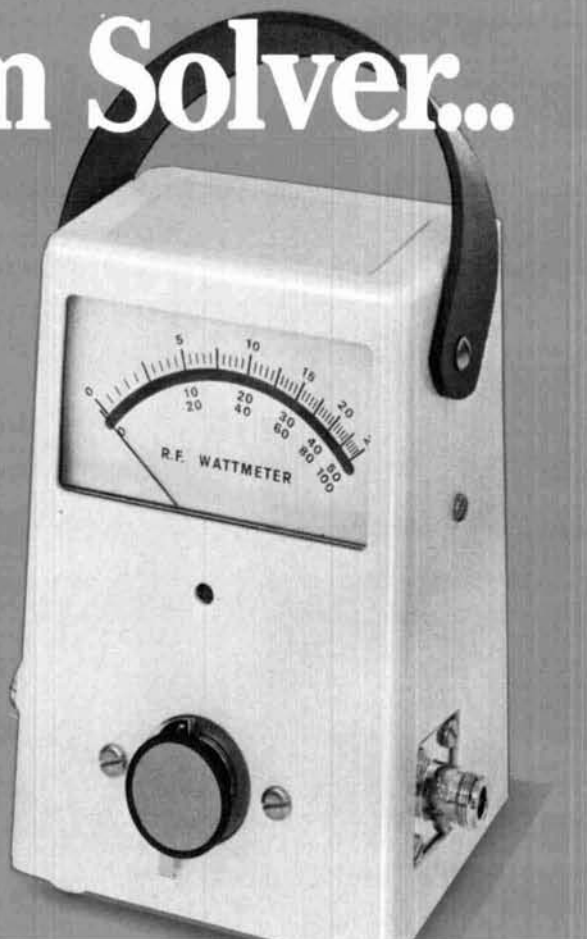
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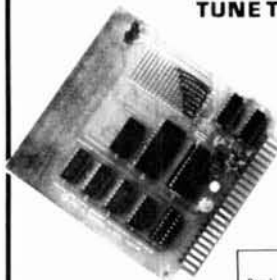
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