MAY 1986 / $2.50

ANNUAL ANTENNA ISSUE

ham radio magazine

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NEW! IC-735

ICOM HF Tra...

Ultra Compact

The new ICOM IC-735 is what you've been asking for...the most compact and advanced full-featured HF transceiver with general coverage receiver on the market. Measuring only 3.7 inches high by 9.5 inches wide by 9 inches deep, the IC-735 is well suited for mobile, marine or base station operation.

More Standard Features

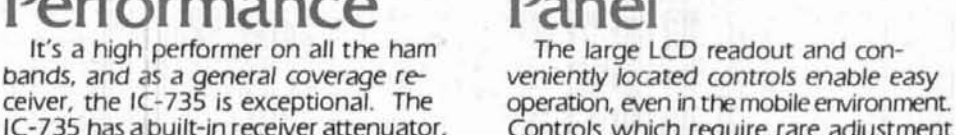
Dollar-for-dollar the IC-735 includes more standard features...FM built-in, an HM-12 scanning mic, FM, CW, LSB, USB, AM transmit and receive, 12 tunable memories and lithium memory backup, program scan, memory scan, switchable AGC, automatic SSB selection by band, RF speech processor, 12V operation, continuously adjustable output power up to 100 watts, 100% duty cycle and a deep tunable notch.

Superior Performance

It's a high performer on all the ham bands, and as a general coverage receiver, the IC-735 is exceptional. The IC-735 has a built-in receiver attenuator, preamp and noise blanker to enhance receiver performance. PLUS it has a 105dB dynamic range and a new low-noise phase locked loop for extremely quiet rock-solid reception.

Simplified Front Panel

The large LCD readout and conveniently located controls enable easy operation, even in the mobile environment. Controls which require rare adjustment are placed behind a hatch cover on the front panel of the radio. VOX controls, mic gain and other seldom used controls are kept out of sight, but are immediately accessible.



Options. A new line of accessories is available, including the AT-150 electronic, automatic antenna tuner and the switching PS-55 power supply. The IC-735 is also compatible with most of ICOM's existing line of HF accessories.

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Kantronics "SMARTS"

Presenting three intelligent, versatile, compatible terminal units.

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

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

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

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

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

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- Superior receiver dynamic range
  Kenwood DynaMix™ high sensitivity direct mixing system ensures true 102 dB receiver dynamic range. (500 Hz bandwidth on 20 m)
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- Superb interference reduction
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- MC-42S UP/DOWN mic. included
- Computer interface port
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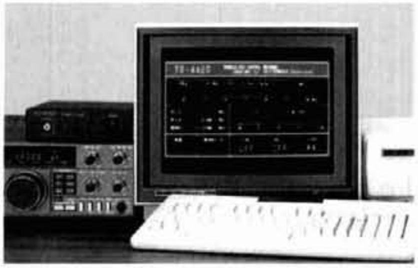

Optional accessories:
- AT-440 internal auto. antenna tuner (80 m—10 m)
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contents

16 secrets of successful low-band operation: part 1
Rich Rosen, K2RR

28 computer-aided design of long VHF Yagi antennas
David G. Hopkins, VK4ZF

39 ham radio techniques
Bill Orr, W6SAI

47 active antenna preamplifiers
R. W. Burhans

56 the W2PV 80-meter quad
Bill Meyers, K1GQ

61 the Colagi antenna
Bob Morton, VE3BFM

69 practically speaking: using the antenna noise bridge
Joe Carr, K4IPV

74 solving transmission line problems on your Commodore 64
Gary E. Myers, K9CZB

81 HF ground wave propagation
Lynn A. Gerig, WA9GFR

89 how high should your HF antenna be?
Ted Hart, W5QJR

103 VHF/UHF world: Yagi facts and fallacies
Joe Reisert, W1JR

141 the Guerri report
Ernie Guerri, W6MGI

142 advertisers index and reader service
9 comments
118 DX forecaster
134 flea market
136 ham mart
95 ham notes
124 new products
6 presstop
4 reflections
71 short circuits

REFLECTIONS

communication for fun and profit

Wouldn't you think that after working an eight-hour day you'd do *anything* except continue the same thing you'd been doing all day?

Some people work at jobs that they dislike. Perhaps they're stuck — but for one reason or another, they just can't leave their positions. They wouldn't be caught dead spending even a minute thinking about their work once they're finished for the day. Others enjoy their jobs but make it a point to sharply differentiate between their work and their private lives. Still others don't see this separation so clearly; they either take work home or participate in some aspect of it after hours.

Psychiatrists would probably agree that the middle group is the healthiest and well-balanced. They could earn a living treating the first and third groups.

As editor of a ham magazine I find that I gravitate towards the third group. I spend my daylight hours pushing papers from one side of the desk to the other; miraculously, manuscripts are edited, schedules are developed, correspondence is answered, and magazines get published. But when it's time to quit, I still find myself thinking about a preamplifier that exhibits extremely high IM performance, a multi-element antenna design that can develop a high forward gain and front-to-back ratio, or a multi-stage bandpass filter that can be designed and optimized through the use of a CAD program.

Often I just go down to the radio room to briefly scan the band to see if Europe is coming through on a more southerly route — didn't WWV just announce a *K* index of 5? But wait a second . . . there's LZ1KDP on 3792 describing his three-element wire beam at 200 feet above the streets of Sofia. Trying to picture that scene, I find that I have the microphone in hand and I'm dropping my call several times. Suddenly there's Stefan's voice coming out of the loudspeaker, warmly saying hello from Bulgaria, and we basically continue where we last left off from the previous contact. Pop, (Popa, YU7PFR), comes on frequency and we find ourselves discussing the minor pattern distortion achieved by adding segments at one end only that change the resonant frequency of his director, reflector in his three-element wire Yagi. Perhaps we're discussing Serbo-Croatian music or — back to the technical realm — the merits of the Plessey SL1640 IC in a circuit he's building. In short, we find ourselves going beyond what some perceive as the humdrum nature of today's all-too-common Hello/Goodbye QSO: "Hello, your signal is . . . my QTH is . . . my name is . . . please QSL . . .Goodby."

Just think of the opportunity presented to us. We can communicate with others over thousands of miles, discussing — within the limits of reason and common sense — a myriad of subjects. We can increase our friendships, learn languages, discuss mutual problems we have with a particular computer program. It's almost like having good company over after dinner.

This form of communications is not just fun — I *profit* from this. We all do. For when you extend friendship, hear that laughter from someone who's been trying very hard to say something in English while you try to respond in his language, even though you know only a few words, we all profit. We profit when suddenly we start to observe the makings of a bent propagation path from both ends of the circuit . . . see it develop, peak, and disappear, and see the potential for other exciting contacts as well. We profit by learning to live with each other under crowded conditions, not entirely unlike those of an inner-city tenement, on this cluster of frequencies we call an Amateur band. It's all here to do with as we please. I choose to communicate for fun and profit.

Rich Rosen, K2RR
Editor-in-Chief

presstop de W9JUV

THE CONCEPT THAT CITIZENS HAVE NO RIGHT OF ACCESS TO THE RADIO SPECTRUM is still very much alive, according to comments by California Congressman Carlos Moorehead at the fourth and final House subcommittee hearing on the Communications Privacy Act of 1985 March 5. Early in the hearing Deputy Assistant Attorney General James Knapp of the Justice Department Criminal Division testified that his agency didn't believe scanning for "recreational purposes" should incur "criminal or civil liability." Instead, the Justice Department position was that it would be a crime only if "the citizen both intercepts and divulges communications under circumstances in which the interception and divulgence are illegal, tortious, or for criminal gain" -- which is pretty much the present law!

However, Congressman Moorehead Severely Criticized The Justice Position, stating "It's very clear there are all kinds of mischievous things you can do if you have one of these scanners" such as hearing "family fights, conversations between someone and their girl friend, inside information that stockbrokers might be giving out over the phone..." He then read from a scanner ad a long list of the things that can be heard -- including Amateur Radio -- noting that "these are private calls and obviously something has got to be done to limit the range of these scanners." He further stated the purpose of the bill was to prevent people "from deliberately trying to intercept any or all of these calls..." though admitting that accidental interception such as through a TV set shouldn't be prosecuted if the listener quickly "switched to the next band."

Following Moorehead's Condemnation Of The Justice Position, Knapp agreed Justice would consider whether "We should go that second step and predicate a violation based upon the interception of 'the radio signal' itself."

"Shockingly Pervasive Misrepresentation" By The Cellular Industry in its previous testimony about cellular privacy before the subcommittee was charged by the Association of North American Radio Clubs (ANARC) in its comments. ANARC emphasized that cellular transmissions are even less private than a cordless phone's, due to the far greater range of cellular transmitters and the variety of means by which cellular can be intercepted.

Subcommittee Work On HR 3378 Is Expected To Be Completed By Late March, at which time it will be taken up by the full Committee and could quickly move to the house floor. At the same time the Senate version of HR 3378 will become active there as well. As the report above demonstrates, this bill's threat to a citizen's traditional access to the radio spectrum as described in Ham Radio's February editorial is still a very real one!

FCC ACTION ON ARRL'S PROPOSAL TO ENHANCE NOVICE PRIVILEGES may very well come in time for the Dayton Hamvention in the form of a Notice of Proposed Rule Making. Most of the comments filed in response to the proposal (RM 5Ø38) were favorable, though some did in fact raise questions about just what it is expected to accomplish, since it would require raising Novice qualifications to correspond with the new privileges. Another concern was that it might decrease incentive to either learn the code properly or even upgrade, since the "enhanced" Novice license would provide access to both HF and VHF phone bands.

THE COUNCIL FOR AMATEUR RADIO EXAMINING IS NOW OFFICIALLY recognized as a "Not For Profit" corporation under Illinois law, and efforts are under way to establish its tax-exempt status for donations as well. Representatives of the CARE member VECs, which now include all national VECs (except the ARRL) as well as many regional VECs, plan to hold an informal strategy meeting during the Dayton Hamvention weekend.

"WESTERN INTERNATIONAL COORDINATOR'S ASSOCIATION" IS THE NEW NAME tentatively chosen for the "Pacific Area Coordination Association" announced in last month's Presstop. The new name was adopted to reflect the group's expanded sphere of influence, now planned to extend to Alaska and the western portions of both Canada and Mexico. A formation meeting has now been set for September 6, during the ARRL National Convention in San Diego.

APPARENT ON-THE-AIR "BUSINESS" ACTIVITES ON "FLORIDA TRADERS" 75-meter swap net led to issuance of FCC Notices Of Violation to 22 Amateurs in the Southeast. The notices were sent out by the Ft.Lauderdale Field Office after it monitored two net sessions, and went only to Amateurs who quoted prices on the air or whose "stock" gave the appearance that they were running a business rather than disposing of excess personal equipment.

Though Swap Nets Per Se Are Not Prohibited By The Rules, "business" activities on the Amateur bands are. This crackdown, which came about as a result of numerous complaints from Amateurs about this particular net's activities, does not herald any FCC change in direction or indicate the beginning of a nationwide FCC effort.

THE FCC RELAXED ITS PROHIBITION AGAINST "AUTOMATIC CONTROL" for third party traffic relays in a waiver issued March 14. The third party traffic problem had arisen in the FCC's Report and Order on PR Docket 85-1Ø5, which permitted automatic control of digital communications above 5Ø MHz but pointed out that the rules still required a control operator's presence when third party traffic was being handled -- and that any traffic not originated by the relaying station was considered "third party."

The Waiver Applies To Packet Communications Using AX.25 Protocol, and remains in effect until the Commission can consider a number of Petitions For Reconsideration that were filed in PR Docket 85-1Ø5. It was granted in response to a Petition for Extraordinary Relief filed by the ARRL. FCC review is likely late this year.

THE 12TH ANNUAL EASTERN VHF/UHF CONFERENCE WILL BE HELD May 16-18 at Rivier College in Nashua, NH. It opens with a Friday night hospitality suite followed by tech sessions and symposia all day Saturday and a noise figure and antenna gain session on Sunday. Dave Knight, KA1DT, 15Ø Oakdale, Nashua, NH Ø3Ø52 can provide details.

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Handy Handful...

TR-2600A/3600A

Kenwood's TR-2600A and TR-3600A feature DCS (Digital Code Squelch), a new signalling concept developed by Kenwood. DCS allows each station to have its own "private call" code or to respond to a "group call" or "common call" code. There are 100,000 different DCS combinations possible.

- **Simple to operate**
  Functional design is "user friendly." Built-in 16-key autopatch encoder, TX STOP switch, REVerse switch, KEYboard LOCK switch, high efficiency speaker.
- **Large LCD**
  Easy to read in direct sunlight or in the dark with convenient dial light that also illuminates the top panel S-meter.
- **Extended frequency coverage**
  Allows operation on most MARS and CAP frequencies. Receive frequency range is 140-160 MHz. (TR-3600A covers 440-450 MHz.)
- **Programmable scan**
  Channel scan or band scan, search for open or busy channels.
- **SLIDE-LOC battery case**
- **10 Channels**
  10 memories, one for non-standard repeater offsets.
- **2.5 watts high power, 350 mW low**
  TR-3600A has 1.5 watts high or 300 mW low.

The Kenwood TR-2600A and the TR-3600A pack "big rig" features into the palm of your hand. It's really a "handy handful"!

Optional accessories:

- TU-35B built in programmable sub-tone encoder
- VB-2530 2-m 25 W RF power amp.
- ST-2 base stand/charger
- MS-1 mobile stand/charger
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- DC-26 DC-DC converter
- HMC-1 headset with VOX
- SMC-30 speaker microphone
- LH-3 deluxe leather case
- SC-9 soft case with belt hook
- BT-3 AA manganese/alkaline battery case
- EB-3 external C manganese/alkaline battery case
- RA-3 2-m telescoping antenna
- RA-5 2-m/70-cm telescoping antenna
- AX-2 shoulder strap w/ant. base
- CD-10 call sign display
- BH-2A belt hook

More TR-2600A and TR-3600A information is available from authorized Kenwood dealers.

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TR-2600A shown. TR-3600A is available for 70 cm operation.
Complete service manuals are available for all Trio-Kenwood transceivers and most accessories.
Specifications and prices are subject to change without notice or obligation.

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Matches coax, balanced lines, random wires—1.8 to 30 MHz. 3 KW PEP *—the power rating you won't outgrow* (250pf-6KV caps).

Roller inductor with a 3-digit turns counter plus a spinner knob for precise inductance control to get that SWR down to minimum every time.

Built-in 300 watt, 50 ohm dummy load, built-in 4:1 ferrite balun.

MFJ-989 $329.95

Accurate meter reads SWR plus forward and reflected power in 2 ranges (200 and 2000 watts). Meter light requires 12 VDC. Optional AC adapter, MFJ-1312 is available for $9.95.

6 position antenna switch (2 coax lines, through tuner or direct, random/balanced line or dummy load). SO-239 connectors, ceramic feed-throughs, binding post grounds.

Deluxe aluminum low-profile cabinet with sub-chassis for RFI protection, black finish, black front panel with raised letters, tilt bail.

MFJ's Fastest Selling TUNER

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MFJ's fastest selling tuner packs in plenty of new features. New styling! Brushed aluminum front. All metal cabinet. **New SWR/Wattmeter!** More accurate. Switch selectable 300/30 watt ranges. Read forward/reflected power.

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Matches everything from 2.8 to 30 MHz! dipoles, inverted vee, random wires, verticals, mobile whips, beams, balanced and coax lines.

Built-in 4:2 balun for balanced lines. 1000 V capacitor spacing. Black. 11 x 3 x 7 inches. Works with all solid state or tube rigs. Easy to use anywhere.

MFJ's 1.5 KW VERSA TUNER III

MFJ-962 **$229.95**

Run up to 1.5 KW PEP and match any feedline continuously from 1.8 to 30 MHz: coax, balanced line or random wire.

Built-in SWR/Wattmeter has 2000 and 200 watt ranges, forward and reflected power. 2% meter movement. 6 position antenna switch handles 2 coax lines (direct or through tuner), wire and balanced lines. 4:1 balun 250 pf 6 KV variable capacitors. 12 position inductors. Ceramic rotary switch. All metal black cabinet and panel gives RFI protection, rigid construction and sleek styling. Flip *stand tilts tuner for easy viewing. 5 x 14 x 14 in.*

MFJ's Best VERSA TUNER

MFJ-949C **$149.95**

MFJ's best 300 watt tuner is now even better!

The MFJ-949C all-in-one Deluxe Versa Tuner II gives you a tuner, cross-needle SWR/Wattmeter, dummy load, antenna switch and balun in a new compact cabinet. You get quality conveniences and a clutter-free shack at a super price.

A new cross-needle SWR/Wattmeter gives you SWR, forward and reflected power—all at a single glance. SWR is automatically computed with no *controls to set. Has 30 and 300 watt scale on easy-*to-read 2 color lighted meter (needs 12 V).

A handsome new black brushed aluminum cabinet matches all the new rigs. Its compact size (10 x 3 x 7 inches) takes only a little room.

You can run full transceiver power output—up to 300 watts RF output—and match coax, balanced lines or random wires from 1.8 thru 30 MHz. Use it to tune out SWR on dipoles, vees, long wires, verticals, whips, beams and quads.

A 300 watt 50 ohm dummy load gives you quick tune ups and a versatile six position antenna switch lets you select 2 coax lines (direct or thru tuner), *random wire or balanced line and dummy load.*

A large efficient airwound inductor—3 inches in diameter—gives you plenty of matching range and less losses for more watts out. 100 volt tuning capacitors and heavy duty switches gives you safe arc-free operation. A 4:1 balun is built-in to match balanced lines.

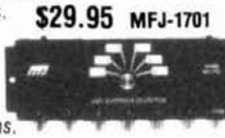
Order your convenience package now and enjoy.

2 KW COAX SWITCHES

MFJ-1702 **$19.95**

MFJ-1702, $19.95. 2 positions. 60 dB isolation at 450 MHz. Less than .2 dB loss. SWR below 1:1.2.

$29.95 MFJ-1701



MFJ-1701, $29.95. 6 positions. White markable surface *for antenna positions.*

MFJ's Smallest VERSA TUNER

MFJ-901B **$59.95**

MFJ's smallest 200 watt Versa Tuner matches coax, random wires and balanced lines continuously from 1.8 thru 30 MHz. Works with all solid *state and tube rigs. Very popular for use between* transceiver and final amplifier for proper matching. Efficient airwound inductor gives more watts out. 4:1 balun for balanced lines. 5 x 2 x 6 inches. Rugged black all aluminum cabinet.

MFJ's Random Wire TUNER

MFJ-16010 **$39.95**

MFJ's ultra compact 200 watt random wire tuner lets you operate all bands anywhere with any transceiver using a random wire. Great for apartment, motel, camping operation. Tunes 1.8-30 MHz. 2 x 3 x 4 inches.

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Designed for mobile operation! Small, compact. Takes just a tiny bit of room in your car. SWR/dual range wattmeter makes tuning fast and easy. Careful placement of controls and meter makes antenna tuning safer while in motion.

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comments

fair comparison?

Dear HR

The article, "AMTOR, AX.25, and HERMES: A Performance Analysis of Three Systems" in the December, 1985, *ham radio*, purports to be a fair comparison between the three systems. However, on finding several errors in this article, and noting that the author, W9JD, is also the "inventor" of HERMES, I would like to take the opportunity, as the "inventor" of AMTOR, to correct these errors.

W9JD introduces the concept of "minimum required error-free time" being the minimum "clear channel" time required to get any traffic through at all, and he claims that AMTOR needs 4450 mS. This is not true: it is only necessary to have a 210-mS "clear patch" to get one block through; the corresponding "ack" need not return in the same clear patch but through any subsequent 70-mS clear patch. In this, the block-synchronous AMTOR system has an advantage over the other two systems. Even if, to make comparison easier, we insist that the "ack" must get through the same clear patch as the corresponding block, the minimum clear patch size is 280 mS, since the one signal follows immediately after the other in the same way as the other two systems.

In using the concept of "bit error-rate to stop" W9JD says that one bit error in every 450-mS AMTOR cycle will stop the link, deducing from this that the link will be stopped by a random B.E.R. of 2.2 percent (1 in 45). This is wrong on two counts. First, a random B.E.R. of 2.2 percent doesn't guarantee that every cycle will contain one error, and some will have none, allowing the link to continue to pass traffic. Second, since only 280 mS of the 450-mS cycle contain signals, a randomly-occurring error will "hit" only 28 out of every 45 cycles. In fact, a B.E.R. of 2.2 percent will only slow the link down to about 50 percent, not stop it.

In analyzing the probability of an undetected error in an AMTOR character, W9JD says that this will occur if the channel reverses an even number of bits. This is nonsense. An undetected error will occur only if the number of 0-to-1 corruptions equals the number of 1-to-0 corruptions. The probability of this occurring is highest with random noise input at 27 percent, not 50 percent. However, the probability of an undetected error in a block of three is higher than the third power of this when there is some signal in the noise. It reaches a peak of 5.6 percent when the B.E.R. is 11 percent, then falls rapidly to zero below this. (See IEEE's *Transactions on Communications*, July, 1985, page 710, for a full explanation of this strange effect.) However, 5.6 percent is still less than half of W9JD's figure of 12.5 percent.

While writing, I would like to introduce a concept which is very relevant when comparing systems for use in Amateur Radio, namely "latency," or the time taken for traffic to propagate through the system. Although not important for one-way broadcasts, excessive latency is a disadvantage in a two-way conversation, as anyone who has experienced the 240-mS delay of a satellite telephone link will testify! The latency of AMTOR is 0.21-0.45 second; of AX.25 (using figures from the W9JD article), 2.8-23.4 seconds; and of HERMES, 13.9-43.4 seconds. Its relevance to two-way QSOs is that it will take at least twice the latency figure to "pass it over" to the other station. Although the longer block sizes of AX.25 and HERMES make for lower undetected-error rates, their very high latency would, in my opinion, make them unusable for two-way conversational QSOs on HF, for which purpose AMTOR still leads the field.

J. Peter Martinez, G3PLX
Gosport, Hantshire, England

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See what high-performance stations do to achieve big-gun status on 80/160 meters

secrets of successful low band operation: part 1

I was curious . . . I would often hear stations on the low bands comfortably exchanging signal reports with rare DX contacts and wonder what type of antenna system they were using to achieve such good results. Therein was the beginning of a project that has provided more answers and technical enjoyment than I would ever have imagined possible.

Late last year a three-page survey was composed and sent to 113 of the "big gun" station operators and owners. After reading and digesting a two-inch thick sheaf of replies, many of my questions — as well as many unasked ones — have been answered. It is our pleasure to share this information with you. Much can be learned from the thousands of hours of experience in not only system design but also propagation observations made through the use of these outstanding systems.

A sincere note of thanks is due to the 47 individuals who took the time to fill out the lengthy survey form. Although a considerable amount of information was requested, some respondents not only entered their answers to questions but added more data as well. Responses were received from 21 countries from all continents. A special note of thanks goes to our overseas friends who, besides providing the data, responded in English, which is, for the most part, not their primary language. Responses were received from the following:*

CN2AQ	DJ0IA	DL0WU	EA8ADP	G2PU
G3WMZ	G4AMN	GW4OFQ	I5NPH	JA1FRE
JF1IST	K1MEM	K2FV	K3ZO	K5UR
KG7D	LA7ZO	N1ACH	N4AR	N4RJ
N4SU	NW5K	N6DKP	N7CKD	OE6MBG
OH1RY	OZ8BV	PA3DFU	SM4CAN	SM6EHY
SP3GEM	TI5EWL	VE2HQ	VE3BMV	VE7BS
VK6LK	W1FV	W1NH	WB2ITR	W2JB
W3BGN	W4DR	W6NLZ	W6RJ	YU7PFR
ZL4BO	4X4NJ			

a word on format

Originally, I had considered providing the information in a strictly tabular fashion, following the format of the survey with a list of callsigns and the data in the adjacent columns. But this approach would have required 13.5 printed pages, just for the data! Instead, each category is discussed and tabulated individually, with callsigns provided in some cases.

low band transmitting antennas

Wow! The variety and creativity evident in this area is outstanding and as diversified as the users themselves. One of the reasons people are attracted to the low bands is because it is (or at least was) virgin territory where you cannot simply buy your station and

*A note to the others who received a copy of the survey, but whose names do not appear on the list: if you have not yet sent in the form please do so and the information will continue to be compiled. If a form was not sent to you please consider it an oversight on my part and send for it.

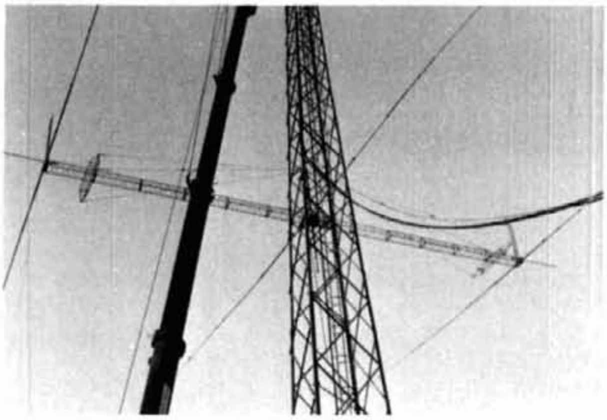


fig. 1. Three full-size element homespun 80-meter Yagi helps produce the outstanding signal heard from I5NPH.

By Rich Rosen, K2RR, Editor-in-Chief, *ham radio*

Table 1. 80 meter transmitting antennas

Antenna type	D/P	Additional comments
Yagi, 4 el,tubing	P	Double driven, W6NLZ
Yagi, 3 el,tubing	P	Full size el,OH1RY,I5NPH
Yagi, 3 el,tubing	P	Loaded el, VE2HQ,K3ZO,W6RJ
Yagi, 2 el,tubing	P	40% full size, N6DKP
Yagi, 3 el,wire	P	Wire added one side,YU7PFR
Half loops, 3 el,wire	P	Versatile system, N4SU
Delta Loop, two element	D	240' per loop,DJ0IA
Delta Loop, single element	-	@135',VE3BMV;@20m SP3GEM
Bobtail curtain, phased 2 bay	D	Vt el=238/freq, N4AR
Bobtail curtain, single bay	D	Remote-tuning cap, SM4CAN
Vertical arrays, 4 elements	D	W1NH, W4DR, K2BT, SM6EHY
Vertical arrays, 3 elements	D	0.125 wave, 2 active,W1FV
Vertical arrays, 2 elements	D	HyTowers @ 0.5 wave,W3BGN
Vertical, quarter-wave	-	63' of Rohn 25, NW5K
Inverted Vee	-	@36',70',OE6MBG
Slopers, half-wave, 3 el	P	1 driven, 2 reflect,LA7ZO
Slopers, half-wave, 2 el	P	Fed 70' apart,WB2ITR
Slopers, half-wave, single	-	@80', VK6LK
Slopers, quarter-wave	-	@100',K5UR
Half Square	D	Fed RG58 upper corner,K2FV
Dipoles, phased	D	Phase 0.25 wave both,K2FV
Dipole,tubing	-	94' rotary,@160' N4RJ
Dipole,wire	-	@50',GW4OFQ
W8JK	D	140' el, @ 65',W2JB

Table 2. 160 meter transmitting antennas

Antenna type	D/P	Additional comments
Vertical plus reflector	P	Elec rotatable, 4X4NJ
Vertical, plus parasitic el	D	Cardioid, SM6EHY
Vertical, quarter-wave	-	Grounded monopole,N1ACH
Vertical, quarter-wave	-	Loaded, DL0WU
Half-wave loops, phased	P	Refl/Dir switching,N4SU
Inverted Vee	-	4" open wire @90',W2JB
Inverted L, phased	D	Hytower with 108' H,W3BGN
Inverted L	-	75' Vert,55' H, VE7BS
Slopers,quarter-wave,phased	P	Driven+3 refl,N4RJ
Slopers, quarter-wave	-	3 switched, KG7D
Sloping delta loop	-	Fed 26' fm corner,W3BGN

fig. 2. JF1IST uses a commercially available model CY-703 (Create Manufacturing) shortened three-element Yagi.

have someone else erect and install a competitive system. It meant — and still often means — climbing to greater heights, literally, and getting dirt under your fingernails. That's changed to some extent with the availability of commercial Yagis for 80 meters, but the challenge and achievement remain. The full-sized homebrew three-element 80-meter Yagi of I5NPH is seen on its way up (**fig. 1**). There is nothing "amateur" about this installation.

Tables 1 and **2** list the 80- and 160- meter Driven and Parasitic transmitting antennas used by a representative sample of those surveyed.

A few notable examples of some very effective 80-meter Yagi installations are apparent in **figs. 2, 3, 4,** and **5.**

low band receiving antennas

As a general rule, those surveyed agreed that two basic types of antennas are used for reception: the elaborate transmitting array or Beverages. That poor, often-repeated statement about verticals working (and hearing in this case) equally poorly in all directions is incorrect. As part of an array, vertical antennas exhibit directivity and discrimination against unwanted noise and QRM.

Beverages, for those who have the space, can also be used very effectively to receive signals from a preferred direction and discriminate against others. A two-wire version, recently known as an SWA and described by Beverage in his original AIEE paper[1] has the additional ability to rotate an azimuthal null. As with any other antenna, Beverages have their supporters and detractors. That they work is indisputable; that most are installed far from optimally is probably also correct.

Table 3 includes details of Beverages used effectively by the surveyed stations. Lengths, terminations, installation heights, preamp use, and callsigns are provided. Though most Beverages preferably are installed over low conductivity soil, OZ8BV proves that they still perform over salt water with his four unterminated 200-meter long antennas.

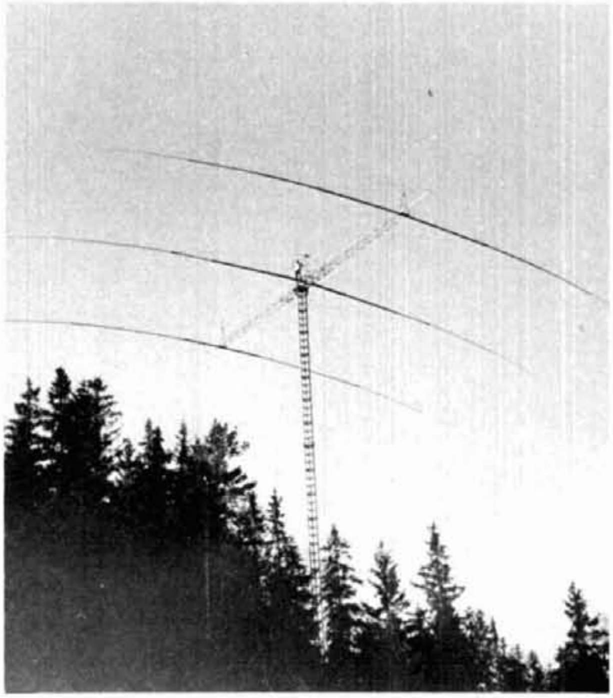


fig. 3. Full size element Yagi is installed "in the clear" and accounts for OH1RY's strong signal from Finland.

Table 3. Low band Beverage receiving antennas

Lengths	Term.	Notes	Callsign
Three @300-600'	Unterm		VE3BMV
Five @540'	450 ohms	20dB preamp	N1ACH
One @800'		10'	4X4NJ
One @390'	440 ohms	8'	VK6LK
One @350'	Bidirect	10',2 #19	VE7BS
Two @750' One @500'			W3BGN
Six @1000'			W1NH
Seven @550'	150-1100	3-12'	K5UR
One		2 wire SWA	SM4CAN
Two @700'		2 wire	N4RJ
One @500'		1 wire	N4RJ
One		2 wire SWA	N7CKD
Four @600'		Reversible	N4SU
Three @500'		Fed both ends	W4DR
One @500'	Unterm	6' +preamp	K1MEM
One @950'		8'	K1MEM
One @450'	450 ohms		W1FV
One @550'	Unterm		W1FV

Table 4. Yagi material description

Nr. of el.	Element description	Wgt.
3 (K3ZO)	90',linearly loaded (KLM)	400#
3 (OH1RY)	142' (R),135.5' (DR),129.7' (D),5 diff.dia. R-DR=37.7', DR-D=34.45' (Homebrew)	1057#
2 (N6DKP)	El 40% full size, DR-R=24' (Homebrew)	
4 (W6NLZ)	90' el, 76' boom (KLM)	
3 (JF1IST)	96.5' max el,50' boom, (Create CY-703)	264#
3 (VE2HQ)	110' lin loaded el, 11 diff dia,65' boom	515#
2 (JA1FRE)	33' boom (Homebrew)	220#
3 (W6RJ)	(KLM)	

Table 5. VSWR bandwidths for typical 80/160 meter antennas

Antenna	VSWR	Bandwidth (kHz)	
3 el Yagi,shorter el	2:1	100 on CW,100 on SSB	(80)
3 el Yagi,full size	2:1	380	(80)
3 el Yagi,wire	2:1	240	(80)
2 el Yagi,40% full size	2:1	60	(80)
Dipole,rotary (KLM)	2:1	100-120	(80)
Vertical,4 el driven	2:1	>300	(80)
Vertical,2 el driven	2:1	>70	(160)
Vertical,130' shunt fed	2:1	40	(160)
Vertical,quarter-wave	2:1	100	(160)
Vertical,quarter-wave	2:1	375	(80)
Half-wave slopers	2:1	250	(80)
Delta Loop	2:1	75	(160)

antenna materials

This broad category discusses the materials used to assemble the previously described transmitting antennas. In general the Yagis use tapered sections of aluminum, if made from tubing, and copper-clad wire otherwise. The verticals using aluminum (6061-T6) or steel masts, or single or multiple bare or covered wires, show more variety. In addition, most of the rotatable Yagis use a combination of aluminum tubing and insulating sections that are linearly loaded by multiple turns of wire. **Table 4** provides data on the rotaries in terms of length of elements, total weight of antenna and miscellaneous details. All of these are for 80 meter antennas. So far, to my knowledge, no one has an operational 160-meter rotatable Yagi.

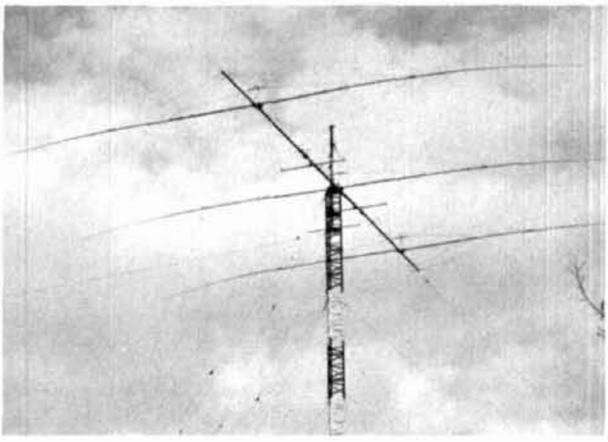


fig. 4. VE2HQ's homemade Yagi uses linearly-loaded elements but still is quite large.

hardware

This category encompasses the large rotaries, verticals and wire antennas. Once again the consensus is to use hardware that will last under all weather conditions. For the Yagis, this implies stainless steel or other non-rusting metals; for the wire antennas, good quality rope that is UV-resistant or "Phillystran." To withstand all weather conditions, liberal use of paint, tape, epoxy, Dow plastic sealant, Copper-kote®, or Coax-Seal® is recommended where applicable. Remember that if the antenna is going to fail, it will most probably fail in the worst weather, during the low-banders' best operating season.

electrical characteristics

The great variety of responses to this question were not only a function of the particular antenna in use but also a matter of personal preference for instantaneous bandwidth operation versus tuning with a matching unit. There were those who wanted only flat 50-ohm lines using coax, and there were quite a few who thought that open wire line and use of a matchbox was a better approach. N4SU summed up the latter opinion with the following statement: "It boggles my mind to think about all the Megawatts of RF energy being wasted in heating coaxial cable on the ham bands in this country." An example of N4SU's approach is shown in **fig. 6** where he uses his multiloop array for 20, 40, 80 and 160 meters.

By my way of thinking, both approaches have their obvious advantages and disadvantages. **Table 5** summarizes some of the achievable VSWR bandwidths correlated with the particular antennas used. This is just a rough guide; VSWR is a function of many parameters.

antenna gain

Another somewhat controversial term is achievable gain. However, unlike the low-banders' higher frequency cousins (with their 10 to 20-meter high-gain arrays), due to the large element dimensions on 80 and 160, the actual variation between lower and higher gain antennas is not too great. After reviewing all the data, the highest gain antenna described, I believe, is the phased Bobtail curtains built by N4AR; he estimated the gain at 7 to 8 dB over a single ground-mounted vertical. The three-element Yagis are not far behind, with those surveyed indicating a range of 5.5 to 6 dB. Next in the gain line are the phased four-element vertical arrays, coming in at between 4.9 and 6 dB, depending upon whom you talk to.

The textbooks provide, of course, the theoretical maximum values, but there are several important points that should be stressed before getting carried away with these numbers. Though the maximum difference in antenna gain between a *big gun* and a *little pistol* on 80 and 160 is around 6 dB, it is not the most important factor in the success story. The true criterion that makes these high performance stations shine is in their ability to *hear* — and I'm not necessarily talking about the use of Beverages.

A four-square vertical array does not have much more gain than a standard (quarter wave electrically and spatially separated) two-element array. But look at their front to back ratios, i.e., their E and H field patterns). The larger system provides considerably more attenuation off the back over a greater azimuthal beamwidth than does the cardioid version. This translates to receiving better and not disturbing others on adjacent frequencies as much if they're not in the beam direction when you're transmitting. It is for this reason, and the fact that it is difficult to quantify the received survey data (without all the parameters and operating conditions being known) that more specific antenna gains are not listed.

Before we leave this subject, that "measly" 6 dB variation in gain mentioned before can, at times, on the low bands, represent an enormous difference. During marginal conditions, even a 1 dB change in signal level can mean the difference between contact and no contact.

front-to-back ratios

Getting down to basics, what determines a high front-to-back ratio? "Front" is where the signals add and "back" is where they cancel, vectorially speaking. Even simple arrays (two elements) can experience a front-to-back (ratio) in excess of 60 dB! However, this is for very specific signal arrival angles (azimuthal and elevation) and polarization on sky-wave signals in particular. A slight change in one angle is all that is needed to upset the relationship. And changes do occur, sometimes over a very short period of time.

More complex arrays, however, can and are designed to produce azimuthal patterns that exhibit deep nulls (30 dB or more) over a 90-plus degree beamwidth. The four-square and the three-element inline are just two examples. The proponents of these driven arrays are quick to point out that they have two major advantages over rotary Yagis: instant direction change (through switching) and better front-to-back and front-to-side values. However, in fairness to the Yagi constituency, there are "Horizontal" nights and "Vertical" nights, and many a time a high horizontal beam has handily beaten the vertical arrays into Europe on the short path. But let's see, in **table 6**, what F/B's have been observed by the actual users of the low band antennas.

polarization

There are no eye-openers here. Both horizontally and vertically polarized antennas are used effectively by the high-performance stations. Due to the large antenna dimensions at these low frequencies, there are more vertical than horizontal *arrays*. However, as pointed out before, there is no one *best* antenna for all propagation conditions, locations, and times. If there were, it would probably have the following properties: instantaneous switching in azimuth, ele-

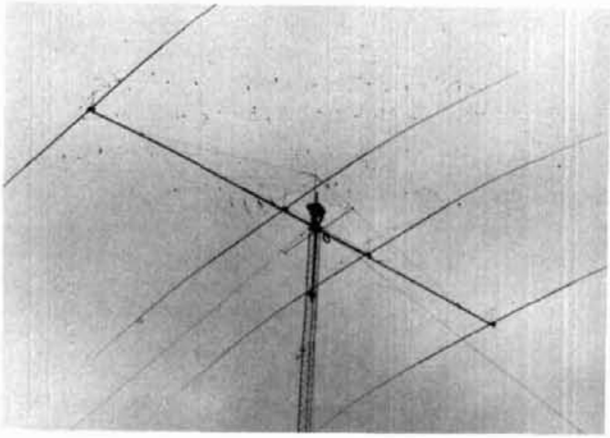


fig. 5. A double-driven element is used in W6NLZ's four-element Yagi, a product of KLM.

Table 6. F/B ratios for low band antennas

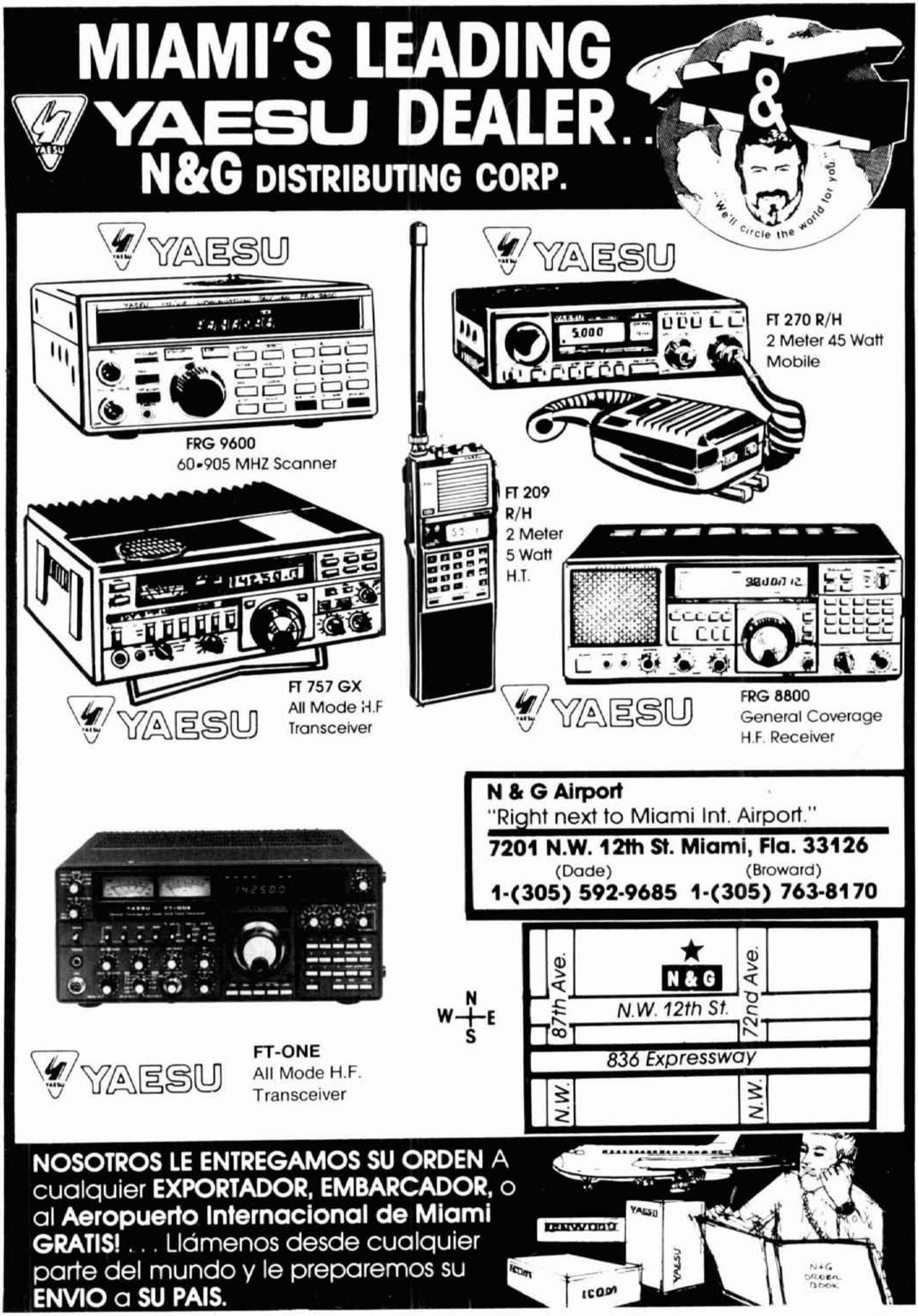
Antenna type	F/B (dB)	Comments
2 element Yagi, short el	10-15	JA1FRE
3 element Yagi, short el	10-15	*function of freq.*
3 element Yagi, full size	30	
3 element Yagi, wire	8-12	YU7PFR design
4 element Vert. phased array	30	W1NH
4 element Vert. phased array	15-45	SM6EHY
2 element Vert. phased array	20-30+	W1FV
Bobtail curtain, two bay	15-20	Great F/S
Delta loop, 2 element driven	20	DJ0IA

Table 7. Rotators

Designation	Comments	# in use
Telrex	#BA32899RIHS (Largest)	3
Homebuilt	1:250 ratio, 0.5 rpm	1
Create RC5A-3X3	Manufactured in Japan	2
Modified prop-pitch	Rotates KLM 4 el Yagi	1

Table 8. Support structures

Description	Height	Station
Building plus tower	180'	EA8ADF
Rohn 45	160'	N4RJ
Rohn 80 plus 10' mast	150'	K3ZO
Self-supporting	131	JA1FRE
Rohn 45G plus 10' mast	130'	K5UR
Trees	130'	VE7BS
Westover series XHD	120'	LA7ZO
Tri-ex T-20	120	W6NLZ
Homebuilt 50' on 60' microwave twr	110'	VE2HD
Telrex Big Bertha	110'	VE3BMV
Heights	98'	N4SU
Create KT-11N	98'	JF1IST
Tri-ex Skyneedle	90'	W6RJ
Trees	90'	K2FV
Rohn 25	78'	K1MEM
Pole	65'	DJ0IA
Buildings	59'	YU7PFR
Self-supporting	40'	TI5EWL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vation and polarization, variable beamwidth control, and no sidelobes. In addition, it would have the capability of being scanned in wider arcs while simultaneously being operated in narrow mode. After daydreaming for a second, even the super stations compromise in this respect. That's basically why many use multiple antennas that offer different polarization and optimum angle of arrival reception capability.

steering

There are two basic means of steering low band arrays: mechanical and electrical. Two or more elements can be made to transmit or intercept signals from specific directions if certain amplitude and phase relationships at their terminals are satisfied. This is accomplished through the use of delay lines, lumped components, or combinations thereof. YU7PFR illustrates in **fig 7** his method of "steering" a three-element 80-meter wire array. The specific details have been provided in many articles and books. An excellent treatise on the design and construction process for phased vertical arrays (also applicable to horizontal arrays) can be found in a recent series of articles by Forrest Gehrke, K2BT.[2]

Mechanical rotation of the large arrays is not a task to be taken lightly. It requires careful consideration of many factors, including antenna wind-swept area,

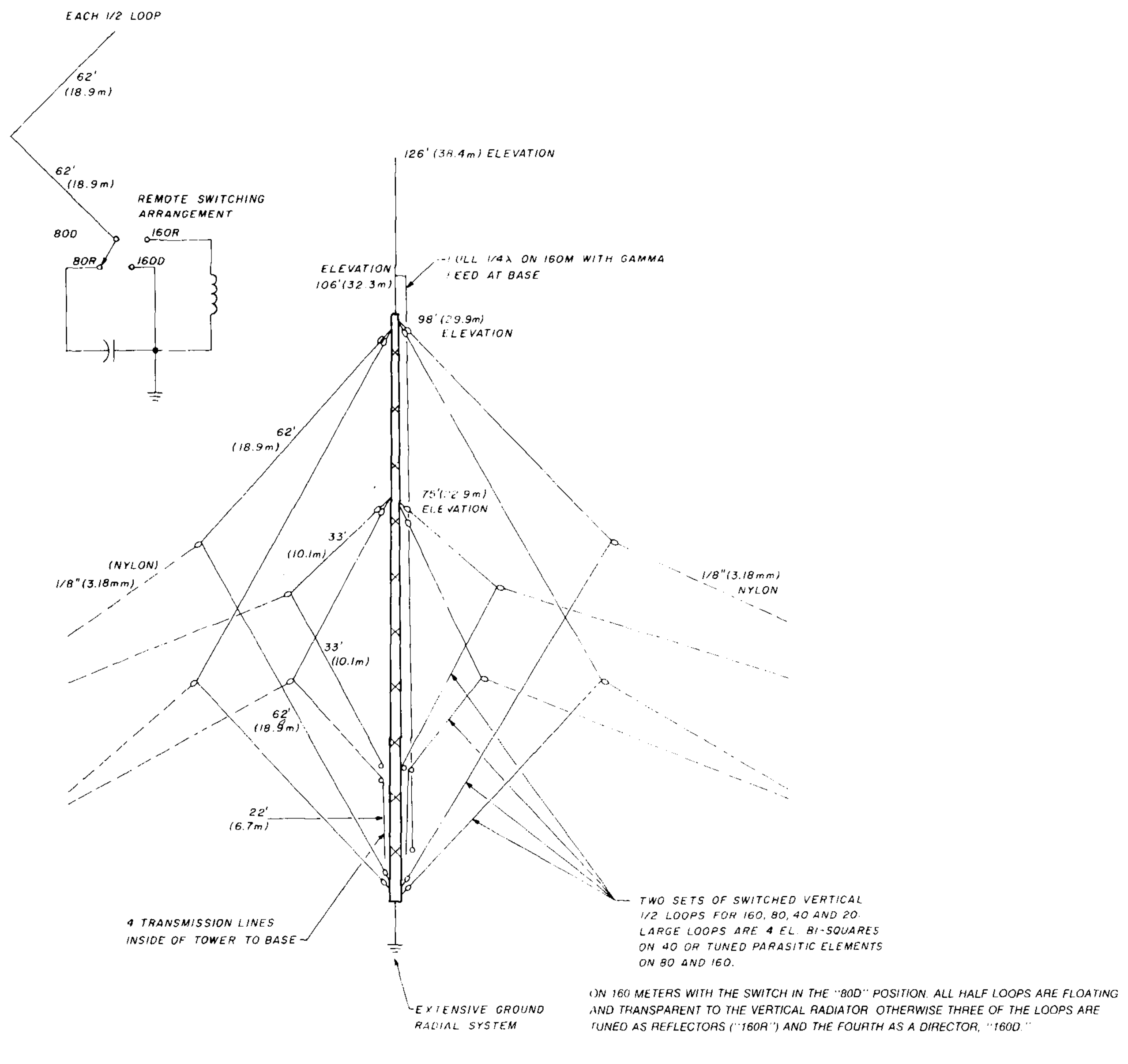

fig. 6. N4SU's multiband antenna array uses open wire line from the elements to the matching units.

mounting height, height above local terrain (i.e., is it shielded by trees from high winds?), weight, mast length, metallurgy, speed of rotation, weather conditions — both average and extreme — and expense, to name a few. To accomplish this task, the rotators listed in **table 7** are used by several of the superstations. Unfortunately, only a few of these responded to this particular survey question.

skyhooks that support these antennas

Man-made and natural structures consisting of towers, masts, buildings, and trees provide the support for the 80- and 160-meter antennas used by the stations surveyed. Considering the heights required, they probably represent the single greatest installation expense (excluding trees, of course). **Figure 8** illustrates the turnbuckles and guy lines used to tie down a 160-foot tower.

Towers and masts can and often do serve dual purpose as support structure and radiator, as in the case of verticals. The variety of the towers is considerable, with some installations surpassing, in quality, even those used by the commercial radio services.

Many not wishing to avail themselves of commercial units choose to build or modify other existing structures to suit their needs. Those fortunate enough to have tall trees on their property have been able to construct low band wire antennas that compete effectively with tower-mounted aluminum behemoths. On the other hand, it might surprise a few to see how *low* some of the big-gun stations have their antennas. **Table 8** is a compilation of some of the support structures used by the high-performance stations.

When a tower or mast is mounted on the roof of a building, the effective height of the antenna is not necessarily the combined heights. The building roof, depending on its dimensions, electrical characteristics, and separation from the antenna could determine an array factor with a much *higher* takeoff angle than would be indicated by the total height of the antenna above ground. In the case of EA8ADP, his strong signal into the United States would indicate that everything is working in his favor.

ground systems

This perennial question is asked all the time: how large a ground system is needed? The simple answer is *the larger the better*. Unless your antennas are situ-

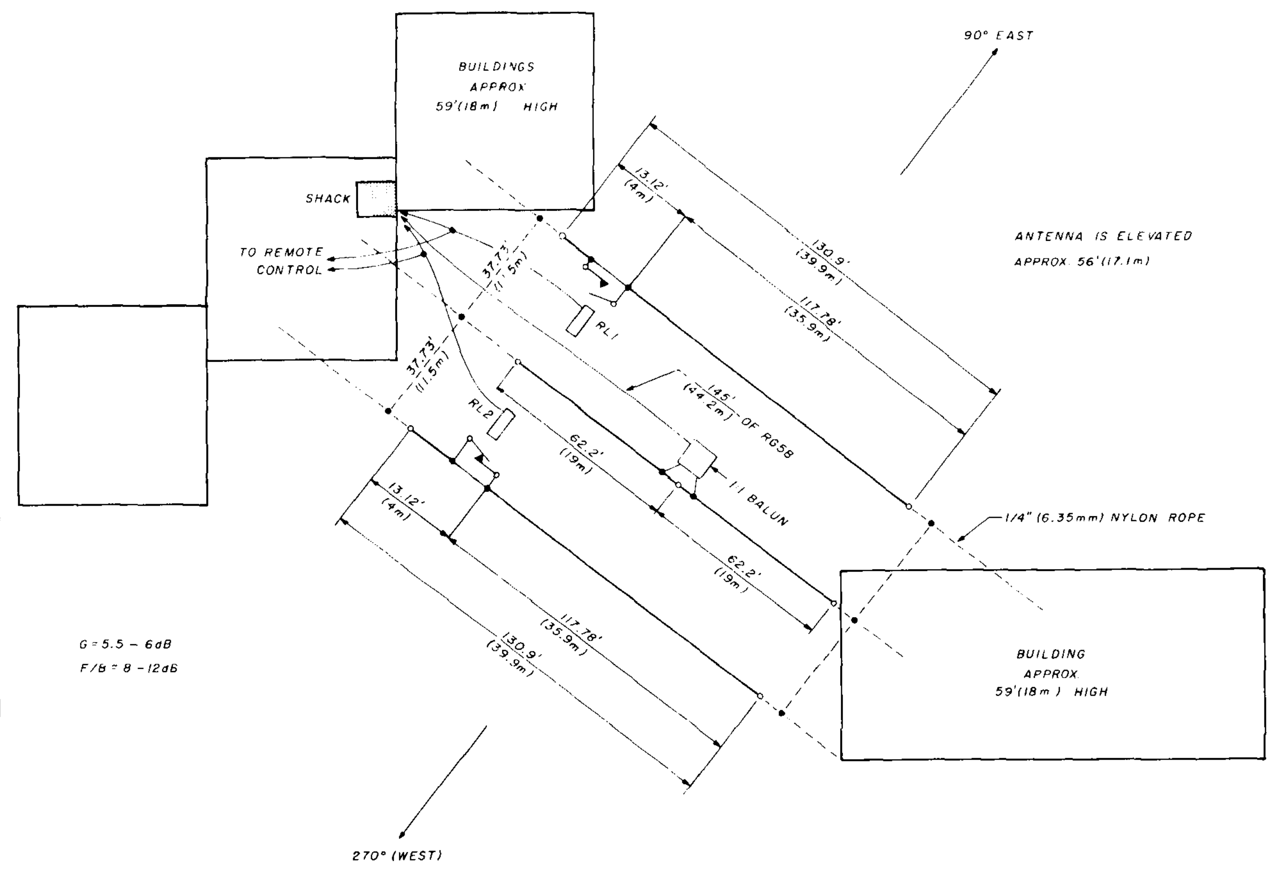

fig. 7. YU7PFR is able to switch antenna firing directions by opening and closing relays.

ated above an infinite extent, infinite conductivity ground plane, there is room for improvement. For those using verticals, two conditions should be met:

1. The immediate area around each vertical should have a high density of wire within a quarter wavelength of the radiators. A minimum of 100 radials is recommended. This determines and stabilizes the zone impedance and reduces losses, which is especially important if the current loop (current maximum) is close to or at ground level.
2. An extended ground or radial system should be installed as long as possible in the preferred transmission and reception directions. This increases the amount of energy present at truly low angles. *How long*, you ask? That's a function of several parameters, including propagation path and mode, distance, far field conductivity and permittivity (dielectric constant), solar activity, state of the geomagnetic field, transmitter power, and receive site conditions, to name just a few. Specifically, if I recall correctly, a six-wavelength radial system will produce a maximum elevation lobe at 6 degrees from the horizon using a single vertical.

SM6EHY suggested that it might be worthwhile to have the capability of remotely switching an extended radial ground system in and out. When switched in, lower angle of arrival signals are enhanced. When switched out, higher angle takes over. This could be accomplished through the use of convenient ground-bus point located relays. (Possibly another way to achieve this result would be through the use of *two* concentric ground rings at the antenna — the longer radials being attached to the outer switched in/out ring.) One useful application of enhanced lower angle transmission would be to "sneak under" the auroral high absorption layers. (More on this later under "propagation.")

Those using vertical antenna systems where the current loop is *not* at ground level should still be concerned with providing as large an extended radial system as possible for the second reason, even though, the ground loss resistance term represents a smaller fraction of the total antenna, in this case feed impedance.

A useful compromise for all vertical users is to place a mesh under the antenna as well as a radial system. The larger, of course, the better — but since maximum return currents *want* to exist within the immediate vicinity of the antenna, that's where it's most useful. The mesh, in addition to a 0.25 or 0.3 wavelength radial system, would improve the performance of the composite antenna system.

The existence of an extensive and symmetrical ground system also aids the phased vertical array designer. It eliminates one of the unknowns, or, stated differently, doesn't introduce yet another complex term to deal with. (Warning: before you begin quoting the above statements as gospel, I should mention that the information represents my own educated opinion, based on the work of others, whom, I believe, are correct).

An extensive ground system also aids the horizontal antenna user. It helps establish the distance between the antenna and its image (Green's function) and consequently determines the composite elevation pattern. This represents an increase of up to 6 dB in the total signal (sky and ground reflected wave) at a specific takeoff angle. If this angle is optimum for the particular path, then, in simple terms your signal will be louder at the point of reception and vice-versa. **Table 9** is a compilation of the ground systems used by the super-stations. Notice, however, that only a few of the stations that utilize horizontal arrays have extensive ground systems.

In addition, NW5K uses 30 square feet of chicken mesh; 4X4NJ puts 2 pounds of copper sulphate around his ground stakes, and N7CKD, besides using 55 square feet of chicken mesh and a half-mile of 5-foot (1.52 meters) chain link fence and barbed wire, pours 500 pounds of rock salt and 150 pounds of copper sulphate into trenches that he keeps moist at all times. (I'd be a wee bit concerned about the latter chemical, especially with regard to the possibility of its leaching into the water table).

I personally try to practice what I preach and am presently using 200 radials that vary in length from 65 to 300 feet (20 to 91 meters) in addition to an approximately 1000 square foot (93 square meter) ground mesh. And that's for just one vertical.

soil characteristics

As mentioned previously (see "ground systems"), the importance of a good ground, especially for vertical antenna users, cannot be stressed enough. There are those who are fortunate to have an antenna site whose soil has high conductivity or, even better, a high salt water table close to the surface. Under these circumstances the requirements for both near and far field enhancement are approached. An almost ideal site would consist of a high tower mounted antenna overlooking salt water on all sides.

Notice that vertically polarized antennas have been stressed. Though it is true that horizontally-polarized antennas are affected by a good ground system in the near field, it's the far field conditions of a horizontally-polarized antenna that show striking dissimilarities to that of a vertically-polarized antenna.

A figure of merit can be assigned to the reflective "nature" of the earth's surface in the form of a complex quantity that has both amplitude and phase terms. This reflection coefficient is very different for signals impinging on the earth that are vertically, rather than

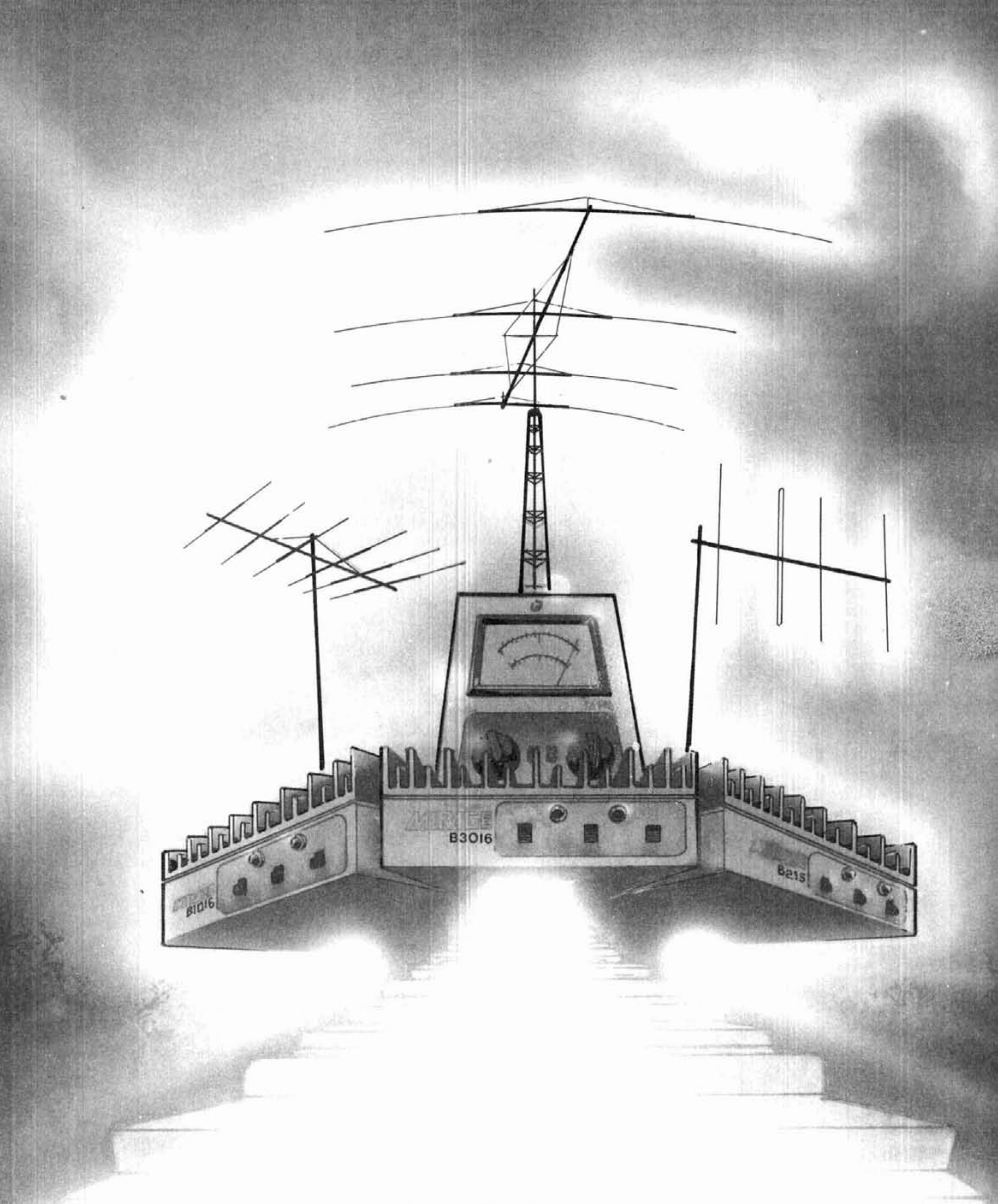
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Table 9. Ground systems

Radials	Length	Gnd rods	Length	Station
3	125'	3	8'	K3ZO
–	–	3	8'	VE3BMV
2	131'	–	–	PA3DFU
3	135'	4	10'	4X4NJ
65	65' +	–	–	SP3GEM
50	62'	–	–	VK6LK
20	75'	–	–	VE7BS
125	65'	4	8'	NW5K
90	80'	6	6'	W3BGN
–	–	9	6.6'	JF1IST
320	80'	500	4'	W1NH
100	130'	1	2'	K5UR
65	130'	–	–	N4RJ
5	250'	–	–	N4RJ
400	70-1000'	30	10'	SM6EHY
496	65'	–	–	W4DR
15	65'	3	6'	DJ01A
300-360	30-130	–	–	W1FV

horizontally, polarized (i.e., the E-field of the electromagnetic wave is vertical or horizontal by definition). The reflection coefficient is a function of the conductivity and dielectric constant of the earth, the frequency, and the angle by which the wave strikes the surface.[3]

Let's consider three sites and observe the amplitude and phase of the ground reflected component for both vertical and horizontal polarization. The first site is a typical New England location with low conductivity, rocky soil. The second is farm land — the pastoral, low hills, and rich soil typical of Dallas, Texas or Lincoln, Nebraska. The third site consists of an installation over salt water — for example, any coastal location right on the beach. Let's also examine two different angles of arrival (or takeoff); 15 degrees for the long path and 45 degrees for the short path to Europe from the east coast. **Table 10** summarizes the various conditions and results.

For those who wish to replicate the calculations, I used the following soil parameters:

Wavelength: 80 meters		Pastoral:	Conductivity: 30 mS
Frequency: 3.75 MHz			Dielectric constant: 20
Rocky soil:	Conductivity: 2 mS	Salty:	Conductivity: 4.64 S
	Dielectric constant: 14		Dielectric constant: 81

Table 10. Reflection coefficient vs soil type and takeoff angle

Soil	Angle	Polarization	Amplitude	Phase
Rocky	15	Horizontal	88% of max	2.00 deg
Pastoral	15	Horizontal	97%	1.63
Salty	15	Horizontal	99.75%	0.14
Rocky	15	Vertical	17%	75.53
Pastoral	15	Vertical	62%	25.02
Salty	15	Vertical	96%	2.10
Rocky	45	Horizontal	72%	6.24
Pastoral	45	Horizontal	92%	4.45
Salty	45	Horizontal	99.75%	0.14
Rocky	45	Vertical	51%	12.44
Pastoral	45	Vertical	84%	8.85
Salty	45	Vertical	98.67%	0.77

interpretation of results

There are a few eye-openers here that help to explain observations made over the years. Did you ever wonder, for example, why stations using a relatively low dipole (50 or 60 feet/15.24 or 18.28 meters) on 80 meters would often be heard just as well as those using verticals working against a good ground screen? Compare the seventh and tenth lines in **table 10**; the ground reflected component of the signal from the low horizontal antenna is actually stronger than the vertical antenna (72 percent of maximum versus 51 percent). Though this was calculated for rocky soil conditions, examination of the other entries shows that the low horizontal beats the vertical for all soil types at a *45* degree takeoff angle.

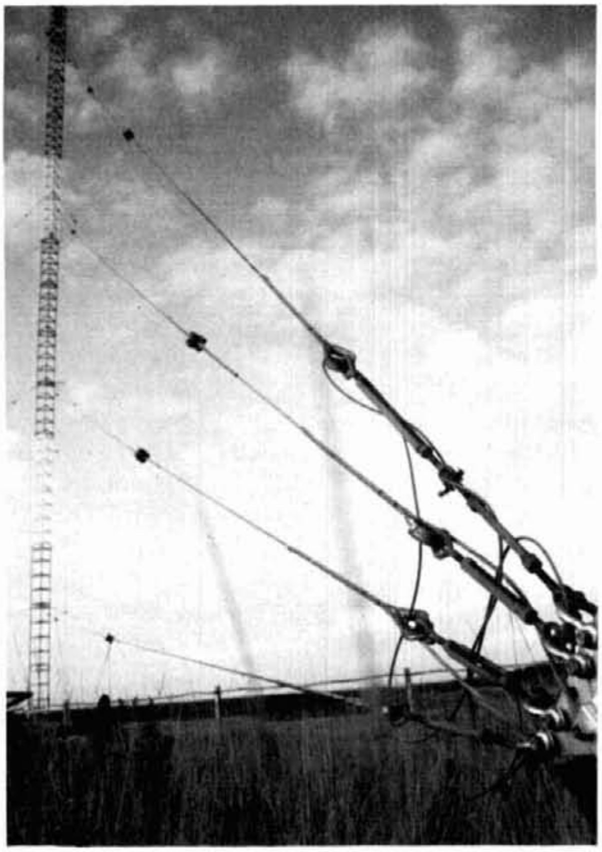

fig. 8. To gain an appreciation of the type of tower needed to handle low-band rotaries, examine VE2HQ's new 160-foot structure ready to support his three-element Yagi.

The situation is even more pronounced for a 15-degree takeoff angle condition. Compare lines 1, 2, and 3 with lines 4, 5, and 6; notice that for every soil type, the high horizontal beats the vertical. However, a horizontal antenna produces a maximum elevation lobe of 15 degrees when it is one wavelength up (250 feet/76.2 meters). There are probably only a few low-banders (WA1EKV, for example) who, thanks to a high tower and local topography, have their antennas at this height. Consequently, for that low-angle, low-path shot, it's perhaps easy to construct a vertical and get approximately the same performance as you would with the high horizontal. (This is true for medium to high conductivity far field soils).

Finally, if you're a lover of verticals, then the importance of an extended radial ground screen becomes apparent when you examine lines 4 and 6 in **table 10.** Copper, an even better conductor than salt water, provides an almost 600 percent improvement in reflected component level. This requires radials several wavelengths long to achieve a maximum elevation lobe of 15 degrees.

Let's say that you're considering several sites that have vastly different soil conditions for your ultimate super-station location. If you favor horizontal antennas, there's not a lot of difference in the reflected wave amplitude as a function of angle or soil parameters (compare lines 1 to 3 and 7 to 9 in **table 10**.)

But why are we so concerned with the reflected component? Simply because the composite launched wave or signal is a combination of the sky wave and the ground-reflected wave representing a doubling in signal level if everything works out. Which brings us to the next point: what factors are involved in maximum signal transmission/reception? The answer is that at the optimum launched angle (takeoff angle) — i.e. the angle best suited for that path, time of day, solar activity, and geomagnetic field conditions — the two components must add constructively. This means that the phase relationships must also match. Now, since the earth looks like a big capacitor, the reflected component always lags (negative phase angle) the incident wave. Notice in the last column of **table 10** the amount of phase delay is listed for the various soils, takeoff angles, and polarizations. It normally follows that if the amplitude of the reflected component is near unity, then the phase angle is quite small.

Upon examining all the survey responses no commonality between soil type and station performance could be discerned. The super-stations run the gamut from rocky to salt water ground characteristics and, in some cases, possibly have chosen their antennas carefully on this basis.

concluding installment

In Part 2 of this article, we'll examine responses from those surveyed to see how they rate their sites, including descriptions of near- and far-field conditions, obstructions, and noise sources with which they must contend.

We'll also consider the danger of lightning strikes and see what precautions these high-performance station operators, particularly those with exposed installations, have taken, both at the shack and at the antennas. Those who've sustained lightning strikes will describe the damage that occurred.

Construction of large antenna systems — whether they be rotaries, long wire antennas, or other elaborate systems — requires extensive planning, labor, expense, and maintenence. What periodic maintenence do these high-performance station operators recommend? Most of these stations have or are using different antennas — how do they compare? Next month, you'll also see how owners rate their stations against the competition. Propagation notes, including some startling results derived from thousands of hours of operating time by those with rotatable and switchable arrays, will be included.

It appears that the days of simple verticals and dipoles are rapidly passing; in our concluding installment, high-performance station owners and operators will describe additional improvements they plan to make to their stations to make them even more competitive in the future.

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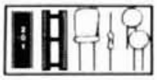

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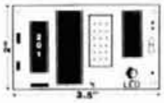

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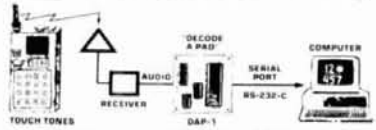

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computer-aided design of long VHF Yagi antennas

Design up to 40 elements on a single boom

This article describes a program for designing nine to 40-element Yagi antennas. You provide the design frequency, the number of elements, and boom and element diameters; the computer calculates the element lengths, element spacing, and several additional characteristics of the antenna. Whether the elements are insulated from or pass through the boom is also taken into consideration.

While this program breaks no new ground as far as antenna design is concerned, it does provide a quick way of designing long Yagis based on the designs of DL6WU, to whom all credit for these excellent antennas must be given.[1]

One of the most useful features of this program is the ability to easily change the number of elements and see — immediately — the resulting change in performance. You know, at once, whether the increase in length is worth the increase in gain obtained.

program description

The program was originally written on a TRS-80 Model 1 and given to a number of local VHF Amateurs, who were asked to evaluate the program and suggest improvements. This program is the result of that venture and resembles the original only slightly. The version printed here was written on an Apple IIe with a Z-80 processor, running Microsoft Basic™. Because this is a universal form of BASIC, there should be no difficulty using the program on most popular personal computers.

Three commands, peculiar to the computer on which this program was written, may need to be altered for use on other machines. They are **HOME**, to clear the screen and return the cursor; **INVERSE**, to change the background from light to dark, and **BEEP**, to sound a tone of predetermined pitch and duration. The latter two commands are cosmetic; no change in performance would result from their omission.

The disc-based program consists of the main program and 16 data files. (The data files could have been entered as data statements, but because only one is required each time the program is run, I opted for data files.)

The program begins in earnest at **line 160**, where the screen is cleared and the title screen is presented. (The code for this resides in **lines 1820** to **1920.**) After pressing any key, a few seconds will elapse while the computer reads the data for element spacing (**lines 180-220**), reflector multiplier (**lines 230-260**), radiator multiplier (**lines 270-300**), and element material size data (**lines 310-340**).

The next section (**lines 340-430**) asks for the design frequency, number of elements — which must be between 9 and 40 — the diameter of the boom and whether the elements are insulated or pass through the boom.

Lines 440-490 clear the screen and display the information entered. In **lines 500-640**, you're given the opportunity to change any of the input data.

Lines 650-790 calculate boom diameter in wavelengths, electrical boom length, beamwidths, and stacking distances. Data on the designed Yagi is displayed by **lines 800-940**. Should the design be unsatisfactory, **lines 950-990** allow you to start again.

Lines 1000-1100 input the size of the elements to be used. Calculation of the element lengths is achieved by lines **1120-1300**. Printing of the design and element data is done in **lines 1310-1750**.

operating the program

Operation is straightforward. When <RUN> is typed, the screen is cleared and the title is displayed. Pressing any key clears the screen, and after a few seconds you're asked to input "center frequency," "number of elements," "diameter of the boom," and whether "the elements are insulated from the boom." The screen is cleared and the input data is displayed. You'll

By David G. Hopkins, VK4ZF, #4 Handsworth Street, Capalaba, Queensland 4157, Australia

fig. 1. VK4ZF Yagi design program.

```
10 REM ********************************************************************************
20 REM                         YAGI DESIGN PROGRAM.
30 REM                                  BY
40 REM                         DAVID G HOPKINS  (VK4ZF)
50 REM                          # 4 HANDSWORTH ST
60 REM                                CAPALABA
70 REM                                QLD. 4157
80 REM                                AUSTRALIA
90 REM          PROGRAM BASED ON THE WORK DONE BY GUNTER HOCH (DL6WU)
100 REM                  AND PUBLISHED IN VHF. COMMUNICATIONS
110 REM                   REQUIRES THE USE OF LINE PRINTER.
120 REM                                 V 2.2A
130 REM ********************************************************************************
140 REM
150 REM
160 HOME : GOSUB 1820
170 CLEAR:DIM SP(40),DS(40),TS(40),LE(45):Q$="####":Q$(1)="###.##":Q$(2)="###.##
#":Q$(3)="####.#"
180 REM-----------------LOAD ELEMENT SPACING DATA-------------
190 DATA .240,.075,.180,.215,.250,.280,.300,.315,.330,.345,.360,.375,.385,.390,.
395,.400,.400,.400,.400,.400,.400,.400,.400,.400,.40
0,.400,`.400,.400,.400,.400,.400,.400,.400,.400,.400,.400,.400,.400,.400,.400
200 FOR X=1 TO 40
210 READ SP(X)
220 NEXT
230 REM---------------------LOAD REFLECTOR MULTIPLIER------------
240 DATA .4905,.4900,.4885,.4875,.4865,.4855,.4845,.4835,.4825,.4820,.4810,.4785
,.4770,.4765,.4750,.4740
250 DIM RE(17)
260 FOR X=1 TO 16:READ RE(X):NEXT
270 REM-------------------LOAD RADIATOR MULTIPLIER------------
280 DIM DR(17)
290 DATA .4675,.4665,.4640,.4620,.4601,.4585,.4575,.4550,.4530,.4515,.4500,.4460
,.4435,.4430,.4400,.4385
300 FOR X=1 TO 16:READ DR(X):NEXT
310 REM ------------------SELECT ELEMENT  MATERIAL SIZE----------------
320 DATA .003,.0035,.0042,.005,.0056,.0063,.007,.0078,.0088,.01,.01145,.0131,.01
5,.0165,.0182,.02
330 DIM EL(16):FOR X=1 TO 16:READ EL(X):NEXT
340 REM-----------------INPUT DESIRED PARAMETERS----------------
350 HOME :BEEP 20,10 :INPUT "WHAT IS THE CENTER FREQUENCY OF THE ANTENNA IN MHZ.
";F
360 BEEP 20,10:PRINT:INPUT"HOW MANY ELEMENTS DOES THE ANTENNA REQUIRE.";N
370 PRINT :IF N<9 OR N>40 THEN INVERSE :PRINT "NUMBER OF ELEMENTS MUST BE BETWEE
N  9 AND 40":NORMAL :GOTO 360
380 PRINT:BEEP 20,10:INPUT"WHAT IS THE DIAMETER OF THE BOOM IN MILLIMETERS.";BD
390 PRINT:BEEP 20,10:PRINT"ARE THE ELEMENTS TO BE INSULATED FROM THE BOOM Y=YES
N=NO ";
400 IN$=INKEY$ :IF LEN(IN$)=0 GOTO 400
410 IF IN$ ="Y" OR IN$= "y" THEN I=1: GOTO 450
420 IF IN$= "N" OR IN$="n" THEN I=0: GOTO 450
430 GOTO 400
440 REM -------------------DISPLAY SPEFICATIONS-----------------
  450 HOME :PRINT "SPEFICATIONS FOR THE ANTENNA TO DESIGN ":PRINT:PRINT:PRINT"1.
      DESIGN FREQUENCY :- ";F;" MHZ"
460 PRINT"2.          DIAMETER OF BOOM :- ";BD;" MILLIMETERS."
470 PRINT"3.          NUMBER OF ELEMENTS :- ";N
480 IF I=1 THEN PRINT"4.          ELEMENTS ARE TO BE INSULATED FROM THE BOOM"ELS
E PRINT"4.       `  ELEMENTS ARE TO BE NON INSULATED
 AND THROUGH THE BOOM"
490 IF (BD/1000)/(299.792/F)>.05 THEN PRINT :PRINT :PRINT :PRINT "BOOM DIAMETER
IS TO LARGE FOR THIS FREQUENCY": PRINT :PRINT :PRINT
 "ENTER A SMALLER DIAMETER ":INPUT BD:GOTO 440
500 REM-------------------CHECK SPEFICATIONS---------------
510 PRINT :PRINT :PRINT :PRINT "ARE ALL THE ENTRIES CORRECT Y=YES  N=NO ";
520 IN$=INKEY$ :IF LEN(IN$) =0 THEN GOTO 520
530 IF IN$="Y" OR IN$="y" GOTO 650
540 IF IN$="N" OR IN$="n" GOTO 560
550 BEEP 100,10:GOTO 520
560 PRINT :INPUT "WHAT IS THE NUMBER OF THE INCORRECT ENTRY ";X
570 IF X< > 4 GOTO 600
580 IF I=0 THEN I=1: GOTO 440
590 IF I=1 THEN I=0: GOTO 440
600 INPUT "WHAT IS THE CORRECT VALUE ";CV
610 IF X=1 THEN F=CV
620 IF X=2 THEN BD=CV
630 IF X=3 THEN N=CV
640 GOTO 450
650 REM--------------CALCULATE BOOM DIAMETER WAVELENGTHS--------
660 W=299.792/F
670 BW=BD/1000/W
680 BC=BD*(526.286*BW^.648831/100)
690 REM------------------CALCULATE BOOM LENGTH----------------
700 TL=0
710 W=299.792/F
720 FOR X=1 TO N-1
730 DS(X)=SP(X)*W*1000
```

```
740 TL=TL+DS(X)
750 NEXT
760 PG=(TL/1000)/W
770 REM-------CALCULATE BEAM WIDTHS AND STACKING DISTANCES------
780 BH=50.2709*PG^-.484091:SH=W/(2*(SIN(BH/2*.0174533)))
790 BV=66.5112*PG^-.617261:SV=W/(2*(SIN(BV/2*.0174533)))
800 REM--------------------PRINT PRELIMINARY DATA------------
810 HOME
820 PRINT "              YAGI PRELIMINARY DATA":PRINT
830 PRINT "FREQUENCY                      ";F;" MHZ."
840 PRINT"WAVELENGTH                     ";W;" METERS."
850 PRINT "# OF ELEMENTS                  ";N
860 PRINT "DIAMETER OF BOOM               ";BD;" MILLIMETERS"
870 PRINT "ELECTRICAL BOOMLENGTH          ";INT(TL);" MILLIMETERS"
880 PRINT "BOOM WAVELENGTHS               ";PG
890 PRINT "MAXIMUM PRACTICAL GAIN ";:PRINT USING Q$(1);7.8*( LOG (PG)/ LOG (10))
+9.2;:PRINT " dBD"
900 PRINT "HORIZONTAL BEAM WIDTH  ";:PRINT USING Q$(3);BH;:PRINT " DEGREES"
910 PRINT "VERTICAL BEAM WIDTH    ";:PRINT USING Q$(3);BV;:PRINT " DEGREES"
920 PRINT "                        STACKING DISTANCES"
930 PRINT "           HORIZONTAL:- ";:PRINT USING Q$(2);SH;:PRINT "  METERS"
940 PRINT "           VERTICAL  :- ";:PRINT USING Q$(2);SV;:PRINT "  METERS"
950 PRINT :PRINT :PRINT "DO YOU WISH TO CONTINUE WITH THIS DESIGN Y=YES  N=NO ";
960 IN$=INKEY$ :IF LEN(IN$) =0 GOTO 960
970 IF IN$="Y" OR IN$="y" GOTO 1000
980 IF IN$="N" OR IN$="n" GOTO 440
990 BEEP 100,10 :GOTO 960
1000 HOME :NU=0
1010 PRINT :PRINT "YOU MAY USE ANY OF THE FOLLOWING TUBING SIZES FOR THE ELEMENT
S"
1020 PRINT :PRINT "SELECT THE SIZE CLOSEST TO THE COMMERCIAL TUBE SIZE"
1030 FOR X=1 TO 16
1040 NU=NU+1
1050 PRINT "# ";X;".          ";:PRINT USING Q$(3);(EL(X)*W)*1000;:PRINT " MM":I
F (EL(X)*W)*1000>12 THEN X=16
1060 NEXT
1070 PRINT :PRINT :PRINT :PRINT "ENTER THE # OF THE TUBING SIZE YOU WISH TO USE"
;
1080 INPUT TS$
1090 IF VAL(TS$) >NU THEN BEEP 100,10 :GOTO 1000
1100 TS=VAL(TS$) :TT=EL(TS):TD(1)=TT*W*1000
1110 HOME :PRINT "STAND BY THIS WILL TAKE A FEW SECONDS"
1120 REM-----------------LOAD TUBING SIZE TABLES--------------
1130 N$="CURVE":N2$=N$+TS$
1140 OPEN "I",1,N2$
1150 FOR X=1 TO 38
1160 LINE INPUT #1,O$
1170 TS(X)=VAL(O$)
1180 NEXT
1190 CLOSE
1200 REM---------------CALCULATE ELEMENT LENGTHS----------------
1210 FOR X=3 TO 42
1220 IF I=1 THEN LE(X)=W*TS(X-2)*1000 ELSE LE(X)=(W*TS(X-2))*1000+BC
1230 NEXT
1240 LE(1)=W*RE(TS)*1000
1250 IF I=0 THEN LE(1)=LE(1)+BC
1260 LE(2)=W*DR(TS)*1000
1270 IF I=0 THEN LE(2)=LE(2)+BC
1280 HOME
1290 PRINT "PRESS ANY KEY WHEN THE PRINTER IS READY":BEEP 10,20
1300 IN$=INKEY$ :IF LEN(IN$) =0 GOTO 1300
1310 LPRINT "                           YAGI DESIGN DETAILS :-"
  1320 LPRINT "-----------------------------------------------------------------"
1330 LPRINT :LPRINT
1340 LPRINT "DESIGN FREQUENCY :- ",F;"  MHZ."
1350 LPRINT "WAVELENGTH       :- ",:LPRINT USING Q$(2);W;:LPRINT "  METERS"
1360 LPRINT "NUMBER OF ELEMENTS :- ",N
1370 LPRINT "DIAMETER OF BOOM   :- ",BD;" MM"
1380 LPRINT "DIAMETER OF ELEMENTS :- ",: LPRINT USING Q$(3);TD(1);: LPRINT " MM"
1390 IF I=1 THEN LPRINT "ELEMENTS ARE INSULATED FROM THE BOOM" ELSE LPRINT "ELEM
ENTS ARE NOT INSULATED FROM AND PASS THROUGH THE BOO
M"
1400 LPRINT "ELECTRICAL BOOM LENGTH :- ",INT(TL);"MM"
1410 LPRINT "BOOM WAVE LENGTHS :- ",PG
1420 LPRINT "MAXIMUM PRACTICAL GAIN :- ",: LPRINT USING Q$(1);7.8*( LOG (PG)/ LO
G (10))+9.2;:LPRINT "  dBD"
1430 LPRINT "HORIZONTAL BEAM WIDTH :- ",:LPRINT USING Q$(3);BH;:LPRINT " DEGREES
"
1440 LPRINT "VERTICAL BEAM WIDTH   :- ",:LPRINT USING Q$(3);BV;:LPRINT " DEGREES
"
1450 LPRINT "HORIZONTAL STACKING DISTANCE :-",: LPRINT USING Q$(2);SH;: LPRINT "
 METERS"
1460 LPRINT "VERTICAL STACKING DISTANCE :- ",: LPRINT USING Q$(2);SV;: LPRINT "
METERS"
1470 LPRINT :LPRINT
1480 LPRINT "     ELEMENT LENGTHS IN MILLIMETERS.             DISTANCE FROM REFLE
CTOR MM."
1490 LPRINT "  ==================================================================
============"
```

```
1500 LPRINT
1510 LPRINT "REFLECTOR        ",: LPRINT USING Q$(3);LE(1),: LPRINT ,: LPRINT ,:L
PRINT "  0"
1520 LPRINT "DRIVEN           ",: LPRINT USING Q$(3);LE(2),: LPRINT ,: LPRINT,:L
PRINT USING Q$(3); SP(1)*W*1000
1530 PS=SP(1)*W*1000
1540 FOR X=3 TO N
1550 PS=PS+SP(X-1)*W*1000
1560 LPRINT "DIRECTOR # ";X-2,: LPRINT USING Q$(3);LE(X),:LPRINT ,:LPRINT ,:LPRI
NT USING Q$(3);PS
1570 NEXT
1580 LPRINT
1590 LPRINT "    ELEMENT SPACING IN MILLIMETERS "
1600 LPRINT "========================================="
1610 LPRINT
1620 LPRINT "REFLECTOR - DRIVEN ",:LPRINT USING Q$(3);DS(1)
1630 LPRINT "DRIVEN    - DIR  1",:LPRINT USING Q$(3);DS(2)
1640 FOR X=3 TO N-1
1650 LPRINT "DIR";X-2;"     - DIR ";X-1,:LPRINT USING Q$(3);DS(X)
1660 NEXT
1670 LPRINT :LPRINT :LPRINT"                                NOTES"
 1680 LPRINT :LPRINT "1.  THE DIMENSIONS ARE FROM CENTER TO CENTER IN ALL CASES"
1690 LPRINT "    FOR EXAMPLE THIS MEANS THE BOOM MUST BE CUT LONGER THAN THAT GI
VEN"
1700 LPRINT"    TO BE ABLE TO MOUNT THE ELEMENTS."
1710 LPRINT "2.  IF YOU WANT WIDE BANDWIDTH USE A FOLDED DIPOLE AS THE DRIVEN EL
EMENT."
1720 LPRINT "3.  THE DRIVEN ELEMENT DIMENSION IS THE LENGTH OVERALL."
 1730 LPRINT "4.  YOU MUST WORK TO AN ACCURACY OF BETTER THAN 1MM AT FREQUENCIES
ABOVE 400MHZ."
1740 LPRINT "5.  ACCURACY BELOW 400MHZ SHOULD BE WITHIN 1.5 MM."
1750 LPRINT "6.  ELEMENT MOUNTING MUST BE BETTER THAN .5 MM OF THE ELEMENT CENTE
R."
1760 HOME :FOR X= 1 TO 8:LPRINT :NEXT
1770 PRINT "ANOTHER CALCULATION ?  Y=YES   N=NO";
1780 IN$=INKEY$:IF LEN(IN$) =0 GOTO 1780
1790 IF IN$ ="Y" OR IN$="y" THEN GOTO 440
1800 IF IN$="N" OR IN$="n" THEN END
1810 BEEP 100,20 :GOTO 1780
1820 HOME :PRINT :PRINT "THIS PROGRAM WILL DESIGN LONG YAGI ANTENNAS"
1830 PRINT "   WITH ANY NUMBER OF ELEMENTS BETWEEN 6 AND 40"
1840 PRINT :PRINT :PRINT
1850 PRINT " THE PROGRAM IS BASED ON ARTICLES BY GUNTER HOCK"
1860 PRINT "  AND PUBLISHED IN VHF. COMMUNICATIONS"
1870 PRINT :PRINT :PRINT
1880 PRINT " YOU WILL REQUIRE A LINE PRINTER TO OBTAIN THE RESULTS"
1890 PRINT :PRINT :INVERSE :PRINT "PRESS ANY KEY TO CONTINUE ";: NORMAL:BEEP 20,
10
1900 IN$=INKEY$ : IF LEN (IN$)=0 GOTO 1900
1910 HOME
1920 RETURN
1930 END
```

be asked if you wish to correct any input. If all is correct the screen displays the information shown in **fig. 1**. Once again, you're asked whether you wish to continue or go back and change any input value.

If the design is acceptable, you next select the size of the tubing to use for the elements. Depending on the frequency, up to 16 different sizes of element material will be offered. Choose the size nearest the one you can readily buy from your supplier. The screen will now clear and after about 15 seconds, the computer will ask if the printer is ready, then print out the complete design.

```
             YAGI PRELIMINARY DATA
FREQUENCY                      432  MHZ.
WAVELENGTH                     .693963  METERS.
# OF ELEMENTS                  15
DIAMETER OF BOOM               2Ø  MILLIMETERS
ELECTRICAL BOOMLENGTH          28Ø3  MILLIMETERS
BOOM WAVELENGTHS              4.Ø4
MAXIMUM PRACTICAL GAIN        13.93 dBD
HORIZONTAL BEAM WIDTH         25  DEGREES
VERTICAL BEAM WIDTH           28  DEGREES
               STACKING DISTANCES
      HORIZONTAL:-    1.6Ø3  METERS
      VERTICAL  :-    1.434  METERS
```

fig. 2. Preliminary data display.

The first part of the printout provides the characteristics of the Yagi followed by the element lengths and the progressive distance from the reflector to each element. The next section gives the distance between the centers of the elements and concludes with some notes about the construction of the antenna.

The program is simple to use, in that any numerical input requires the pressing of the enter (return) key, but any input requiring a "Y" or "N" does not. Either upper or lower case may be used for the "Y" or "N" inputs. In the version shown, a *high* pitched tone is sounded when the computer requires an input and a *low* tone is sounded when it receives an unexpected input — i.e., when you've made a mistake. (This feature can easily be removed if your computer doesn't support the BEEP command.)

typing in the program

There's a lot of typing to do. *No errors are allowed.* The main program should pose no real problem, but the data files are a real chore. You may use the listing

```
10 HOME
20 DIM A(39):O$="CURVE"
30 PRINT "WHAT IS THE NUMBER OF THE CURVE YOU WISH TO ENTER ";:INPUT C$
40 F$=O$+C$
50 PRINT "ENTER THE VALUES FOR THE CURVE"
60 FOR X=1 TO 38
70 PRINT"#"; X;".";:INPUT A(X)
80 NEXT
90 HOME
100 PRINT "THESE ARE THE VALUE FOR CURVE";C
110 PRINT
120 PRINT
130 FOR X=1 TO 38
140 PRINT"#"; X;".  ";A(X),
150 NEXT
160 PRINT
170 PRINT "ARE ALL THE VALUES CORRECT Y =YES    N=NO";INPUT A$
180 IF A$="Y" GOTO 250
190 IF A$="N" GOTO 210
200 GOTO 170
210 PRINT "WHICH # IS INCORRECT" :INPUT D
220 PRINT "WHAT IS THE CORRECT VALUE FOR :- #";D
230 INPUT A(D)
240 GOTO 100
250 HOME
260 PRINT "OUTPUT TO DISC"
270 OPEN "O" ,1, F$
280 FOR X= 1 TO 38
290 PRINT #1,A(X)
300 NEXT
310 CLOSE
320 PRINT "END OF PROGRAM"
330 END
```

fig. 4. Program to input data files.

```
                    YAGI DESIGN DETAILS :-
 -----------------------------------------------------------------

DESIGN FREQUENCY :-            145.825   MHZ.
WAVELENGTH        :-            2.Ø56  METERS
NUMBER OF ELEMENTS :-          9
DIAMETER OF BOOM    :-         25  MM
DIAMETER OF ELEMENTS :-         1Ø.3 MM
ELEMENTS ARE NOT INSULATED FROM AND PASS THROUGH THE BOOM
ELECTRICAL BOOM LENGTH :-      3813 MM
BOOM WAVE LENGTHS :-           1.855
MAXIMUM PRACTICAL GAIN :-      11.29  dBD
HORIZONTAL BEAM WIDTH :-        37.3 DEGREES
VERTICAL BEAM WIDTH    :-       45.4 DEGREES
HORIZONTAL STACKING DISTANCE :-                3.216 METERS
VERTICAL STACKING DISTANCE :-                  2.662 METERS

    ELEMENT LENGTHS IN MILLIMETERS.           DISTANCE FROM REFLECTOR MM.
  ======================================================================

REFLECTOR                     1ØØ9.7                  Ø
DRIVEN                         957.3                493.4
DIRECTOR #  1                  9Ø9.6                647.6
DIRECTOR #  2                  899.3               1Ø17.6
DIRECTOR #  3                  889.5               1459.6
DIRECTOR #  4                  88Ø.2               1973.6
DIRECTOR #  5                  871.Ø               2549.2
DIRECTOR #  6                  863.9               3166.Ø
DIRECTOR #  7                  857.Ø               3813.6

    ELEMENT SPACING IN MILLIMETERS
======================================

REFLECTOR - DRIVEN             493.4
DRIVEN    - DIR  1             154.2
DIR 1     - DIR  2             37Ø.1
DIR 2     - DIR  3             442.Ø
DIR 3     - DIR  4             514.Ø
DIR 4     - DIR  5             575.6
DIR 5     - DIR  6             616.8
DIR 6     - DIR  7             647.6

                             NOTES

1.  THE DIMENSIONS ARE FROM CENTER TO CENTER IN ALL CASES
    FOR EXAMPLE THIS MEANS THE BOOM MUST BE CUT LONGER THAN THAT GIVEN
    TO BE ABLE TO MOUNT THE ELEMENTS.
2.  IF YOU WANT WIDE BANDWIDTH USE A FOLDED DIPOLE AS THE DRIVEN ELEMENT.
3.  THE DRIVEN ELEMENT DIMENSION IS THE LENGTH OVERALL.
4.  YOU MUST WORK TO AN ACCURACY OF BETTER THAN 1MM AT FREQUENCIES ABOVE 4ØØMHZ.
5.  ACCURACY BELOW 4ØØMHZ SHOULD BE WITHIN 1.5 MM.
6.  ELEMENT MOUNTING MUST BE BETTER THAN .5 MM OF THE ELEMENT CENTER.

                    YAGI DESIGN DETAILS :-
 -----------------------------------------------------------------

DESIGN FREQUENCY :-            432.5   MHZ.
WAVELENGTH        :-            Ø.693  METERS
NUMBER OF ELEMENTS :-          2Ø
DIAMETER OF BOOM    :-         19  MM
DIAMETER OF ELEMENTS :-          6.1 MM
ELEMENTS ARE NOT INSULATED FROM AND PASS THROUGH THE BOOM
ELECTRICAL BOOM LENGTH :-      4183 MM
BOOM WAVE LENGTHS :-           6.Ø35
MAXIMUM PRACTICAL GAIN :-      15.29  dBD
HORIZONTAL BEAM WIDTH :-        21.1 DEGREES
VERTICAL BEAM WIDTH    :-       21.9 DEGREES
HORIZONTAL STACKING DISTANCE :-                1.897 METERS
VERTICAL STACKING DISTANCE :-                  1.822 METERS

    ELEMENT LENGTHS IN MILLIMETERS.           DISTANCE FROM REFLECTOR MM.
  ======================================================================

REFLECTOR                      344.1                  Ø
DRIVEN                         323.7                166.4
DIRECTOR #  1                  3Ø6.3                218.3
DIRECTOR #  2                  3Ø2.4                343.1
DIRECTOR #  3                  298.8                492.1
DIRECTOR #  4                  295.1                665.4
DIRECTOR #  5                  291.8                859.5
DIRECTOR #  6                  288.8               1Ø67.5
DIRECTOR #  7                  286.2               1285.8
DIRECTOR #  8                  283.6               1514.6
DIRECTOR #  9                  281.8               1753.7
DIRECTOR #  1Ø                 28Ø.Ø               2ØØ3.2
DIRECTOR #  11                 278.6               2263.2
DIRECTOR #  12                 277.1               253Ø.Ø
DIRECTOR #  13                 275.9               28ØØ.4
DIRECTOR #  14                 274.8               3Ø74.2
DIRECTOR #  15                 273.7               3351.4
DIRECTOR #  16                 272.6               3628.7
DIRECTOR #  17                 271.6               39Ø6.Ø
DIRECTOR #  18                 27Ø.7               4183.2

    ELEMENT SPACING IN MILLIMETERS
======================================

REFLECTOR - DRIVEN             166.4
DRIVEN    - DIR  1              52.Ø
DIR 1     - DIR  2             124.8
DIR 2     - DIR  3             149.Ø
DIR 3     - DIR  4             173.3
DIR 4     - DIR  5             194.1
DIR 5     - DIR  6             2Ø7.9
DIR 6     - DIR  7             218.3
DIR 7     - DIR  8             228.7
DIR 8     - DIR  9             239.1
DIR 9     - DIR  1Ø            249.5
DIR 1Ø     - DIR  11           259.9
DIR 11     - DIR  12           266.9
DIR 12     - DIR  13           27Ø.3
DIR 13     - DIR  14           273.8
DIR 14     - DIR  15           277.3
DIR 15     - DIR  16           277.3
DIR 16     - DIR  17           277.3
DIR 17     - DIR  18           277.3

                             NOTES

1.  THE DIMENSIONS ARE FROM CENTER TO CENTER IN ALL CASES
    FOR EXAMPLE THIS MEANS THE BOOM MUST BE CUT LONGER THAN THAT GIVEN
    TO BE ABLE TO MOUNT THE ELEMENTS.
2.  IF YOU WANT WIDE BANDWIDTH USE A FOLDED DIPOLE AS THE DRIVEN ELEMENT.
3.  THE DRIVEN ELEMENT DIMENSION IS THE LENGTH OVERALL.
4.  YOU MUST WORK TO AN ACCURACY OF BETTER THAN 1MM AT FREQUENCIES ABOVE 4ØØMHZ.
5.  ACCURACY BELOW 4ØØMHZ SHOULD BE WITHIN 1.5 MM.
6.  ELEMENT MOUNTING MUST BE BETTER THAN .5 MM OF THE ELEMENT CENTER.
```

fig. 3. Sample printouts.

CURVE1	CURVE2	CURVE3	CURVE4	CURVE5
.4478	.4448	.4418	.4388	.4366
.4433	.4401	.437	.4338	.4315
.4389	.4356	.4323	.429	.4267
.4354	.4318	.4281	.4245	.422
.4316	.4277	.4239	.42	.4175
.4281	.4242	.4204	.4165	.4138
.4251	.4211	.4172	.4132	.4105
.4222	.4181	.4141	.41	.4072
.4196	.4156	.4116	.4076	.4047
.4175	.4135	.4094	.4054	.4024
.4158	.4117	.4076	.4035	.4005
.4141	.41	.4058	.4017	.3986
.4125	.4083	.4042	.4	.3969
.4109	.4067	.4026	.3984	.3953
.4096	.4053	.4011	.3968	.3937
.4082	.4039	.3995	.3952	.3921
.4071	.4027	.3984	.394	.3908
.406	.4016	.3972	.3928	.3896
.4048	.4004	.3959	.3915	.3883
.4036	.3992	.3947	.3903	.3871
.4026	.3981	.3937	.3892	.386
.4017	.3972	.3926	.3881	.3849
.4009	.3963	.3918	.3872	.384
.4	.3954	.3908	.3862	.383
.3992	.3946	.39	.3854	.3821
.3985	.3939	.3892	.3846	.3813
.3979	.3932	.3884	.3837	.3804
.3971	.3924	.3876	.3829	.3796
.3965	.3917	.3869	.3821	.3788
.396	.3912	.3863	.3815	.3781
.3954	.3905	.3857	.3808	.3774
.3949	.39	.3851	.3802	.3768
.3943	.3894	.3845	.3796	.3763
.3938	.3889	.3839	.379	.3756
.3933	.3884	.3834	.3785	.3751
.3929	.3879	.383	.378	.3746
.3925	.3875	.3825	.3775	.3741
.3922	.3871	.3821	.377	.3736

CURVE6	CURVE7	CURVE8	CURVE9	CURVE10
.4345	.4323	.4301	.4279	.4257
.4293	.427	.4247	.4223	.42
.4243	.422	.4195	.4171	.4146
.4196	.4171	.4144	.4118	.4091
.4151	.4126	.4098	.407	.4042
.4112	.4085	.4056	.4027	.3998
.4077	.405	.4019	.3989	.3958
.4043	.4015	.3983	.3952	.392
.4019	.399	.3957	.3925	.3892
.3995	.3965	.3933	.39	.3868
.3974	.3944	.3911	.3879	.3946
.3955	.3924	.3891	.3858	.3825
.3937	.3906	.3873	.3841	.3308
.3921	.389	.3857	.3825	.3792
.3905	.3874	.3841	.3809	.3776
.3889	.3858	.3826	.3793	.3761
.3876	.3844	.3812	.3779	.3247
.3864	.3832	.3799	.3766	.3733
.3852	.382	.3786	.3753	.3719
.384	.3808	.3774	.374	.3706
.3829	.3797	.3763	.3728	.3694
.3817	.3785	.3751	.3716	.3682
.3807	.3775	.374	.3706	.3671
.3797	.3765	.373	.3695	.366
.3789	.3756	.3721	.3685	.365
.378	.3747	.3711	.3676	.364
.3772	.3739	.3703	.3666	.363
.3763	.373	.3693	.3657	.362
.3754	.3721	.3685	.3648	.3612
.3747	.3713	.3677	.364	.3604
.374	.3706	.367	.3633	.3597
.3734	.37	.3664	.3627	.3591
.3729	.3696	.3658	.3621	.3583
.3722	.3688	.3651	.3613	.3576
.3716	.3682	.3645	.3607	.357
.3711	.3677	.364	.3602	.3565
.3706	.3672	.3635	.3597	.356
.3702	.3668	.363	.3592	.3554

CURVE11	CURVE12	CURVE13	CURVE14	CURVE15	CURVE16
.4231	.4206	.418	.4153	.4127	.41
.4173	.4146	.4119	.4089	.406	.403
.4117	.4089	.406	.4028	.3997	.3965
.4062	.4034	.4005	.3973	.3941	.3909
.4011	.3981	.395	.3918	.3885	.3853
.3965	.3933	.39	.3869	.3838	.3807
.3926	.3894	.3862	.383	.3798	.3766
.3888	.3857	.3825	.3792	.3758	.3725
.386	.3828	.3796	.3762	.3728	.3694
.3835	.3803	.377	.3736	.3703	.3669
.3813	.378	.3747	.3713	.368	.3646
.3792	.3758	.3725	.3691	.3656	.3622
.3774	.3739	.3705	.3671	.3636	.3602
.3757	.3722	.3687	.3653	.3618	.3584
.3741	.3706	.3671	.3636	.3601	.3566
.3726	.369	.3655	.362	.3586	.3551
.3711	.3674	.3638	.3604	.3569	.3535
.3697	.3661	.3625	.359	.3555	.352
.3683	.3646	.361	.3575	.354	.3505
.3669	.3633	.3596	.3561	.3525	.349
.3657	.3619	.3582	.3547	.3511	.3476
.3645	.3607	.357	.3535	.3499	.3464
.3633	.3596	.3558	.3523	.3487	.3452
.3622	.3584	.3546	.3511	.3475	.344
.3612	.3573	.3535	.35	.3464	.3429
.3602	.3563	.3525	.3489	.3453	.3417
.3592	.3553	.3515	.3479	.3442	.3406
.3582	.3543	.3505	.3469	.3432	.3396
.3573	.3535	.3496	.346	.3423	.3387
.3565	.3525	.3486	.3451	.3415	.338
.3557	.3517	.3477	.3441	.3406	.337
.3551	.351	.347	.3434	.3398	.3362
.3543	.3502	.3462	.3426	.3391	.3355
.3536	.3495	.3455	.3419	.3382	.3346
.3529	.3488	.3447	.341	.3373	.3336
.3523	.3482	.344	.3403	.3367	.333
.3518	.3475	.3433	.3396	.3359	.3322
.3511	.3468	.3425	.3388	.3352	.3315

fig. 5. Sample data files.

```
10 HOME
20 INPUT "OVERALL DIMENSION OF DIOPLE IN MM :- ";DO
30 INPUT "INTERNAL DIMENSION OF FOLDED DIOPLE IN MM :- ";T :R=T/2
40 INPUT "DIAMETER OF ELEMENT :- ";DE
50 A=2*(DO-2*(DE+R))
60 C=2*22/7*(R+DE)
70 D=A+C
80 PRINT "TOTAL LENGTH OF MATERIAL REQUIRED :- ";D;" MM"
90 PRINT "START OF BENDS FROM CENTER OF ELEMENT :- ";A/4;"  MM."
100 END
```

fig. 6. Program to calculate material for a folded dipole.

in **fig. 2** to help with this task. This program enables you to enter the values for the file and then check the results before writing the file to the disc.

If your computer has graphic capabilities, it's a good idea to draw the curves on the screen from the saved data files. The curve should be smooth, — no bumps. *Any points out of line means you have a wrong value in the file that must be corrected.*

folded dipole construction

If you're going to use a folded dipole as the driven element, the program shown in **fig. 3**, which gives the length of tubing required and the points at which the bends forming the folded dipole should be started, will save some time. You simply enter the overall dimension of the dipole, the inside dimension of the folded dipole, and the diameter of the tubing.

The computer then specifies tubing length and the distance from the center of the element to the point to start the bend. (Once you start building the actual antenna, be sure your tube bender doesn't flatten the tube as it bends. If it does, don't forget to make allowance for this.)

when all else fails, read the screen

Several Amateurs here in VK4 have worked on the program, and we believe that it should, by now, be just about bug-free. After using the program a few times, you'll find designing Yagis much easier.

I am continually amazed at how earlier versions of the program have made their way around the world. Should you happen to have a copy of one of the earlier versions, it's important to replace it with this updated version, since the earlier versions had some errors and included none of the latest improvements.

acknowledgement

In the original articles six tubing sizes were shown on the graph; Allan, VK4KAZ, spent many hours drawing the other curves and reducing them to the values shown in the data files.

references

1. Günter Hoch, DL6WU, "More Gain with Yagi Antennas," *VHF Communications*, Volume 9 (3/1977), (4/1977); Volume 14 (3/1982).

ham radio

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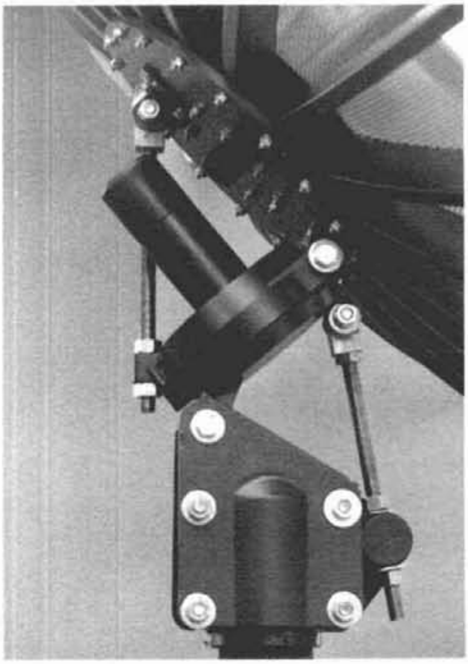

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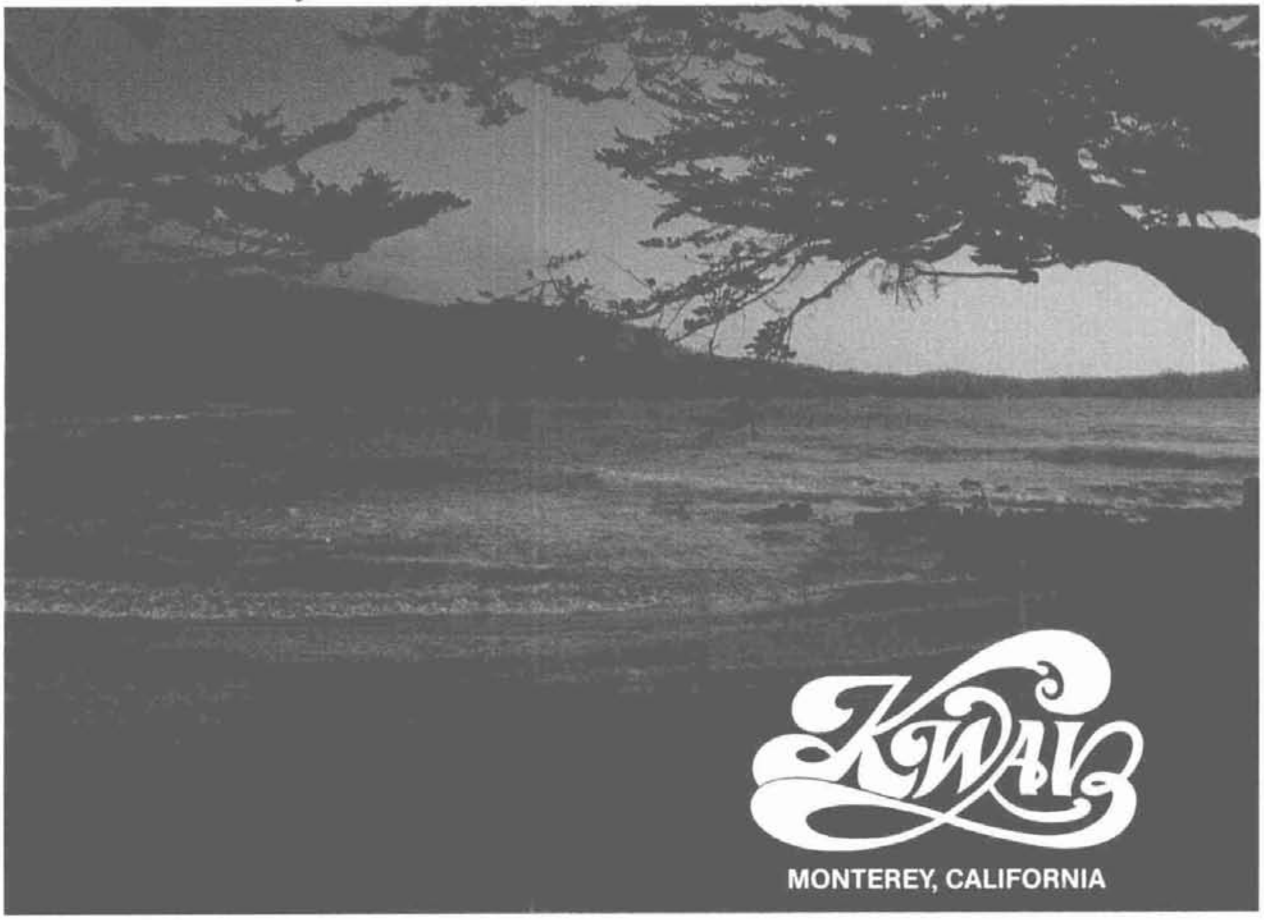

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ham radio TECHNIQUES

Bill Orr W6SAI

the greatest contest ever staged

One of the high points of Amateur Radio is the annual ARRL DX contest, one of the oldest contests in the game. While the rules have changed from year to year, the aim of the contest is still the same: to work as much DX as possible in a given span of time.

In May, 1934, *QST* announced "the greatest DX contest ever staged!" The results of the 1933 contest had finally been tabulated and the scores were sky-high. NY1AB (Canal Zone), for example, amassed a breathtaking 25,000 points, working as many as 16 stations in an hour. And W3ZI topped the US entries with his grand total of 33,000 points. (Today it's not unusual for a contestant to pile up over a *million* points and work stations at over 250 contacts in a single hour).

What equipment were hams using in those long-gone days? The 1933 Sweepstakes provides a clue. Over 64 percent of the hams who submitted sweepstakes scores were running less than 50 watts and over 85 percent of the entries ran less than 400 watts. An amazing 15 percent of the contestants ran less than 20 watts.

In passing, *QST* noted that many high-speed CW operators were running at 25 to 30 WPM in the contest and that, in general, code speed on the DX bands was gradually increasing, year by year. Of course, there were only about 10 percent as many hams licensed in 1933-34 as there are today!

Finally it should be noted that during the 1930's, most ham gear — receiving as well as transmitting equipment — was home-made. Very few items of commercial manufacture were available, and the money to buy it was absent, for these were the years of the Great Depression.

Now I see the wheel has turned full circle. The Canadian Department of Commerce is proposing that it will require Canadian Amateurs to possess a special, advanced-type license if they want to put home-made equipment on the air!

Doesn't that seem to be placing a roadblock in the path of experimenters who want to build equipment? Experimenters should be encouraged, not harassed with the problem of getting a special license to do what should come naturally!

is your line voltage really 117 volts ac?

Have you ever checked your line voltage with a good RMS responding meter of known accuracy? You may be surprised if you do. In my case, the voltage varies over a small range from minute to minute and takes interesting swoops and dives during the day. Most of the time it runs about 123 volts, but it has dropped as low as 115 volts. Using a borrowed memory 'scope, it was found that short duration "spikes" of over 1000 volts could be observed. These were probably due to the collapsing electric field of inductive devices on the line at various points. The oil burner motor in my house, in particular, puts a nasty high-voltage spike on the power line.

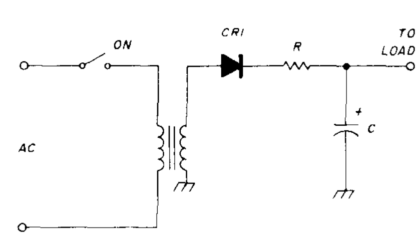

fig. 1. Resistance of transformer windings plus resistor R in series with rectifier limits inrush current to filter capacitor C.

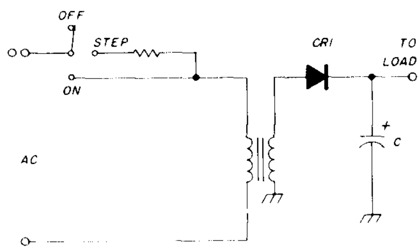

fig. 2. Shorting-type primary switch provides low voltage to supply until capacitor is charged.

Ham gear and computers can be protected from most primary line transients by virtue of inexpensive, easily available surge suppressors. These devices will protect our equipment from low-energy power line "spikes," which are the most common. More robust, industrial surge suppressors are required if you're served by a power line that also serves industrial users.

But what about transients and current surges generated within your own equipment? A surge suppressor on the power line won't help in such cases.

surge protection

It's important to incorporate surge protection in a transmitter power supply to make sure that components are not destructively overloaded during the operating cycle. Diode rectifiers and transmitting tubes are particularly vulnerable in this respect.

In the case of the diode rectifier, each time the power supply is turned on, the rectifier "sees" a low resistance short until the filter capacitor is nearly charged (**fig. 1**). The surge current through the diode to the capacitor can be several hundred amperes for a fraction of a second. In some designs a resistor in series with the rectifier is used to limit diode inrush current. The resistor, however, tends to degrade power supply voltage regulation since the operating current must flow through the resistor.

A more effective means of limiting power supply inrush current is to employ a step-start circuit (**fig. 2**), which applies low primary voltage to the supply until the filter capacitor is charged. This delay time is, typically, about one second in most cases. Once the capacitor is charged, full primary voltage can then be applied.

Various forms of inrush-limiting circuits are shown in **fig. 3**. Circuit *A* employs a variable autotransformer. The operator turns the transformer control and gradually advances the primary voltage as desired.

Circuit *B* employs a series-connected voltage dropping resistor (R) in the primary circuit, which is shorted out by a time-delay relay. There are various forms of time-delay circuits that should be of interest to the equipment builder.

time delay relay

A simple delay circuit is shown in **fig. 4A**. A 120-volt AC relay is connected so that it shorts out the series dropping resistor, R. The initial inrush current causes a voltage drop across the resistor and the relay will not close until the inrush current has decreased to a nominal value and the voltage across the relay coil is close to normal. This circuit is quite effective, but the AC relay tends to "chatter" during the delay period.

The circuit in **fig. 4B** employs a

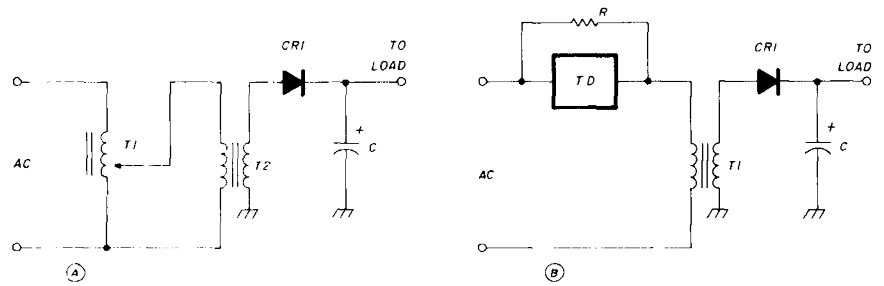

fig. 3(A). Variable autotransformer T1 permits operator to advance primary voltage slowly, thus reducing capacitor inrush current; (B) series-connected time delay relay shorts out surge resistor R after a few seconds.

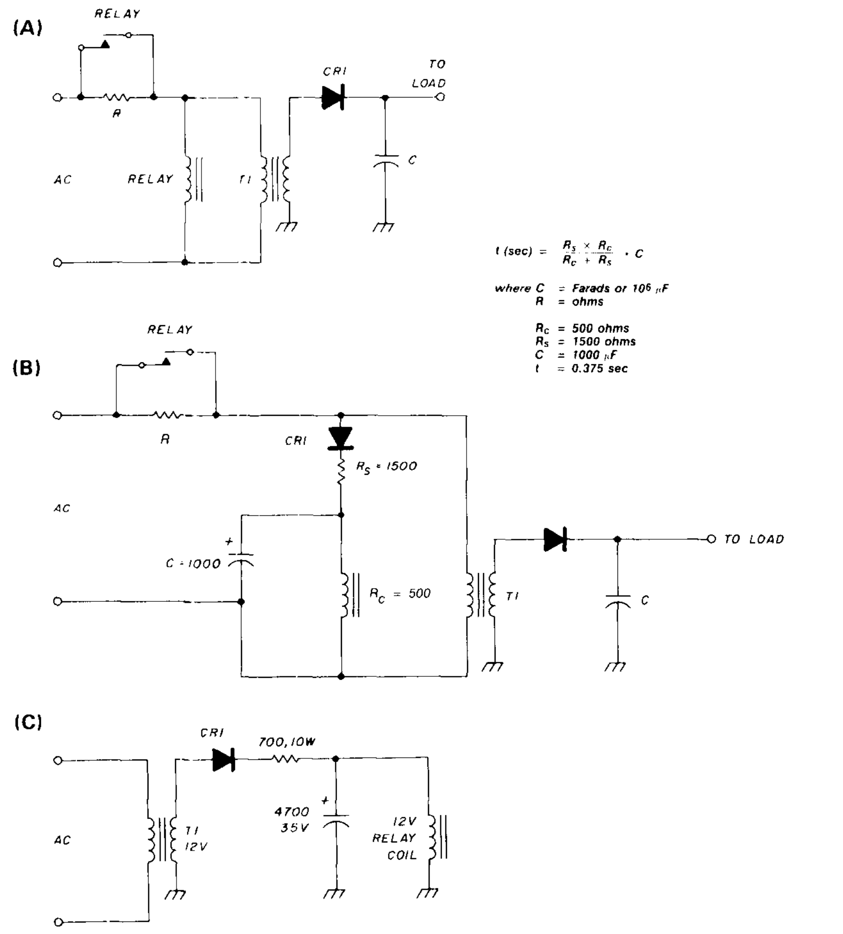

fig. 4(A), AC relay shorts out series dropping resistor R when voltage across relay coil rises close to normal; fig. 4(B), RC circuit provides adjustable time delay for relay R_Y; fig. 4(C), 12 volt relay used in RC time delay circuit.

24-volt DC operated relay with an RC time delay circuit. The line voltage is rectified and applied to the relay through a series resistor and a shunt capacitor. Besides acting as part of the time delay circuit, the capacitor also provides filtering and smoothing for the rectified AC provided by the diode.

The formula for the delay period is given in **fig. 4**. As an example, assume that the DC resistance of the relay coil (R_C) is 500 ohms and the series resistor (R_S) is 1500 ohms. The capacitor (C) has a value of 1000μF. The time delay, then, is about 0.375 seconds. The voltage across the relay coil, determined by Ohm's Law, is about 29 volts, well within the voltage tolerance of the coil.

The value of the coil voltage, series resistor and shunt capacitor can be "juggled" to provide any reasonable value of time delay. In most instances, 12 or 24 volt DC coils are used in Amateur work. The 24 volt relays are more attractive since many varieties of this type can be picked up as military surplus for a fraction of their original cost.

If desired, a 12 volt DC relay may be used, as shown in **fig. 4C**. The time delay for this circuit is about a half-second. It may be increased by increasing the size of the capacitor.

The thermostatic time delay relay consists of relay contacts mounted on a bimetallic strip which is actuated by a heater (**fig. 5**). The time delay is a function of temperature, which is controlled by the heater element. The Amperite thermostatic relay product line provides fixed time delays ranging from 2 to 180 seconds. Although the delay period can be increased by placing a resistor in series with the heating coil circuit, delays greater than 180 seconds cannot be produced. The relays resemble a receiving tube and come in 6, octal- and miniature-base designs. Although nominally 117 volts, the relays can be operated on 234 volts by the addition of a resistor in series with the heating coil.

Another form of time delay relay consists of a DC relay controlled by a small printed circuit timer built into the relay case. The Potter and Brumfield type CU relay is an example of this technique. Members of the CU family of relays have an adjustable time delay period.

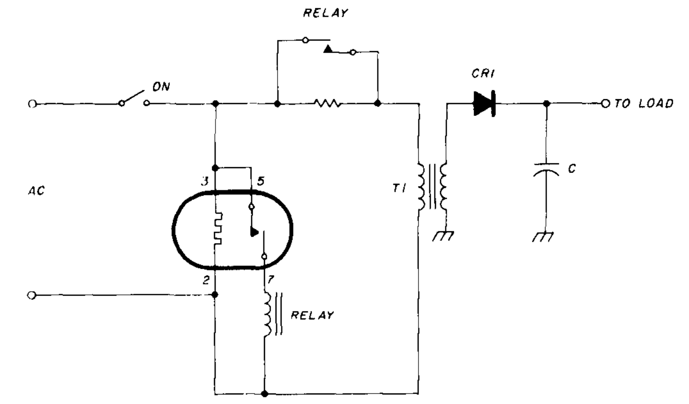

fig. 5. "Amperite" time delay relay consists of contacts mounted on bimetallic strip.

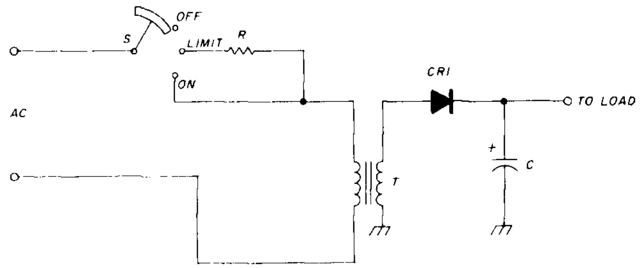

fig. 6. Progressively shorting switch provides step-start function.

Compared to the thermostatic relay, the solid-state controlled relay offers the advantage of being able to be recycled immediately, while the former requires a short time interval for the thermostatic strip to cool and release the closed contacts. On the other hand, the thermostatic relay will remain closed during a short power outage, whereas the solid-state controlled relay will quickly drop open. Each relay type has its own special advantages and disadvantages, depending upon circuit requirements.

Of course, the easiest way to incorporate a surge-limiting circuit is merely to place a single-pole switch across the limiting resistor and forget about relay circuits. A progressively shorting switch (**fig. 6**) in which the positions are "off," "limit," and "on," can also be used. You can control your own time delay with these simple circuits.

filament inrush current

The time delay circuit can play an important role with regard to transmitting tubes. The tungsten filament, or heater, of a power tube has an inverse relationship between operating temperature and resistance. That is, the "cold" resistance is about one-tenth the value of the "hot" resistance. Thus, when the power tube is turned on, the filament inrush current can be as high as ten times the normal filament current.

In very large power tubes (500 kW, for example), it's often necessary to bring up the filament voltage with a motor-controlled variable voltage transformer over a period of minutes to prevent distortion of the filament due to very heavy inrush current. In the case of the lower power tubes used in Amateur service, the problem is not as severe and the restriction of inrush current is less complex.

In many Amateur amplifiers, the filament inrush current is limited by carefully controlling the size and capacity of the filament transformer. In other words, the regulation of the filament transformer is such that the filament voltage "sags" under heavy filament current inrush conditions. This is easily accomplished in some cases by designing the filament transformer so that it's just big enough to do the job, but doesn't have extra power capacity over the amount demanded by the tubes.

In any case, filament inrush current can be limited by a time delay circuit that retards application of full filament voltage for about 3 seconds. This provides enough time for the filament to warm up and increase in resistance. Any of the delay circuits discussed previously will do the job. The series resistor value is adjusted so that about 30 percent of the rated filament voltage is applied to the tube during the delay period.

cathode warmup time

Indirectly heated cathode-type power tubes (such as the 8877 and the 4CX1000A) require a cathode warmup period before the tube is placed in operation. The warmup time required is specified by the manufacturer and depends upon cathode wattage and the physical mass of the cathode structure. The purpose of the warmup period is to ensure that the total cathode area has reached operating temperature and that there is no temperature differential across the structure. Failure to observe the warmup period can result in damage or destruction of the cathode emitting surface. Many Amateurs resent the "intolerable" time required for cathode warmup and some are tempted to cheat and start operation before the required warmup time has passed. Don't do it! You can't fool Mother Nature, so let the cathode structure reach proper operating temperature before you start calling that exotic DX station.

144 MHz EME directory

The 2-meter "moonbounce" directory of Amateurs participating in this exciting communication mode has been reprinted. For your copy, please send five first-class postage stamps or five IRCs to me at: Varian EIMAC, 301 Industrial Way, San Carlos, California 94070.

ham radio

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active antenna preamplifiers

Noiseless feedback and filter techniques improve strong signal handling capability

A recent review of commercial active receiving antennas confirmed my observation that virtually all wideband active antennas are prone to overload and intermodulation distortion in the presence of strong signals. Of eleven different consumer-grade antennas reviewed, all had the same problem.

It's difficult to imagine a high impedance input circuit with unity voltage gain that won't show some distortion when signal levels of 30 volts per meter are experienced from the local AM broadcast band, Amateur, or neighboring CB transmitters, particularly when there is no input filtering prior to amplification for the wideband case. Some improvement over present circuits can be obtained, however, by using active feedback traps for selected interference frequencies and higher power linear amplifiers for the active element. One goal is to achieve good performance from 10 kHz to 200 kHz where many of the present commercial active antennas fail to perform very well. The VLF region 10-14 kHz covering the worldwide long range Omega and Alpha navigation systems, 60 kHz WWVB and GBR time signals, and the 100 kHz LORAN-C navigation system are of interest to many Amateurs and longwave radio observers. These signals can provide very stable frequency standard references, solar activity indicators, and long range propagation data. The recent increased activity in the 160 to 190 kHz, or 1750 meter band, where 1 watt input to a 50-foot (15 meter) high antenna is allowed without license, and the use of this region for emergency government communications are of interest.

MOSFETs

Some practical details of small MOS-power FETs have been investigated with a view to application as sensitive E-field antenna preamplifiers. These are particularly useful at the VLF-LF region, where a short 1-meter whip can be made to perform as well as a much longer wire antenna. A short antenna such as a 1-meter length whip can be considered as a voltage source with a high internal impedance when coupled to a preamp input terminal. The effective source Z is equal to X_{CA}, where C_A is the antenna whip capacitance. A 1-meter whip will typically have a capacitance of 12 pF. This implies a very high input impedance preamplifier is needed, particularly at VLF-LF, where the concept is most useful. These systems are most often operated as impedance converters or voltage followers with nearly unity voltage gain. They have very high power gain in converting a signal at the high-Z source to a similar amplitude, only now at a 50- to 75-ohm receiver load.

JFET preamplifiers are most often found in consumer-grade active antenna systems where the input impedance is very high and especially where the input capacitance of the preamp system in parallel with the antenna is intended to be quite low. Capacitance at the input antenna mount and circuit will reduce the overall system gain by the resulting voltage division between the antenna and the fixed circuit input capacitance C_{IN}. **Figure 1** shows a test circuit that illustrates a way of evaluating the performance of a typical preamplifier using these parameters.

One of the common problems with all wideband active antenna systems is that of intermodulation distortion (IMD) caused by the inherent non-linearity of the preamplifier and the fact that little input filtering can be applied and still achieve a very wide bandwidth. Another problem is JFET burnout due to the relatively fragile character of the input gate structure. With these

By **R.W. Burhans,** 161 Grosvenor Street, Athens, Ohio 45701.

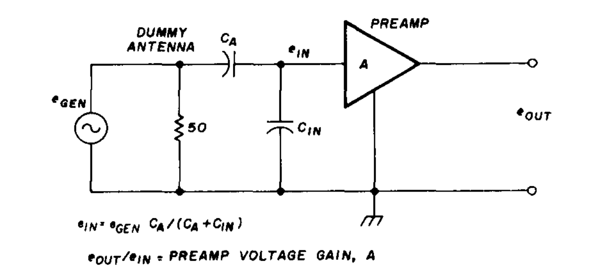

fig. 1. Test circuit.

facts in mind, MOS power FETs have been investigated as possible antenna preamplifiers. At first glance, the much higher input capacitance might appear to be a disadvantage, but more linear operating characteristics in the triode region, and much less tendency for gate punch-through or burnout, are of interest.

inductive feedback

A circuit that can reduce the input capacitance and improve the linearity for MOSFETs involves a "noiseless feedback" method. In this method, a portion of the drain signal is fed back either to the source or gate input via inductive transformer methods. Here the signal is fed back from drain to source with 180-degree phase reversal. The source winding feedback turns ratio determines the final output voltage gain. An experimental circuit is illustrated in **fig. 2**, where a trifilar wound toroid serves both as an output impedance matching transformer and feedback winding. As a practical matter, the greater the amount of feedback, the better the performance up to the point at which the overall circuit gain is reduced too much. With VN10KM or VN2222L VMOSFETs, the voltage gain is reduced to about −2 dB, with the FET input capacitance reduced to practical levels comparable to those of JFETs such as the J-310. **Table 1** illustrates the effects of changing the feedback winding turns ratio with respect to the output windings. The choice of a 1:1:1 ratio transformer gave the best performance in terms of minimum capacitance, gain compression level, and third order intercept as measured over the VLF-MF range from 10 kHz to 3 MHz. The 1:1 turns ratio part of the transformer used as the output provides a good match to the drain circuit of the VN2222L for a 50- to 75-ohm load at the receiver coupler. This circuit was designed originally for a maximum output level of 1V RMS or 20 mW at a 50-ohm level and actually achieved a performance of 50 mW or +17 dBm at the 1 dB gain compression level. **Figure 3** illustrates the IMD performance characteristics. This is as good or better than the performance of most presently available consumer-grade active antenna systems intended for wideband service.

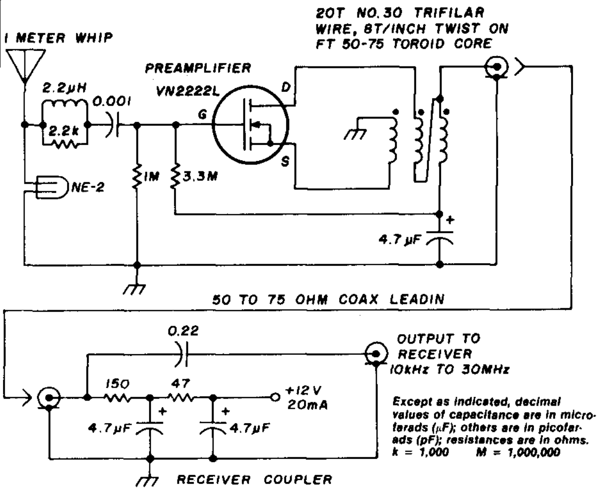

fig. 2. VLF-HF active antenna system.

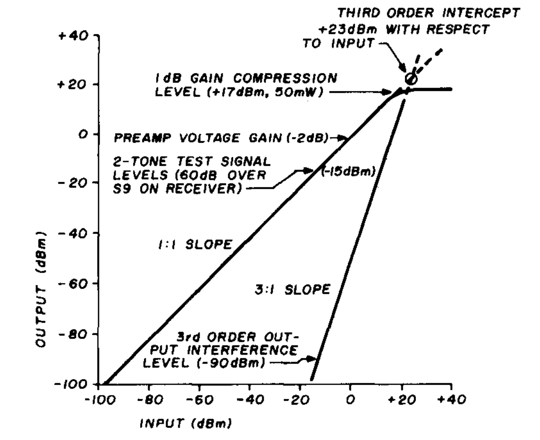

fig. 3. Wideband preamp performance.

Figure 4 illustrates the overall gain and phase shift for the circuit of **fig. 2**. The phase shift starting at 3 to 3.5 MHz is due to the combined effects of the length of cable connecting the coupler to the preamplifier and the output transformer resonance, where the core material tends to have less of an effect at HF. If the preamplifier is not well matched to the coupler or has excessive voltage gain, problems with spurious oscillations are sometimes noted with remote operated active antenna systems, where the total phase shift is a multiple of 2π. The very linear phase change from 10 kHz to 3 MHz for this example is useful in direction-finding applications where the signal from an E-field active antenna is combined with an H-field loop signal for a resulting cardioid directional pattern.

table 1. Feedback winding ratio effect on amplifier performance.

Feedback winding ratio (source)	Preamp voltage gain	Input capacitance (C)	E-Field attenuation (E)
0 (source ground)	+18dB	80pF	—
0.2	+10dB	70pF	—
0.4	+3dB	40pF	−16dB
1	−2dB	26pF	−18dB

sensitivity

An estimate of the antenna's sensitivity is obtained from the E-field attenuation factor noted in **table 1**. This is:

$$E_s\ (dB) = 20 \log 10\ \frac{e_{OUT}}{e_{IN}} \cdot \frac{1}{2}\ \frac{C_A}{C_A + C_{IN}} \quad \textbf{(1)}$$

where the factor 1/2 arises because of a given μV/m field gradient from top to bottom of a 1-meter whip. The potential developed at the preamp input terminal will be the average of the top-to-bottom field gradient. Thus the actual E-field intensity for a 1-meter whip may be estimated at the preamplifier output with a suitable calibrated receiver by applying this attenuation to the resulting signal level measured. However, such experiments are best conducted in a reasonably open area where the antenna is not obstructed by trees or nearby structures. The ultimate sensitivity of a short whip antenna such as this will depend on where it's placed with respect to the actual E-field in free space. These sensitivity numbers may appear somewhat low at the HF range compared to the antenna length, but at the VLF-LF receiving range, where large antennas are difficult or impractical to construct, this active antenna is very effective.

active notch

For severe cases of local interference due to medium wave broadcast band AM signals, an inductive feedback input trap or notch is very useful. A circuit is illustrated in **fig. 5**, which shows a tunable transformer that provides the input inductor with a feedback winding. Without feedback or with the output source winding transformer grounded, high impedance input traps like this have a very annoying peaking effect. This results from the fact that the input source impedance varies inversely with frequency, producing both resonances for these high-Z input systems. Feedback from the source winding to the series trap small coupling winding eliminates the peaking effect. Old timers may recall a related circuit with a small feedback winding used to neutralize tuned-grid, tuned-plate, single vacuum tube triode power amplifiers. The feedback

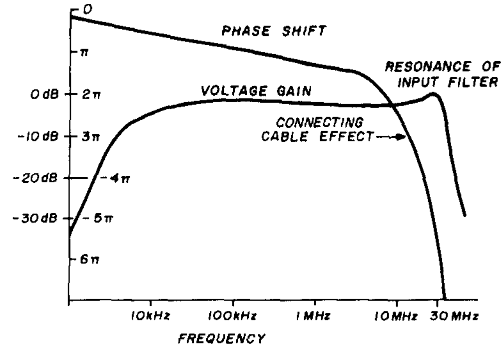

fig. 4. VN2222L antenna preamplifier.

turns ratio for the trap is very small and not critical. That is, a turns ratio of 1:10 to 1:25 will largely eliminate the peaking effect of a high-Z input trap. In choosing trap inductances, the parallel capacitor across the main series inductor (47 pF for the example of **fig. 5**) acts like an additional series capacitor at frequencies well above the notch frequency. Thus a trap of this type will always have some attenuation above the resonant notch frequency compared to the passband below the notch. For a lowpass effect, the inductor is chosen so as to be nearly self resonant and with highest possible Q, with minimum parallel capacitance. In the practical case, most all of these relatively high impedance inductors will have some distributed capacitance, which always results in some signal response above the trap frequency.

In very troublesome cases, several traps connected in series can be effective in providing a rejection filter for much of the AM broadcast band. **Figure 6** illustrates a short whip antenna system for the San Jose, California, area, where there are interference sources on frequencies 1170, 1370, 1430, 1500 and 1590 kHz. In this example the output transformer is an iron core unit normally used at audio frequencies, but which will also operate with a gradual rolloff through the 1 MHz region. The source feedback winding to the input series traps has a lower turns ratio than the examples shown in **figs. 2** and **5**, but still provides quite satisfactory gain and response for operation in the VLF-LF band.

Dual traps can also be effective for the wideband case, where the input trap is tuned to some frequency in the 1 MHz AM broadcast range and the second trap is self-resonant at a cutoff range such as 35 MHz. For this example, the output transformer should be a wideband toroid with a 0.5:1:1 or 1:1:1 turns ratio. In this case, the input trap should have a low reactance at 1 MHz, with a resonating capacitor of 100 pF or more so that the response in the passband above 1 MHz is down only −3 dB or so. In most cases with two or

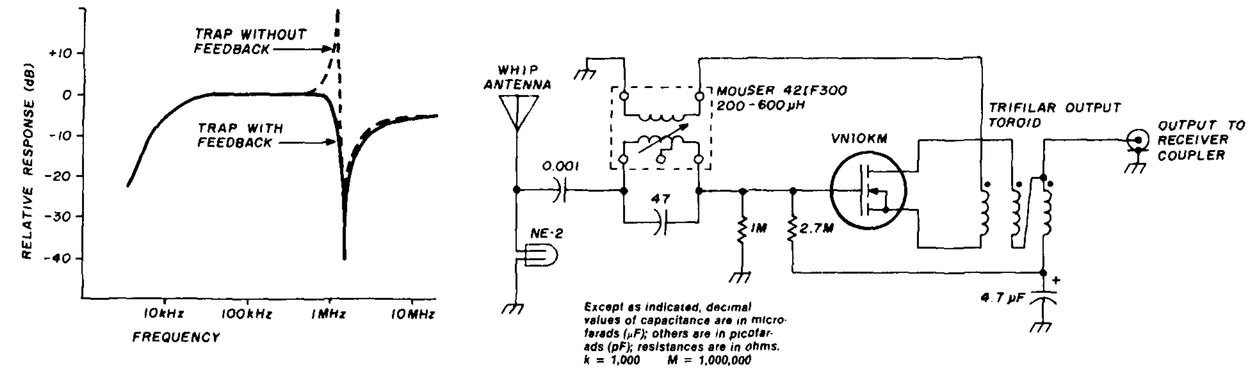

fig. 5. Noiseless feedback and input interference trap.

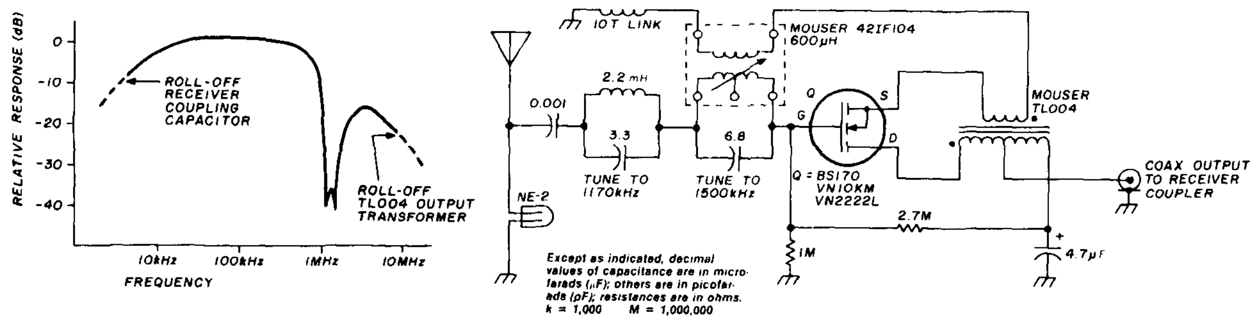

fig. 6. Power MOSFET active VLF-LF antenna with feedback traps.

more traps, the input resonator should be tuned to the lowest notch frequency with the second and succeeding traps tuned to the higher frequencies.

other applications

Another example of the utility of the noiseless feedback method is a broadband low impedance amplifier fabricated from off-the-shelf components covering the 10 kHz to 1 MHz region. The Mouser TL004 iron core transformers are used for both input and output coupling by rearranging the windings to approximate the turns ratios required for operation. A true noiseless feedback amplifier might use an alternate input transformer toroid wound as in the example of **fig. 7**. However, the TL004 iron core transformer can serve as a reasonable substitute with somewhat less power gain because of reduced turns ratios for the feedback and coupling. A proposed application of this circuit might be for a VLF-LF ferrite core loop antenna where the loop windings (N2-N3 only) substitute for the input transformer.

MOSFET selection

Several different power MOSFETs including the VN10KM, IRFDZ13, BS170, 2N7000, and VN2222L have been evaluated for these applications. One problem, however, is that they require different gate bias voltages that vary from +2 to +4 volts. The 1 megohm — 2.7 megohm voltage divider may require changing for optimum linear operation. Thus the 2N7000 series operates better with a 1 megohm — 1.5 megohm divider, producing a bias of about +3V. We have also noted that different batches of the same transistor type may have a different optimum gate bias. These power MOSFETs are designed primarily for switching service applications, but they are also generally more linear in the triode region than many zero-gate bias JFETs. The power MOSFET field has changed so rapidly over the last five years that 3rd generation types are now being introduced with still different properties. Linear circuit applications of this type are not often found in the manufacturers' literature because of the present emphasis on digital applications.

inductors

Input inductors and TL004 output transformers are available from Mouser Electronics, 1143 Woodside

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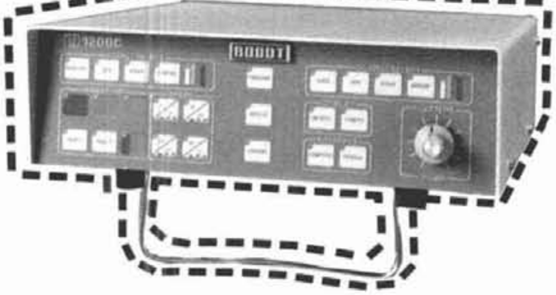

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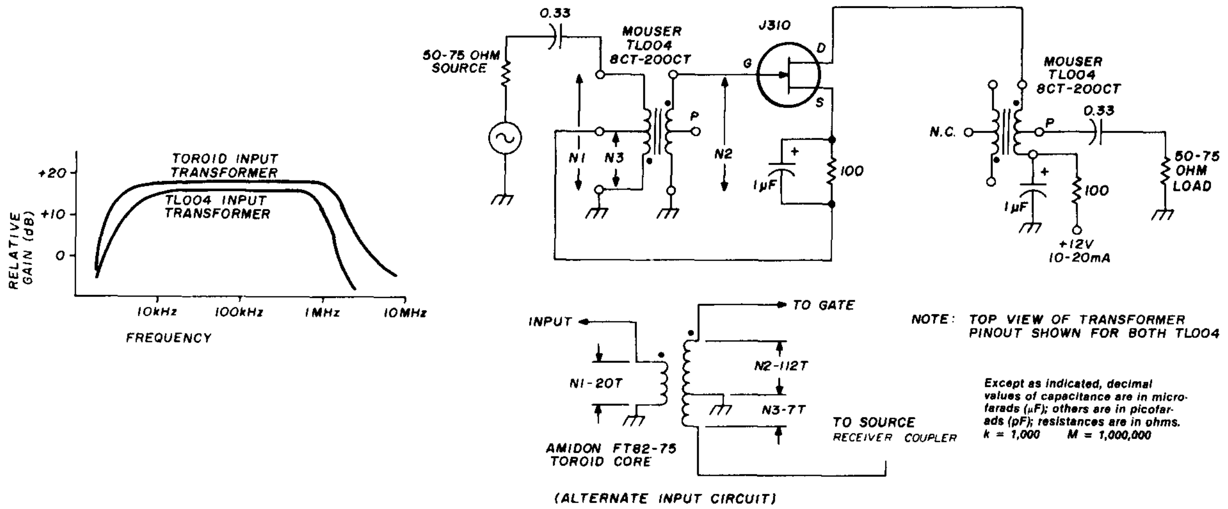

fig. 7. VHF-LF utility amplifier with noiseless feedback input method.

table 2. Series filter resonance of readily available inductors.

Mouser Part No.	Nominal Inductance (mH)	Self-Resonant Frequency (kHz)	Resonance with 10pF added (kHz)	Inductor distributed capacitance
43LJ368	68	174	134	12pF
43LH333	33	335	221	6.8pF
1120-104k	10	588	388	7.3pF
43LH268	6.8	845	516	5.2pF
1120-393k	3.9	885	614	8.2pF
1120-223k	2.2	1460	900	5.5pF
43LH215	1.5	1510	1007	7.3pF
421F104	900µH	2370	1334	5.0pF

Avenue, Santee, California 92071. The 43LHXXX series inductors are encapsulated types with values ranging from 1 mH to 33 mH. The input transformer 421F300 is a variable cup-core type with an inductance range of about 250 to 600 µH and a turns ratio of 12:1. The 421F104 has an inductive range of 500 to 1000 µH and a turns ratio of 22:1. These IF transformers are normally used in AM broadcast band radios but provide very satisfactory traps with the circuits illustrated. For the lower frequencies — below about 800 kHz and where a maximum lowpass effect is desired — as well as the tuned trap frequency, the LH series inductors are wound with a small coupling coil as illustrated in **fig. 8**. The polarity of the coupling is important. The circuits will oscillate with the wrong polarity of the feedback coupling of this neutralizing winding. If other inductors or transformers are substituted, a bench check for proper operation should be conducted using the input test circuit of **fig. 1**.

Table 2, lists the results of a series of measurements of these inductors used to select values suitable for traps in the AM broadcast band and part of the LF beacon band. For the best lowpass effect, the total tuning capacitance across the inductor should be kept to a minimum. The table illustrates the resonant frequencies with the coil only and with an additional 10 pF tuning capacitance. For the best lowpass effect with minimum response above the trap frequency, make the trap tuning capacitance equal to or less than the input antenna capacitance. Conversely, for the best bandpass effect, the trap tuning capacitance should be four to ten times larger than the input antenna capacitance so that the attenuation above the trap frequency is minimized.

future developments

Other experiments indicate that the feedback technique can be used with shunt as well as series inductors to eliminate the undesired peaking effect for highpass filters or traps. For future high impedance filter designs with multiple inductors, analytical methods similar to elliptic filters might be possible using these

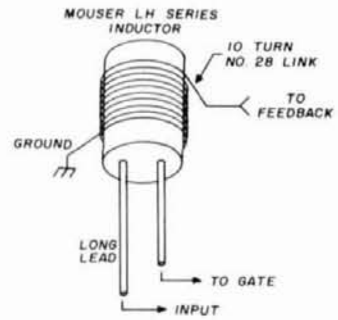

fig. 8. Winding polarity for input trap inductors.

feedback neutralizing methods of each inductor in the circuit. Perhaps a new class of high input impedance filters could be developed in which the input source impedance would vary inversely with frequency and an active feedback technique would be used to neutralize the undesired responses.

In pursuit of these ideas, the experimenter should keep in mind that all inductors have distributed capacitance which then becomes a much more critical circuit parameter. For highpass shunt filters, the active feedback polarity is reversed from the series and lowpass filters, for peaking effect reduction. Another important consideration is the filter layout where mutual coupling between two or more adjacent inductors can enhance or deteriorate a given filter performance. Close shielding of the small encapsulated type of inductors usually increases the self resonant frequency and decreases the Q because of the shorted-turns effect on the outer windings of the inductor. Combinations of feedback neutralized inductors or traps with un-neutralized resonators results in additional variety of bandpass or bandreject filters for use directly at the input from a high impedance source or antenna system.

circuit boards

For a list of experimental circuit boards and related products for these preamplifier systems, send an SASE to Burhans Electronics, 161 Grosvenor St. Athens, Ohio 45701

acknowledgements

The use of spectrum analyzer and signal generator hardware from the Avionics Enginneering Center of Ohio University in Athens, Ohio during the tests on these experimental circuits is greatly appreciated. Operational tests on several of the circuits in interference environments by Mitchell Lee, KB6FPW, have been of considerable help in improving the circuit designs.

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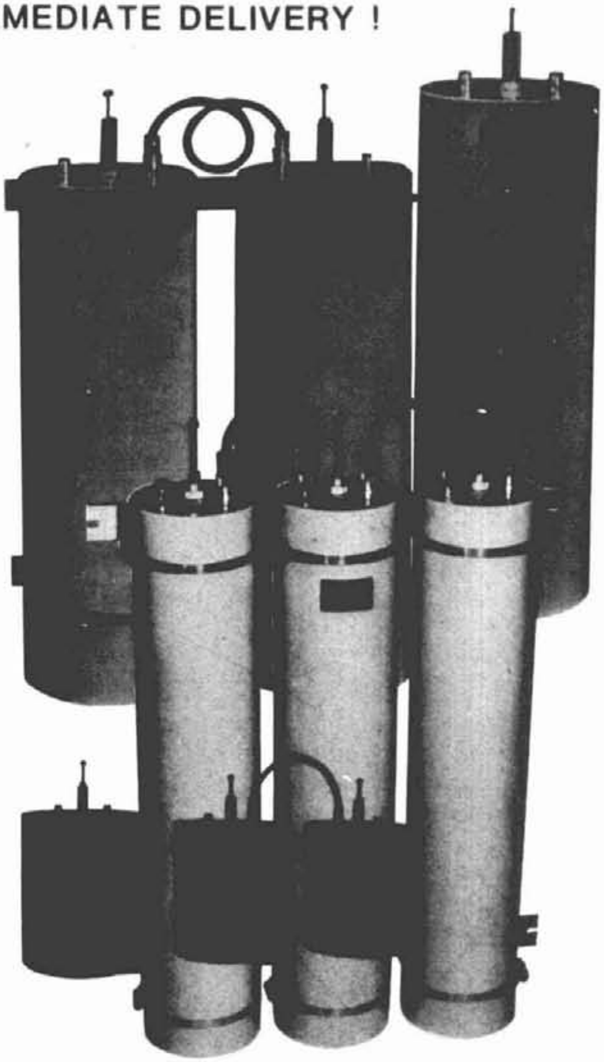

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196

the W2PV 80-meter quad

Design notes for a 2-element parasitic delta loop

I've been searching for a way to improve my 80-meter antenna system for several years. Along the way I acquired (from Fred Lass, K2TR) the switching system for the late Jim Lawson's two-element delta loop array. Fred also sent me a copy of Jim's engineering notes, which describe the evolution of his design over the summer of 1978. Although these notes do not define all of the antenna design parameters — particularly loop circumference and spacing — I've been able to put together a fairly complete picture of Jim's antenna system.

system description

"Quad" is a convenient misnomer; the antenna system is actually a two-element parasitic array. Each element is a nearly one-wavelength equilateral triangular loop, with one vertex (the feedpoint) at the top.

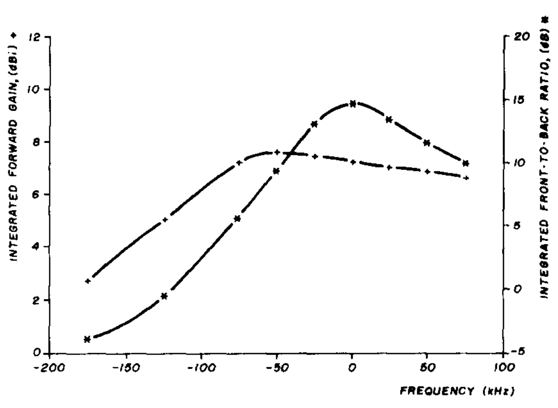

fig. 1. Performance versus relative frequency.

The loops are identical to permit convenient direction switching. The parasitic element is "tuned" to look like a reflector by shunting the feedpoint with an inductance. This arrangement provides very good gain, broad unidirectional main lobe, and moderate front-to-back (F/B) ratio, with reasonable bandwidth. Performance is not too sensitive to spacing and height, so the operating frequency can be moved from the phone band to the CW band by adding inductance in series with the loops. The array radiation resistance is quite high (near 100 ohms) so that losses in air-wound coils are negligible.

There are two principal parameters to be specified for the two-element array: the loop perimeter and the parasitic tuning inductance. W2PV selected values for these parameters through a combination of experimentation and computer analysis. His gôal was to produce a resonant antenna system at the central operating frequency, with a peak in the F/B ratio versus frequency curve also at the central operating frequency. As nearly as I can infer from the notes, the loop perimeter was 254 feet (77 meters) and the reflector inductor was 4 microhenries. These parameters apply specifically to loops with apex at 152 feet (46 meters), spaced 40 feet (12 meters) apart.

gain and radiation pattern

I've modeled this antenna using the MININEC program. **Figure 1** shows the integrated gain versus frequency for fair ground. "Integrated gain" is the average value of the gain over all angles from zenith to horizon in the vertical plane containing the boom. "Integrated F/B" is the ratio of the integrated backward gain to the integrated forward gain. I believe this provides a more useful representation of antenna performance on 80 meters, where the wave angles of interest span a very large range. Note that the direc-

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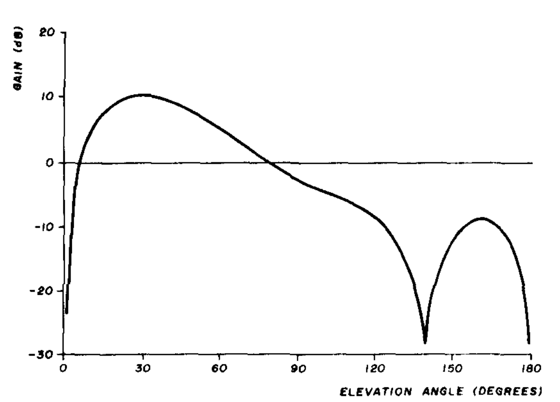

fig. 2. H-plane radiation pattern.

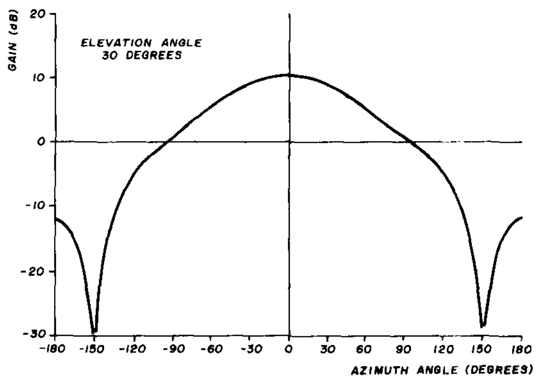

fig. 3. E-plane radiation pattern.

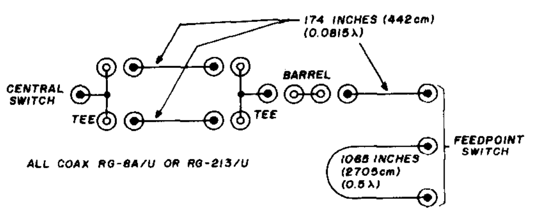

fig. 4. Coaxial matching sections.

tion of maximum gain reverses about 125 kHz below the central operating frequency, where the reflector begins to act as a director. (MININEC seems to produce reasonable radiation pattern predictions for loops, but centered at obviously wrong frequencies, so I left the center frequency undefined in **fig. 1**. Also, the MININEC predictions of input impedance are unreliable, but that's another story.)

The maximum peak gain is 11.2 dBi, 50 kHz below the center frequency. The peak gain at the center frequency is 10.8 dBi at an elevation angle of 30 degrees. These gains compare well with a rough estimate of potential gain: 3 dBi loop gain + 4 dB array gain + 6 dB ground reflection gain = 13 dBi.

Figures 2 and **3** show the H-plane and E-plane radiation patterns at the center frequency. Note that you could claim a very large F/B ratio by selecting 40 degrees and 140 degrees as the forward and backward elevation angles. The fat H-plane forward lobe provides good coverage of DX path wave angles, but less satisfactory coverage for the very high-angle (close-in) paths. The broad azimuth pattern is important because the antenna system is difficult to rotate.

matching system

The input resistance of the driven loop, at the central operating frequency, is about 100 ohms. Initially, Jim used a multi-impedance tapped balun to match this to a 50-ohm transmission line. After exhaustive tests, he concluded that this balun was not suitable and changed to the matching system shown in **fig. 4**. The half-wave balun at the feedpoint converts the 100-ohm input resistance to 25 ohms. The series-section transformer then converts 25 ohms to 50 ohms. All of these transformer sections are made of RG-8 (or RG-213) coax and are cut for 3.65 MHz. W2PV calculated the effect of the error in transformer lengths when operated at 3.5 and 3.8 MHz and decided that the consequent mismatch was unimportant. These length errors do *not* affect the array per-

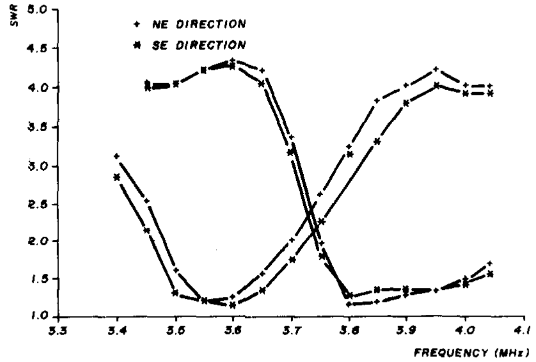

fig. 5. Measured standing wave ratio.

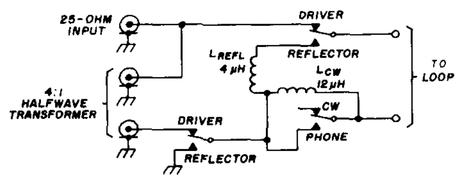

fig. 6. Feedpoint switch.

formance, since the transformers are not part of a phasing system. The SWR data measured by W2PV is plotted in **fig. 5**; note the excellent bandwidth between the 2:1 points.

The central operating frequency is shifted down to 3.5 MHz by adding inductive reactance to both loops. Since the direction switching requires a relay box at each loop feedpoint, it's convenient to include the mode-switching relay in the same box (**fig. 6**). The complete antenna system has three relay boxes; the central box is simply a single-pole, double-throw switch that connects the main feedline to one or the other of the two loops. W2PV arranged his relay controls so that the default (i.e., no power) condition was NE/phone (with the boom running NE/SW).

closing remarks

This summer I plan to install a version of this antenna at 115 feet (35 meters) on a new tower. In addition to W2PV's parasitic arrangement, I plan to provide for feeding both loops out of phase, which yields a bidirectional pattern. The advantages of this feed are overall simplicity and small high-angle lobes. The disadvantages are somewhat lower gain and lower input resistance. If I don't knock the tower over as I cut down trees, I'll let you know how it works.

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the colagi™* antenna

Improve gain, pattern by combining collinear and Yagi designs

One of the most important parts of a communications system is the antenna. Additional gain in an antenna will improve both transmit and receive capability. Combining the gain available from a collinear with the gain of a Yagi yields a high-gain antenna with only short boom requirements.

Omni vertical collinear antennas used by FM repeaters achieve gain by vertically stacking in-phase dipoles (E-plane stack). Yagi antennas achieve gain in both E and H planes through the use of resonant parasitic elements. For Yagis with booms less than one wavelength long, almost all the gain is achieved in the H-plane. **Figure 1** shows the rate of gain improvement for both E and H plane of Yagi antennas with up to 20 dBi directive gain. As can be seen, a 3 dB improvement in the E-plane is not achieved until a total Yagi gain of approximately 16 dBi is reached.

A dipole has 2.15 dB gain over an isotropic source. All this gain is in the E-plane; the H-plane is still omni, or 360 degrees.

A three-element Yagi's −3 dB E-plane beamwidth is approximately 65 degrees, and its −3 dB H-plane beamwidth is approximately 90 degrees.

Gain improvement in the E-plane is:

$$10\ LOG\left\{\frac{78^\circ\ (dipole\ -3\ dB\ BW)}{65^\circ}\right\} = +0.79\ dBd$$

Gain improvement in the H-plane is:

$$10\ LOG\left\{\frac{360^\circ\ (omni)}{90^\circ}\right\} = +6.0\ dBd$$

Total Yagi gain is: 6.79 dBd (E and H plane gain).

* "Colagi" is a registered trademark of Sinclair Radio Laboratories.

If the collinear method of achieving gain in the E-plane could be combined with the Yagi's method of achieving gain in the H-plane, then the results would be rewarding. The broadside collinear "bedsprings" antenna shown in **fig. 2** does just this. The driven element is a pair of half-wave resonant dipoles (fed on the ends for high impedance) spaced a half wave apart (center to center) to achieve 2.4 dBd gain. This type of antenna achieves most of its gain in the H-plane by stacking. For those stations active on several bands and using horizontal polarization, the broadside collinear antenna takes up valuable mast space which may limit the size and number of antennas used on the other bands. A collinear radiator plus a Yagi-type parasitic antenna system seems a logical solution — thus, a collinear Yagi, or "Colagi."

Figure 3 shows the feed for a three-wide Colagi. Each of the three half-wave dipoles is in phase since the delay through the phasing network is a half-wave (180 degrees). The $0.83\lambda_0$ dipole-to-dipole center is determined by the phasing sections. This section is a coaxial line which is dielectrically loaded with polyethylene. Its 180 degree electrical length is:

$$0.659 \cdot \frac{\lambda_o}{2} \cong 0.33\lambda_o$$

physically, so the outer conductor is basically non-resonant at the design frequency.

If teflon dielectric were used, the physical length would be:

$$0.695 \cdot \frac{\lambda_o}{2} \cong 0.35\lambda_o$$

If air-spaced polyethylene were used, the physical length would be:

$$0.82 \cdot \frac{\lambda_o}{2} = 0.41\lambda_o$$

By Bob Morton, VE3BFM, P.O. Box 481, Gormley, Ontario, Canada L0H 1G0

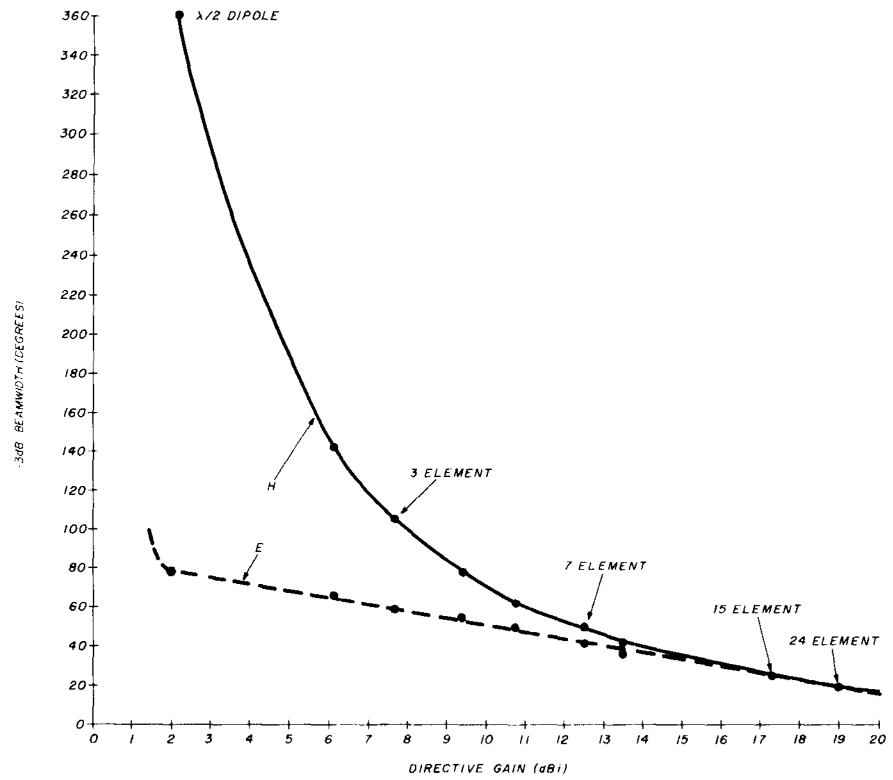

fig. 1. Dipole through 24 element Yagi −3dB beamwidth vs. directive gain.

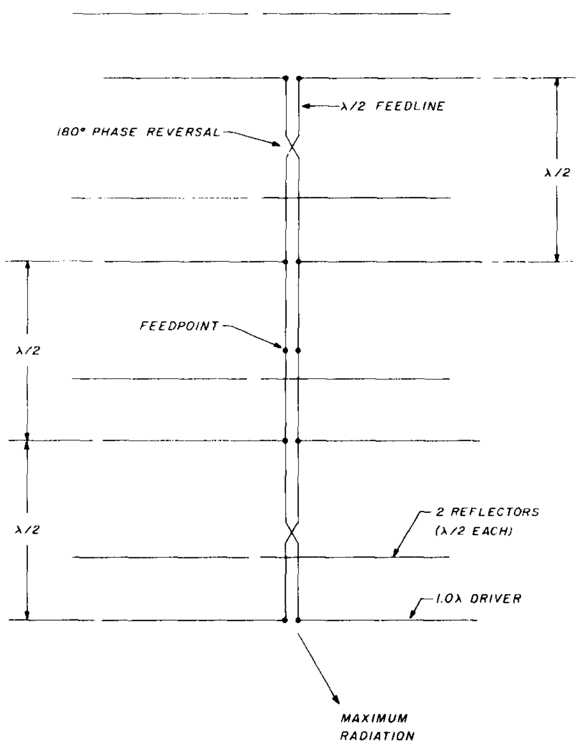

fig. 2. 16-element broadside collinear array "bedsprings."

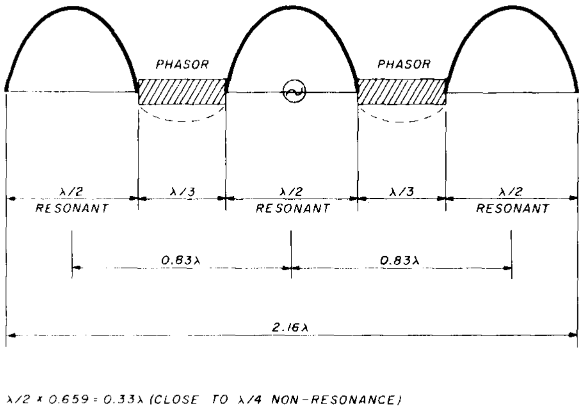

fig. 3. Current distribution for a 3-wide Colagi feed.

This length is now approaching resonance; out-of-phase radiation will occur, causing pattern distortion and reduced gain.

If the basic collinear feed (**fig. 3**) is now backed up by three separate reflectors and three equal sets of directors, a high gain antenna will be produced.

Figure 4 shows a basic seven-element Yagi using a conventional half-wave dipole feed system. E and

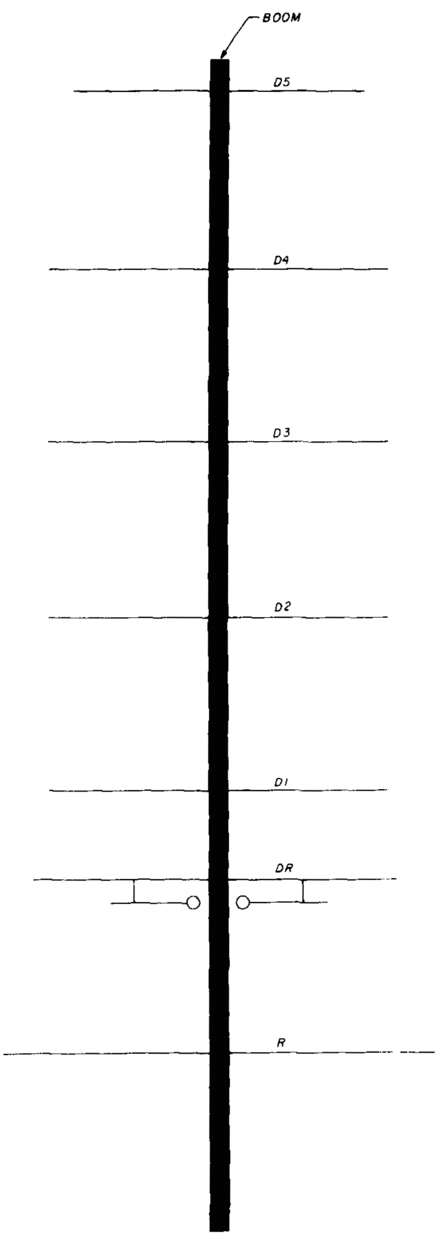

fig. 4. 7-element Yagi.

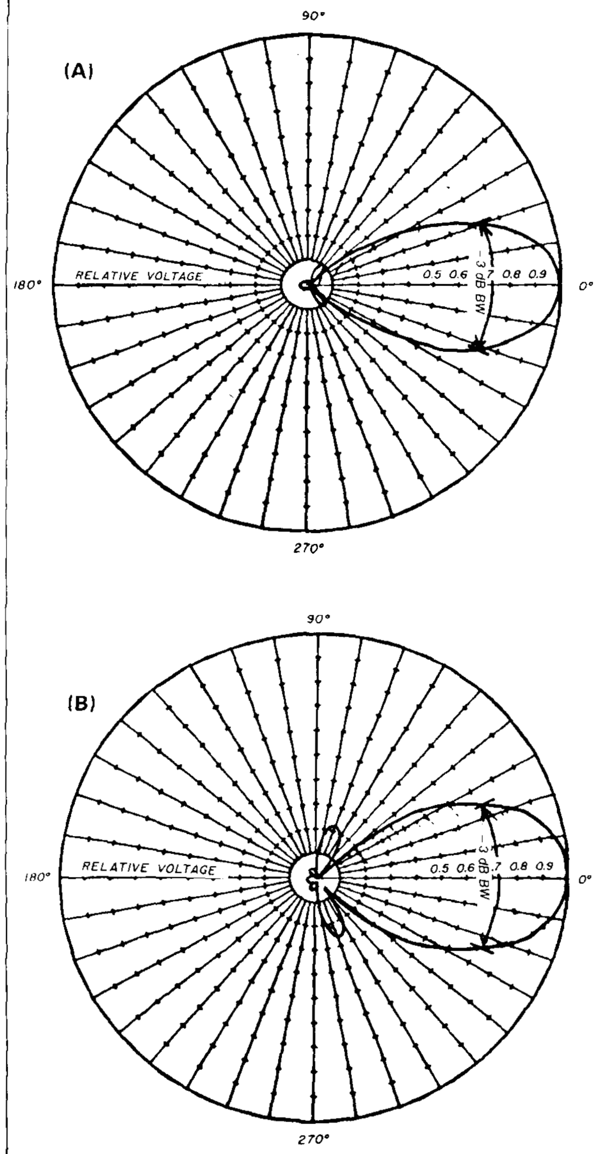

fig. 5. Seven-element Yagi −3 dB beamwidths
A) E-plane — 42 degrees.
B) H-plane — 46 degrees.

H patterns for this Yagi are shown in **fig. 5**. E-plane −3 dB beamwidth is 42 degrees and H-plane −3 dB beamwidth is 46 degrees. Gain is:

$$10\ LOG \left\{ \frac{32{,}000}{42 \cdot 46} \right\} - 2.15 = 10.04\ dBd$$

If this Yagi is made into a Colagi (**fig. 6**), the H-plane −3 dB beamwidth remains the same at 46 degrees. However, the E-plane −3 dB beamwidth now becomes 20 degrees. Gain now is

$$10\ LOG \left\{ \frac{32{,}000}{20 \cdot 46} \right\} - 2.15 = 13.26\ dBd$$

stacking separate Yagis does not yield same improvements

The same pattern could have been achieved by stacking three separate Yagis at $0.83\lambda_0$ apart in the E-plane. The disadvantage of stacking is loss in the coax and loss in the impedance matching section for the three antennas. The Colagi eliminates these particular losses. A gain improvement of 3.3 dB has been achieved and only a single feedpoint and signal boom have been used.

Figure 7 shows the array factor curve[1] for three antennas stacked at $0.83\lambda_0$. The array factor in this

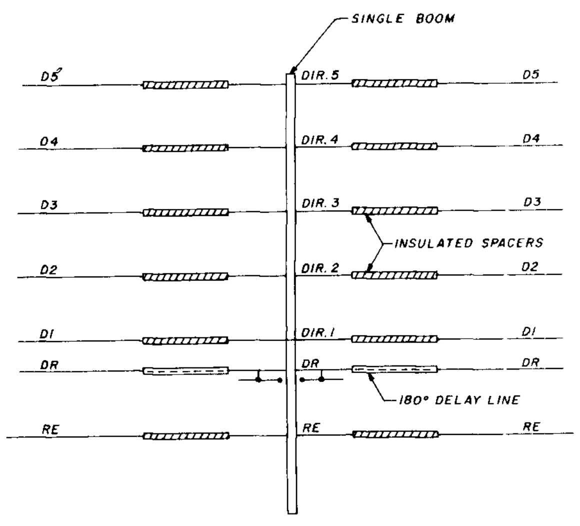

fig. 6. 3-wide Colagi.

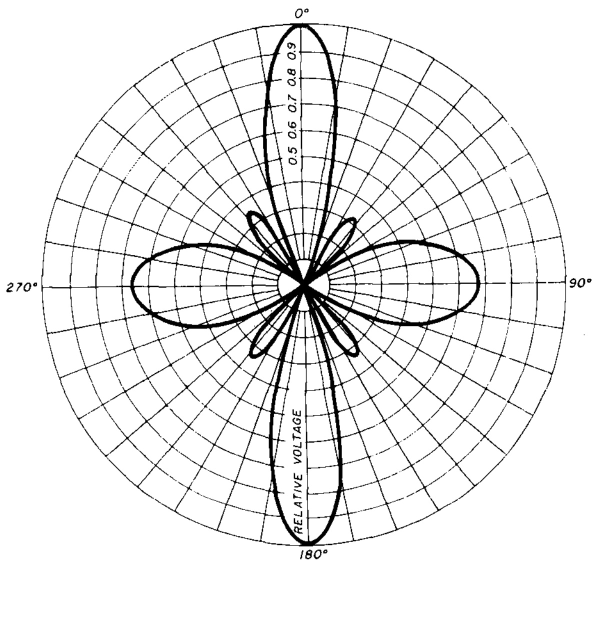

fig. 7. Array factor curve for three antennas stacked at 0.83 λ_0 spacing.

case is the resultant pattern produced by three in-line isotropic radiators of equal amplitude and phase. If this pattern is overlaid on the E-pattern of the original seven-element Yagi, the product of the two patterns will yield the resultant Colagi pattern (for the seven-element long Yagi).

The delay line phasing section is the limiting factor in determining the space between the "individual Yagis" of the Colagi.

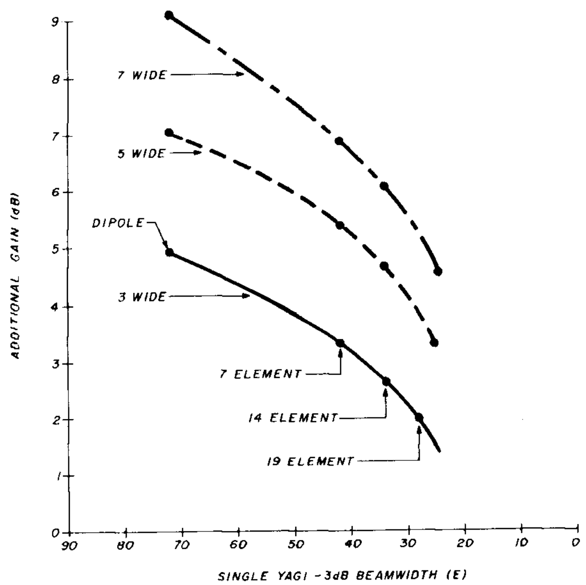

fig. 8. Gain improvement of Colagi over conventional Yagi.

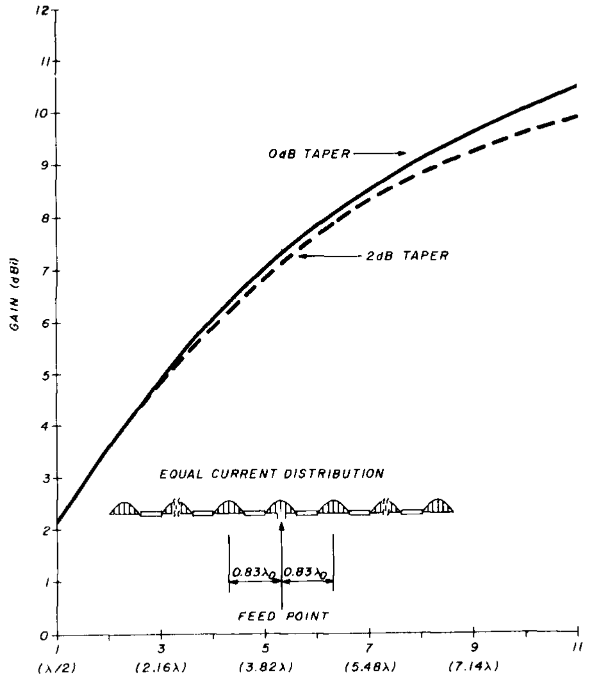

fig. 9. Gain of center fed collinear array of dipoles spaced 0.83 λ_0 with 0dB and 2dB power taper per radiating dipole.

On long-boom Yagis, the E and H patterns are approximately equal. As gain increases, the beamwidths decrease. In order to realize stacking gains, the

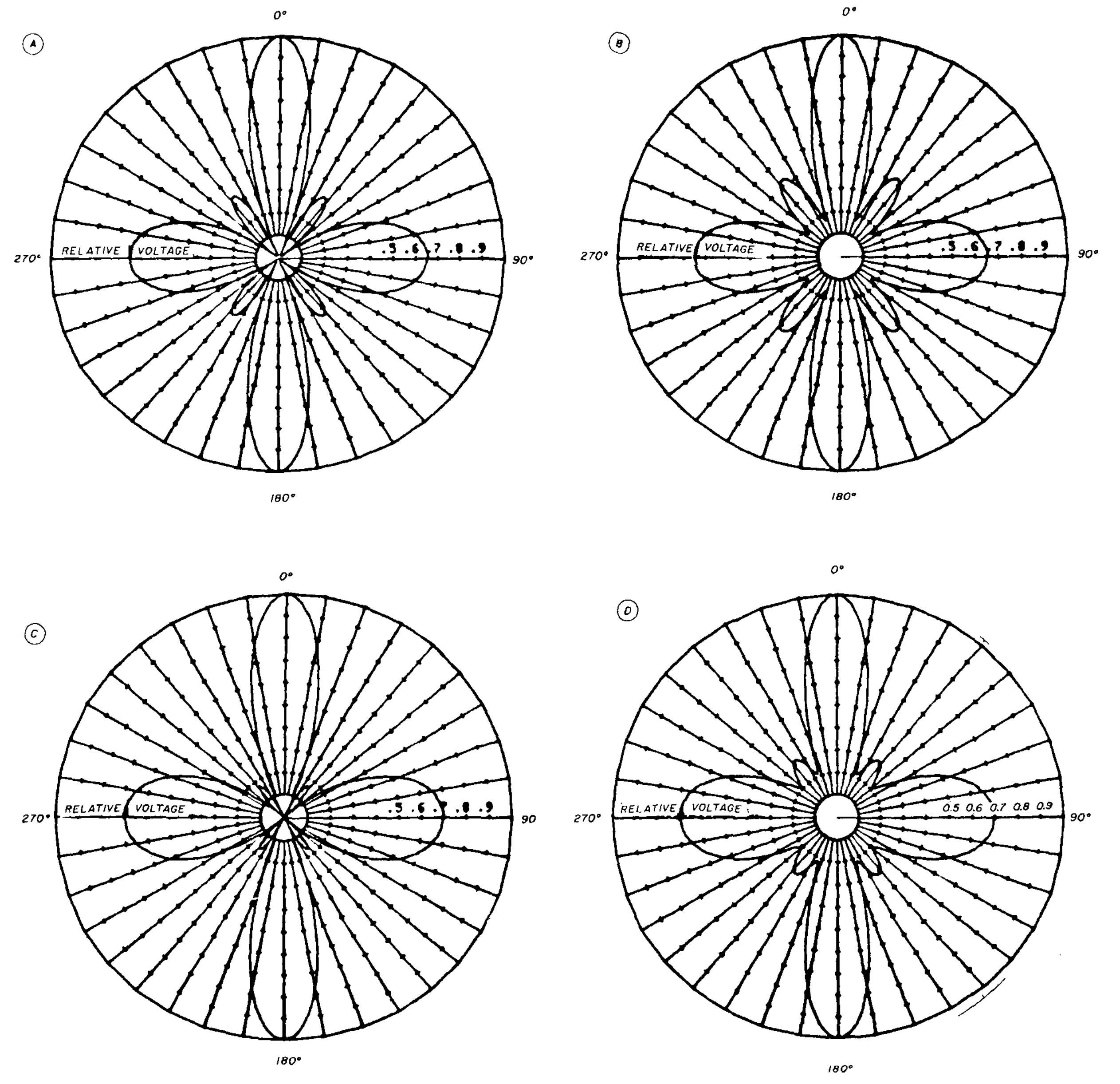

fig. 10. Phase error and power distribution affect on pattern: A) 0dB power taper and 0°, 0°, 0°, phasing. B) 0dB power taper and 30°, 0°, 30°, phasing. C) 3dB power taper and 0°, 0°, 0°, phasing. D) 3dB power taper and 30°, 0°, 30°, phasing.

spacing betwen Yagis must also increase. Using a Colagi type feed system, the spacing is fixed at $0.83\lambda_0$; therefore, an understacking effect occurs on long Yagis and all the gain available is not achieved.

The collinear feed system can be extended to five, seven, nine, . . . dipoles by increasing the number of parasitic elements accordingly.

Figure 8 shows the gain improvements to be expected for three, five, and seven-wide Colagis, based on knowing the −3 dB beamwidth in the E-plane for the single Yagi. For example, a Yagi with a 28-degree beamwidth, made into a three-wide Colagi, would see a gain improvement of only 2.0 dB, while a Yagi with a −3 dB beamwidth of 42 degrees *will* see a gain improvement of 3.3 dB.

unequal dipole feed reduces sidelobes

Since some power is radiated from the center dipole of a Colagi feed, there is not an equal amount left to be radiated by the other dipoles. **Figure 9** shows the gain to be expected from a center-fed collinear feed with a zero dB taper (all radiators equal in power) plus

the gain expected if a 2 dB power taper is used. On an 11-element center-fed collinear, if the center dipole power is used as a reference, then the outermost two dipoles will be 10 dB down in power. That's terrible! Right? Well, not really. The difference in gain between this condition and that with all dipole powers the same is only 0.5 dB. A slight widening of the main beam occurs when a power taper exists, but a big plus is in the reduction of the sidelobes. A very clean radiation pattern is produced. For weak signal work, having very low sidelobes is a real advantage, especially in EME work. The sky is full of noise sources and noise is additive, so why take chances with high sidelobes? A collinear fed Yagi or the Colagi is a natural for clean E-patterns.

reduced phase error pattern distortion

What about phasing errors? **Figure 10** shows the Colagi array factors:

(A) 0 dB power taper and 0°, 0°, 0°, phasing.
(B) 0 dB power taper and 30°, 0°, 30°, phasing.
(C) 3 dB power taper and 0°, 0°, 0°, phasing.
(D) 3 dB power taper and 30°, 0°, 30°, phasing.

A phasing error of 30 degrees, which would be very bad on a conventional two-Yagi stack, has virtually no effect on the resulting pattern of a Colagi with a 3 dB power taper.

By making the Yagi into a Colagi, the E-plane pattern is about 20 degrees or less for any Yagi of three elements or more. The H-plane has not been changed. Conventional stacking will approximately halve this pattern's −3 dB beamwidth each time the number of Colagis (or Yagis) is doubled. A ten-element Yagi (or Colagi) with a −3 dB beamwidth of 38 degrees in the H-plane when stacked four high will have approximately a 10 degree −3 dB beamwidth. Made into a three-wide Colagi, this array will have a gain of:

$$10\ LOG \left| \frac{32{,}000}{18 \cdot 10} \right| - 2.15 = 20.3\ dBd$$

On the 2-meter band, this gain is sufficient to hear EME echoes from a 500-watt transmitter.

A "first-level" Colagi (three-wide) on 2 meters is almost as wide as a 10-meter beam. A "first-level" Colagi on 70 cm is about 60 inches wide.

Expanding to a "second-level" Colagi (five-wide) or a "third-level" Colagi (seven-wide) continues to sharpen the E-plane pattern. For the seven-wide and up, the −3 dB beamwidth is basically the −3 dB beamwidth of the array factor. Once the Colagi is expanded to this level, the effect of adding directors does very little to the E-plane pattern. A set of reflectors behind each half-wave dipole is all that is required. However, the H-plane pattern does benefit from the addition of directors, as seen in **fig. 1**, and each builder must decide how many directors (and how long) to make the antenna.

Optimum stacking of two three-wide Colagis in the E-plane is $2.5\lambda_0$. This will give −14 dB sidelobes if a seven-element long Yagi is used as the starting point. The −3 dB beamwidth is approximately 10 degrees.

Making a seven-wide Colagi will also yield a −3dB beamwidth of approximately 10 degrees. On 432 MHz this width is 12.5 feet (3.8 meters); on 1296 MHz the width is just over 4 feet (1.22 meters). Mechanical considerations dictate just how far this type of antenna can be expanded.

At antenna measuring contests, a "figure-of-merit" is used to determine gain density. It is simply the physical dimensions of the Yagi divided into the measured gain of the antenna. My three-wide, seven-element long Colagi placed first on 1296 MHz at Dayton in 1984.

The groundwork for the Colagi is now complete. Although construction techniques will vary and final combinations will differ, all results should be rewarding.

Extra antenna gain is always desired in weak signal work. The Colagi approach might be the answer.

references

1. John D. Kraus, Ph.D., *Antennas*, McGraw Hill Book Company Incorporated, 1950, References, Appendix 17.

ham radio

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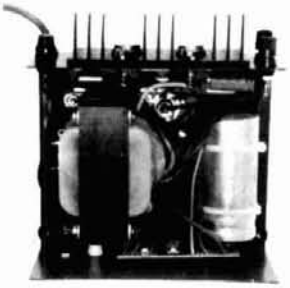

INSIDE VIEW — RS-12A

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SPECIAL FEATURES

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MODEL RM-35A

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Model	Continuous Duty (AMPS)	ICS* (AMPS)	Size (IN) HXWXD	Shipping Wt. (lbs.)
RM-35A	25	35	5¼ × 19 × 12½	38
RM-50A	37	50	5¼ × 19 × 12½	50

• Separate Volt and Amp Meters

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RM-50M	37	50	5¼ × 19 × 12½	50

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MODEL RS-7A

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H x W X D	Shipping Wt (lbs)
RS-4A	3	4	3¾ x 6½ x 9	5
RS-7A	5	7	3¾ x 6½ x 9	9
RS-7B	5	7	4 x 7½ x 10¾	10
RS-10A	7.5	10	4 x 7½ x 10¾	11
RS-12A	9	12	4½ x 8 x 9	13
RS-20A	16	20	5 x 9 x 10½	18
RS-35A	25	35	5 x 11 x 11	27
RS-50A	37	50	6 x 13¾ x 11	46

RS-M SERIES

MODEL RS-35M

• Switchable volt and Amp meter

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H x W x D	Shipping Wt (lbs)
RS-12M	9	12	4½ x 8 x 9	13
RS-20M	16	20	5 x 9 x 10½	18
RS-35M	25	35	5 x 11 x 11	27
RS-50M	37	50	6 x 13¾ x 11	46

VS-M SERIES

MODEL VS-20M

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

MODEL	Continuous Duty (Amps) @13.8VDC	@10VDC	@5VDC	ICS* (Amps) @13.8V	Size (IN) H x W x D	Shipping Wt (lbs)
VS-20M	16	9	4	20	5 x 9 x 10½	20
VS-35M	25	15	7	35	5 x 11 x 11	29
VS-50M	37	22	10	50	6 x 13¾ x 11	46

RS-S SERIES

MODEL RS-12S

• Built in speaker

MODEL	Continous Duty (Amps)	ICS* Amps	Size (IN) H x W x D	Shipping Wt (lbs)
RS-7S	5	7	4 x 7½ x 10¾	10
RS-10S	7.5	10	4 x 7½ x 10¾	12
RS-10L(For LTR)	7.5	10	4 x 9 x 13	13
RS-12S	9	12	4½ x 8 x 9	13
RS-20S	16	20	5 x 9 x 10½	18

PRACTICALLY SPEAKING ... Joe Carr K4IPV

using the antenna noise bridge

One of the most useful, inexpensive, and often overlooked test instruments is the antenna noise bridge. Over the years I've found it to be particularly useful for a variety of test and measurement applications, especially in the HF region, and those applications are not limited to the testing of antennas, which is the main job of the noise bridge. Several companies (Omega-T, Palomar Engineers, M.F.J., etc.) have produced versions of this instrument. Recently, Heath added its new Model HD-1422 (**fig. 1**) to their line-up.

Figure 2 shows a block diagram of this instrument. The bridge consists of four arms. The inductive arms (L1b and L1c) form a trifilar wound transformer over a ferrite core with L1a, so signal applied to L1a is injected into the bridge circuit. The measurement procedure consists of adjusting a 200-ohm potentiometer and a 120 pF variable capacitor. The potentiometer sets the range (from 0 to 200 ohms) of the resistive component of measured impedance, while the capacitor sets the reactive component. Capacitor C2 in the UNKNOWN arm of the bridge is used to balance the measurement capacitor. With C2 in the circuit, the bridge is balanced when C is approximately in the center of its range. This arrangement accommodates both inductive and capacitive reactances, which appear on either side of the "zero" point, i.e. the mid-range capacitance of C. When the bridge is in balance, the settings of R and C reveal the impedance across the UNKNOWN terminal (e.g. your antenna).

A reverse-biased zener diode (zeners normally operate in the reverse bias mode) produces a large amount of noise because of the avalanche process inherent in zener operation. While this noise may be a problem in many applications, in a noise bridge it is highly desirable: the richer the noise spectrum, the better. The spectrum is enhanced somewhat in the HD-1422 because of the 1 kHz squarewave modulator that chops the noise signal. An amplifier boosts the noise signal to the level needed in the bridge circuit.

The detector used in the noise bridge is an HF receiver. The preferable receiver is an AM receiver, or at least an SSB receiver with a wide IF bandwidth. Although it's quite easy to use your ears to detect the noise null that indicates bridge balance, it's best to use a receiver with an S-meter. Thus, the best receiver to use is an AM HF receiver equipped with an S-meter. If your receiver lacks an S-meter, then use an old-fashioned (analog) AC voltmeter across the receiver's speaker output. Since antennas are not always convenient to AC power, you might also consider adding "battery powered" to the list of attributes required of the receiver.

adjusting antennas

Perhaps the most common use for antenna noise bridges is finding the impedance and resonant points of an HF antenna. Connect the RECEIVER terminal of the HD-1422 to the ANTENNA input of the HF receiver through a short length of coaxial cable. The length should be as short as possible, and the characteristic impedance should match that of the antenna feedline. Next, connect the coaxial feedline from the antenna to the ANTENNA terminals on the HD-1422. You're now ready to test the antenna.

• finding impedance

Set the noise bridge resistance control to the antenna feedline impedance (usually 50 or 75 ohms for most Amateur antennas). Set the reactance control to mid-range (zero) Next, tune the receiver to the *expected* resonant frequency (f_{EXP}) of the antenna. Turn the noise bridge on and tune the receiver, looking for a noise signal of about S9 (this will vary on different receivers, and if — in the unlikely event that the antenna is resonant on the expected frequency — the S-meter reading will be much lower).

Adjust the *Resistance* control, R, on the bridge for a null — i.e., minimum noise as indicated by the S-meter. Next, adjust the *Reactance* control, C, for a null. Repeat the adjustments of the R and C controls for the deepest possible null, as indicated by the lowest noise output on the S-meter (there is some interaction between the two controls).

A perfectly resonant antenna of common Amateur designs will have a reactance reading of zero ohms and usually a resistance of 20 to 120 ohms. (There are exceptions, e.g., a resonant quarter-wave vertical has a 36.5-ohm resistive component — Ed.) Real antennas may have some reactance and a resistance that is different from 20 or 120 ohms. Impedance matching methods can be used to transform the actual resistive component to the 20 or 120 ohm characteristic impedance of the transmission line.

In general if the resistance reading is close to zero, then suspect that there's a short circuit on the transmission line and an open circuit if the

fig. 1. Compact antenna noise bridges are useful for antenna work and component value determination.

resistance reading is close to 200 ohms. (There are exceptions — e.g., a vertical longer than $\lambda/2$ — Ed.)

For quarter-wavelength verticals and half-wavelength dipoles near resonance, a reactance reading on the X_L side of zero indicates that the antenna is too long, while a reading on the X_C side of zero indicates an antenna is too short. This convention may not hold true for other antennas, such as a vertical longer than half wavelength.

An antenna that's too long or too short should be adjusted to the correct length. To determine the correct length, we must find the actual resonant frequency, f_R. To do this, reset the *Reactance* control to zero and then *slowly* tune the receiver in the proper direction — downband for too-long and upband for too-short — until the null is found. On a high-*Q* antenna the null is easy to miss if you tune too fast. Don't be surprised if that null is out of band by quite a bit. The percentage of change is given by dividing the expected resonant frequency F_{EXP} by the actual resonant frequency (f_R), and multiply by 100:

$$Change = (f_{EXP} \times 100\%)/f_R$$

resonant frequency

Connect the antenna, noise bridge, and the receiver in the same manner as above. Set the receiver to the expected resonant frequency: i.e., 468/f for half wavelength types and 234/f for quarter wavelength types. Set the resistance control to 50 ohms or 75 ohms, as appropriate for the normal antenna impedance and the transmission line impedance. Set the reactance control to zero. Turn the bridge on and listen for the noise signal.

Slowly rock the reactance control back and forth to find on which side of zero the null appears. Once the direction of the null is determined, set the reactance control to zero and tune the receiver towards the null direction (downband if null is on X_L side and upband if on the X_C side of zero).

A less than ideal antenna will not have exactly 50 or 75 ohms impedance despite the coax impedance usually recommended, so some adjustment of R and C to find the deepest null is in order (actual values will be found throughout the noise bridge resistance range). You'll be surprised how far off some dipoles and other forms of antennas can be if they're not in "free space," — i.e., if they're close to the Earth's surface.

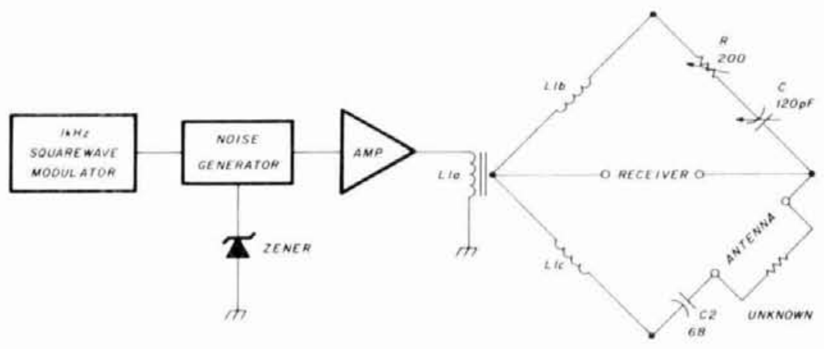

fig. 2. Antenna noise bridge circuit incorporated in the Heathkit HD-1422.

non-resonant antenna adjustment

We can operate antennas on frequencies other than their resonant frequency if we know the impedance (R and X components) and then provide a matching network to transform the impedance. Set up the receiver and noise bridge as described above and then tune the receiver to the desired operating frequency. Find the nulls for R and X (as above) and note the scale readings. The X readings are not the reactance in ohms, but rather the capacitance (0 to 60 pF). We can now calculate the normalized reactance at 1 MHz from the equations below:

$$X_C = X = \frac{159155}{68 - C} - 2340$$

or,

$$X_L = X = 2340 - \frac{159155}{68 + C}$$

Now, plug "X," calculated from one of the above, into $X_f = X/f$ where f is the desired frequency in MHz.

other applications

The Heath HD-1422 noise bridge can be used in a variety of applications. We can find the values of capacitors and inductors, determine the characteristics of series and parallel tuned resonant circuits, and calculate adjustments of transmission lines.

Some antennas and (non-noise) measurements require antenna feedlines that are either quarter wavelength or half wavelength at some specific frequency. We can use the HD-1422 to find these lengths as follows:

- Connect a short-circuit across the UNKNOWN terminals and adjust R and X for the best null at the frequency of interest (note: both will be near zero);
- Remove the short-circuit;
- Connect the length of transmission line to the UNKNOWN terminal — it should be longer than the expected length;
- For quarter wavelength lines, shorten the line until the null is very close to the desired frequency. For half wavelength lines, do the same thing, except that the line must be shorted at the far end for each trial length.

The HD-1422 can also be used to pretune an antenna tuner in order to reduce the amount of tune-up time required on the air. A previous *ham radio article* dealt with a system for doing this same job using another noise bridge.[1]

conclusion

The Heath HD-1422 noise bridge is an easily constructed, simple device that nonetheless produces useful measurement results. I recommend that all Amateurs who operate in the HF bands keep one of these instruments in their armamentareum.

reference

1. Forrest Gehrke, K2BT, "A Precision Noise Bridge," *ham radio*, March, 1983, page 50.

ham radio

short circuit

frequency and level standard

In "A Frequency and Level Standard" (Hans Evers, PA0CX, January, page 10) the caption for **fig. 3** incorrectly identifies U5 as 74SL90. The correct designation is 74LS90.

✓ 182

✓ 183

solving transmission line problems on your Commodore 64™

"Transline Plus" eliminates drudgery from antenna system calculations

When we say the antenna is the most important part of an Amateur Radio station, we're really talking about the antenna *system* — and that includes the transmission line.

Planning a new system, or evaluating one that's already in place, requires transmission line calculations, which are by nature tedious and repetitive, and therefore well-suited for calculation by computer. After reading K4KI's illuminating article[1] I wrote "Transline," a short program (**fig. 1**) for determining the impedance transformation by a given length of transmission line. It soon became apparent that it simply didn't do enough, and that's where the "Plus" came in.

calculations

If the impedance Z_I at the input of a transmission line of length L and characteristic impedance Z_o is known, the load impedance Z_L can be found from:

$$\frac{Z_L}{Z_o} = \frac{Z_I - jZ_o\,(\tan B)}{Z_o - jZ_I\,(\tan B)} \qquad (1)$$

where B = 0.367•F(MHz)•L(feet) and j is the operator $\sqrt{-1}$.

This equation can be solved for Z_I, yielding:

$$\frac{Z_I}{Z_o} = \frac{Z_L + jZ_o\,(\tan B)}{Z_o + jZ_L\,(\tan B)} \qquad (2)$$

Recalling the rule of complex algebra

$$\frac{a + jb}{c + jd} = \frac{ac + bd}{c^2 + d^2} + j\,\frac{bc - ad}{c^2 + d^2}, \qquad (3)$$

both equations can be set into forms which readily yield formulas for R_L and X_L, and R_I and X_I, respectively. Performing these transformations, one is struck by the similarity between the resulting formulas: one needs only to change the sign of the reactance, perform the calculation, and change the sign of the resulting reactance to use **eqn 1** to find the input impedance when the load impedance is known. Physically, this is because the input termination must be the conjugate of the transformed load impedance. As a practical matter, it eliminates the need to include **eqn 2** in the program.

Knowing the load impedance, the SWR can be calculated from:

$$SWR = \frac{1 + G}{1 - G} \qquad (4)$$

where G is the reflection coefficient

$$G = \sqrt{\frac{(R_L - Z_o)^2 + X_L^2}{(R_L + Z_o)^2 + X_L^2}} \qquad (5)$$

These relations may be used to calculate the SWR from the input impedance, substituting R_I for R_L and X_I for X_L, or the input SWR may be measured; however, line loss can cause the measured SWR to be significantly lower than the load SWR. The actual SWR and the total line loss can be determined from:

$$SWR\ at\ load = S_L = \frac{A + B}{A - B} \qquad (6)$$

$$SWR\ at\ input = S_I = \frac{B + C}{B - C}$$

$$Total\ loss = 10 \log \frac{B^2 - C^2}{B(1 - C^2)}$$

where

$$A = \frac{S_I + 1}{S_I - 1} \qquad (7)$$

$$B = 10^{M/10}$$

$$C = \frac{S_L - 1}{S_L + 1}$$

Thus, knowing the matched line loss, M, in dB, and either the input SWR or the load SWR, the total loss and the unknown SWR can be calculated.

Matched loss as a function of frequency for a variety of transmission line types can be found in numer-

By Gary E. Myers, K9CZB, 28W135 Hillview Drive, Naperville, Illinois, 60565

a typical calculation

A half-square antenna has a feedpoint impedance of 1500 + j0 ohms at 7.05 MHz. Sixty-five feet (19.81 meters) of transmission line will be required to bring it into the shack. Since only the 40-foot (12 meters) distance from the antenna to the house is in the clear, it will be difficult to use open wire all the way.

RUN the program, and enter 7.05 at the prompt. Try a *Q*-section of 450-ohm open wire, to bring the impedance down. When asked for the transmission line type, select "Other" and enter 0 for the line loss per 100 feet (30.48 meters), 450 for the line impedance, and 0.95 for the velocity factor. Enter "Y" when asked if you want a *Q*-section.

The program indicates that a *Q*-section at 7.05 MHz will be 33.15 feet (10.10 meters) in length, that the matched loss will be 0 dB, and that the electrical length is 90 degrees. It then asks for the load resistance and load reactance. After you enter 1500 and 0, respectively, it tells you that the input resistance will be 135 ohms, the input reactance will be 0 ohms, the SWR at the load will be 3.3, the input SWR will be 3.2, and that the total loss will be 0.

A *Q*-section of 75-ohm line might help at this point, so answer "Y" to the "try again?" prompt. Again enter 7.05 and choose "E" (RG11). The program says that the matched loss of this cable is 0.6 dB per 100 feet (30.48 meters). Enter 0.66 when asked for the velocity factor. Again, answer "Y" to the *Q*-section prompt, and you're told that a *Q*-section will be 23.03 feet (7.01 meters) in length with a matched loss of 0.1 dB, and that the electrical length is 90 degrees. Enter 135 and 0, respectively, when asked for the load resistance and reactance (the input impedance of the open wire section is now the load for the RG11). The program then tells you that the input resistance will be 41.6 ohms, the input reactance will be 0 ohms, the SWR at the load will be 1.8, the input SWR will be 1.7, and the total loss will be 0.1 dB.

Finally, try again, to see what the results in the shack will be if you finish up with 8.82 feet (2.68 meters) of RG213. Again enter 7.05 and choose "D" (RG8/213). The matched loss is 0.6 dB per 100 feet (30.48 meters); enter 0.66 for the velocity factor. You enter "N" at the *Q*-section prompt and are asked for the line length, which is entered as 8.82. You're told that the matched loss is 0.1 dB for 8.8 feet (2.68 meters) and that the electrical length is 34 degrees. When asked for the known quantity, respond with "B" for the load impedance. When asked for the load resistance and reactance, respond with 41.6 and 0, respectively. The computer says that the load SWR will be 1.2, the input SWR will be 1.1, the total loss will be 0, the input resistance will be 46, and the input reactance will be 8.

With just a few keystrokes, you'll have planned the feedline portion of your antenna system. You can easily do more: if you know the feedpoint impedance of the antenna at frequencies off-resonance, you can determine the 2:1 SWR points and adjust the antenna resonant frequency accordingly, to cover a preferred range of frequencies without the need for a transmatch.

ous sources. The **ARRL Antenna Book**[2] shows plots of log (frequency) vs log (attenuation) for most of the transmission lines in common Amateur use. These plots are approximately linear in the HF and VHF regions, so they can be described by $y = mx + b$ where y = *log (attenuation*, x = *log (frequency)*, m is the slope of the line, and b is the y intercept. Finding m and b for each line then allows one to calculate, with reasonable accuracy, the matched loss at any frequency up to and including VHF.

the program (fig. 1)

Although even the intrepid antenna experimenter cringes at the thought of going through these exercises repeatedly, it's now far less of a chore, because Transline Plus will:

- determine the input impedance, knowing that of the load;
- determine the load impedance, knowing that at the input;
- determine the apparent input SWR, knowing that at the load;
- determine the load SWR, knowing that measured at the input;
- calculate the length of a Q-section; and
- calculate the total loss.

In addition, the program automatically calculates matched line losses for several of the most common types of transmission lines in Amateur use today, and uses those values — no more thumbing through books and reading charts. It even chooses the correct Z_0.

Although the concept is straightforward, a brief

fig. 1. "Transline Plus" program performs transmission line calculations.

```
READY.

10 REM WRITTEN BY GARY MYERS K9CZB
20 PRINT"{CLR}"
30 FORJ=1TO5:PRINT:NEXTJ
40 PRINTTAB(10)"**TRANSLINE PLUS**"
50 PRINTTAB(12)"A PROGRAM FOR"
60 PRINTTAB(4)"TRANSMISSION LINE CALCULATIONS"
70 L=LOG(10)
80 PRINT:INPUT"FREQUENCY (MHZ)";F
90 PRINT:PRINT"TRANSMISSION LINE TYPE:"
100 PRINTTAB(5)"A - RG58"
110 PRINTTAB(5)"B - RG59"
120 PRINTTAB(5)"C - 'MINI 8'"
130 PRINTTAB(5)"D - RG8/213"
140 PRINTTAB(5)"E - RG11"
150 PRINTTAB(5)"F - RG8 FOAM"
160 PRINTTAB(5)"G - OTHER"
170 GETC$:IFC$=""THEN170
180 IFC$="A"THENPOKE1558,31:LI=53.5:GOTO700
190 IFC$="B"THENPOKE1598,31:LI=73:GOTO710
200 IFC$="C"THENPOKE1642,31:LI=50:GOTO720
210 IFC$="D"THENPOKE1681,31:LI=50:GOTO730
220 IFC$="E"THENPOKE1719,31:LI=75:GOTO730
230 IFC$="F"THENPOKE1762,31:LI=50:GOTO740
240 IFC$="G"THENPOKE1799,31:GOTO260
250 GOTO170
260 PRINT:INPUT"LINE LOSS (DB/100')";LO
270 PRINT:INPUT"LINE IMPEDANCE";LI:GOTO310
280 LP=INT(LO*10)/10
290 IFINT(LO*100)/100-LP=>.05THENLP=LP+.1
300 PRINT:PRINT"  MATCHED LOSS=";LP;" DB/100'"
310 PRINT:INPUT"VELOCITY FACTOR";VF
320 PRINT:PRINT"WANT TO CALCULATE A Q-SECTION (Y/N)?"
330 GETT$:IFT$=""THEN330
340 IFT$="N"THEN370
350 QL=(246.063*VF)/F:LL=QL:QL=INT(QL*100)/100
360 PRINT:PRINT"  Q-SECTION AT";F;"MHZ=";QL;"FEET":GOTO380
370 PRINT:INPUT"LINE LENGTH (FEET)";LL
380 AL=INT(10*LL)/10
390 IFINT(100*LL)/100-AL=>.05THENAL=AL+.1
400 ML=(LO*LL)/100:MP=INT(10*ML)/10
410 IFINT(100*ML)/100-MP=>.05THENMP=MP+.1
420 PRINT:PRINT"  MATCHED LOSS=";MP;" DB FOR";AL; "FEET"
430 B=((LL/VF)*2*π)/(984.252/F):BA=B*57.3
440 BP=INT(BA):BA=INT(10*BA)/10
450 IFBA-BP=>.5THENBP=BP+1
460 PRINT:PRINT"  ELECTRICAL LENGTH=";BP;" DEGREES"
470 IFT$="N"THEN540
480 PRINT:INPUT"LOAD RESISTANCE";BR
490 PRINT:INPUT"LOAD REACTANCE";BX
500 GOSUB1270
510 PRINT:PRINT"  INPUT RESISTANCE=";RA
520 PRINT:PRINT"  INPUT REACTANCE=";XA
530 GOTO800
540 PRINT:PRINT"DESIGNATE KNOWN QUANTITY:"
550 PRINTTAB(5)"A - INPUT IMPEDANCE"
560 PRINTTAB(5)"B - LOAD IMPEDANCE"
570 PRINTTAB(5)"C - INPUT SWR"
580 PRINTTAB(5)"D - LOAD SWR"
590 GETD$:IFD$=""THEN590
600 IFD$="A"THEN750
610 IFD$="B"THEN870
620 IFD$="C"THEN1000
```

```
630 IFD$="D"THEN1080
640 GOTO590
650 PRINT:PRINT"TRY AGAIN (Y/N)?"
660 GETQ$:IFQ$=""THEN660
670 IFQ$="Y"THENPRINT"{CLR}":FORJ=1TO8:PRINT:NEXTJ:GOTO70
680 PRINT"{CLR}":FORJ=1TO10:PRINT:NEXT
690 PRINTTAB(13)"73 DE K9CZB":END
700 LA=.5376*LOG(F)/L+LOG(.42)/L:LO=10↑LA:GOTO280
710 LB=.45864*LOG(F)/L+LOG(.4)/L:LO=10↑LB:GOTO280
720 LC=.3979*LOG(F)/L+LOG(.4)/L:LO=10↑LC:GOTO280
730 LD=.515*LOG(F)/L+LOG(.21)/L:LO=10↑LD:GOTO280
740 LF=.52*LOG(F)/L+LOG(.15)/L:LO=10↑LF:GOTO280
750 PRINT:INPUT"INPUT RESISTANCE";BR
760 INPUT"INPUT REACTANCE";BX
770 GOSUB1200
780 PRINT:PRINT"  LOAD RESISTANCE=";RA;" OHMS
790 PRINT:PRINT"  LOAD REACTANCE=";XA;" OHMS
800 NP=(BR-LI)↑2+BX↑2
810 DP=(BR+LI)↑2+BX↑2
820 P=SQR(NP/DP)
830 SW=(1+P)/(1-P):SW=INT(SW*10)/10
840 PRINT:PRINT"  VSWR=";SW
850 GOSUB1120
860 GOTO650
870 PRINT:INPUT"LOAD RESISTANCE";RL
880 INPUT"LOAD REACTANCE";XL
890 NS=(RL-LI)↑2+XL↑2
900 DS=(RL+LI)↑2+XL↑2
910 G=SQR(NS/DS)
920 SW=(1+G)/(1-G):SW=INT(SW*100)/100
930 PRINT:PRINT"  VSWR AT LOAD=";SW
940 GOSUB1120
950 BR=RL:BX=-XL:GOSUB1200
960 RA=INT(RA*10)/10:XA=INT(-XA*10)/10
970 PRINT:PRINT"INPUT RESISTANCE=";RA
980 PRINT:PRINT"INPUT REACTANCE=";XA
990 GOTO650
1000 PRINT:INPUT"INPUT SWR";SI
1010 AS=(SI+1)/(SI-1)
1020 BS=10↑(ML/10)
1030 SW=(AS+BS)/(AS-BS):SW=INT(SW*10)/10
1040 PRINT:PRINT"  SWR AT LOAD=";SW
1050 CS=(SW-1)/(SW+1)
1060 GOSUB1170
1070 GOTO650
1080 PRINT:INPUT"LOAD SWR";SW
1090 GOSUB1120
1100 PRINT:PRINT"  VSWR AT INPUT=";SI
1110 GOTO650
1120 BS=10↑(ML/10)
1130 CS=(SW-1)/(SW+1)
1140 SI=(BS+CS)/(BS-CS):SI=INT(10*SI)/10
1150 IFD$="D"THEN1170
1160 PRINT:PRINT"  VSWR AT INPUT=";SI
1170 LT=(10/L)*LOG((BS↑2-CS↑2)/(BS*(1-CS↑2))):LT=INT(LT*10)/10
1180 PRINT:PRINT"  TOTAL LINE LOSS=";LT;" DB"
1190 RETURN
1200 IFCOS(B)=0THENB=1.57
1210 BB=TAN(B)
1220 D=(LI+(BX*BB))↑2+(BR*BB)↑2
1230 NA=BR*LI*(1+BB↑2):RA=(LI*NA)/D
1240 RA=INT(RA*10)/10
1250 NB=(BX-(LI*BB))*(LI+(BX*BB))+(BR↑2*BB):XA=(LI*NB)/D:
     XA=INT(XA*10)/10
1260 RETURN
1270 RA=(LI↑2*BR)/(BR↑2+BX↑2):RA=INT(RA*10)/10
1280 XA=-(LI↑2*BX)/(BR↑2+BX↑2):XA=INT(XA*10)/10
1290 RETURN

READY.
```

review of the program will help to clarify things and make it easier to modify, if you wish. Since the Commodore 64 works in natural logarithms, **line 70** saves typing later on. **Lines 100-160** let you specify the type of feedline. If "other" is chosen in **line 160**, then **260** and **270** are run to let you specify the matched loss per 100 feet (30.4 meters) and the characteristic impedance; otherwise the program will do it for you. **Lines 180-240** confirm your choice with a graphic, choose the value for Z_0 and send the program to the appropriate matched loss calculation. (The loss for "mini-8" types is based on product review data for Tandy RG-8/M.[3]) **Line 250** prevents invalid entries.

Line 310 allows you to specify the velocity factor of the feedline. This could have been included in **180-240**, but since it tends to deviate from nominal values, especially in foam-dielectric types, the important part of the results may be more accurate if it is measured rather than assumed.[4] **Line 350** calculates the length of a **Q**-section if requested. **Lines 380-410** contain number-rounding operations and **420** displays matched losses. The electrical length of the line is calculated in radians and degrees, and rounded and displayed in degrees, by **lines 430-460**. If a **Q**-section is not requested, **line 470** sends the program to the next stage.

Lines 550-630 let you choose your calculation, based on the known quantity, and send the program to the appropriate routines and subroutines. **Line 1200** prevents "division by zero" errors when the line length is exactly 90 degrees.

After typing in the program, be sure to **SAVE** it before **RUNning**, in case you've made an error that will cause a system lockup. For those with little programming experience, note that the CLR in curly brackets in **lines 20, 670**, and **680** means a **SHIFTed CLR/HOME** key; this shows on the screen as a reversed video heart symbol.

results

The program is designed to be easy to use. Just follow the prompts as they appear on the screen. Prompts that ask for a single letter response are executed immediately by **GET** statements; those that ask for numbers are **INPUT** statements, and require a **RETURN** for execution. If you want a hard copy of your results, add **PRINT#** statements after each appropriate screen **PRINT**.

Some cautions are in order. The impedance transformation calculations don't account for line loss. Normally this is of little consequence in well-designed systems, but it may introduce significant errors if the total loss exceeds 2 dB or so. The exponential relations developed by K0OP[5] might be substituted for the calculations in **lines 1210-1250**, if better accuracy is desired for very lossy situations. The calculations for matched loss are based on the assumption that the log (frequency)/log (attenuation) relationship is linear; this is only approximately true for some types, especially in the UHF region. Rounding operations and some minor approximations cause the program to yield SWR and line loss results that may be inconsistent in the first decimal place.

A typical calculation is illustrated in the sidebar.

This program has taken much of the tedium out of my antenna system studies, and makes "what if?" exercises a real joy. If you don't care to type the program, send me a formatted disk and $5, and I'll provide you with a copy.

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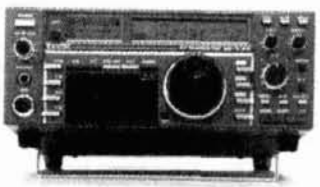

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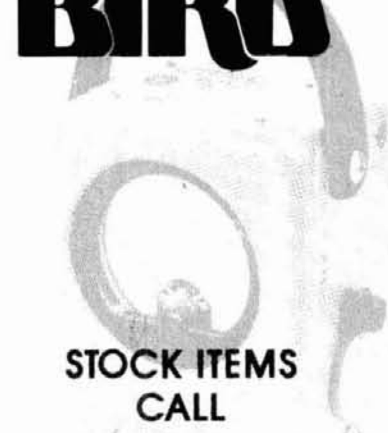

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25 watts	--	25A	25B	25C	25D	25E
50 watts	50H	50A	50B	50C	50D	50E
100 watts	100H	100A	100B	100C	100D	100E
250 watts	250H	250A	250B	250C	250D	250E
500 watts	500H	500A	500B	500C	500D	500E
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hf ground wave propagation

A computer program for calculating expected range

While some hams are busy chasing rare DX, working "skip" via F2 ionized atmospheric layers, many others are busy sending SSTV signals across town to friends or communicating with relatives in adjacent states by using "ground wave" propagation. If you're the latter, and you'd like to discover an armchair method of determining what your expected ground wave communications range should be, then read on.

This article describes a computer program, written in BASIC for the Commodore 64 or 128PC — but easily converted to other computers — which will predict your range in miles as you experiment with transmitter power, receiver sensitivity, polarization, and antenna heights and gains.

The program is completely menu-driven for ease of operation. Two typical screens are shown in **figs. 1** and **2**. The first is used for selection of frequency band, equipment characteristics, and polarization, and the latter is used in the selection of antenna heights and gains. The typical output format is shown in **fig. 3**, and a routine is included to dump all applicable information to your printer.

propagation curves

Although propagation curves have been available for about 40 years, most hams have either not been aware of them or haven't known how to use them. The classic curves developed by Bell Labs cover 200 kHz to 600 MHz over distances of 0.5 to 1000 miles (0.8 to 1600 km) and are arranged in six sections covering propagation over poor soil, good soil, and sea water for vertical and horizontal polarizations, and include ground-to-air data to 40,000 feet (12,000 meters).[1] Typical inputs and outputs are expressed in terms of 1 kW transmitted from a grounded whip and units of field strength in dB above 1 microvolt per meter, however, one must be wise in the ways of antenna conversions to use them. Although propagation predictions at VHF and UHF are fairly straightforward because antennas at these frequencies are usually mounted many wavelengths above earth, where ground effects are negligible,[2,3] they are very complicated at HF, where antennas are usually located within a few wavelengths of ground. Under these conditions, actual antenna directivity and efficiency are a function of polarization and are directly affected by soil conductivity, and other factors.

The user-friendly menu-driven computer program described below utilizes data taken from portions of selected curves in reference 1. Ground wave propagation data are included for the 3.5, 7, 14, 28, and 50 MHz bands, with separate information for both vertical and horizontal polarizations for three different ground conductivities.

program description

The menu-driven HF ground wave propagation program includes a sufficient number of INPUT, PRINT, and REMARKS statements that should make it self-explanatory to most users. The program LISTing in BASIC is shown in **fig. 4**. The following description is for those who wish to follow the program flow line by line.

Lines 10 through **40** display the program title on the screen and provide you an opportunity to select any combination of border, screen, and letter colors desired; you're not stuck with the Commodore 64 default conditions. In **lines 50-74** you choose whether to work with receiver sensitivity and transmitter power in microvolts and watts or in dBm (decibels relative to 1 milliwatt). This is for your convenience only; the program converts either input to the other and displays both as an output.

Line 76 branches to the program data in the subroutine beginning at **line 9000** and running to the end of the program. (Details of the data format will be given later for interested programmers.) **Lines 100-115** then branch to subroutines for initial inputs of the parameters described below. The subroutine in **lines 600-624** prints a menu on the screen (see **fig. 1**) and requires you to select your operating frequency band.

By Lynn A. Gerig, WA9GFR, R.R.#1, Morgan Road, Monroeville, Indiana 46773

```
SELECT FREQUENCY BAND FROM MENU

          1 =  3.5 MHZ
          2 =  7   MHZ
          3 = 14   MHZ
          4 = 28   MHZ
          5 = 50   MHZ

WHAT IS YOUR CHOICE? 5


INPUT XMTR POWER (IN WATTS)? 100
RCVR SENSITIVITY (IN MICRO-VOLTS)? .8

VERTICAL OR HORIZONTAL POLARIZATION
(V OR H)? H


SELECT PROPAGATION PATH FROM MENU

 1 = POOR SOIL
 2 = GOOD SOIL
 3 = SEA WATER

WHAT IS YOUR CHOICE? 2
```

fig. 1. Menus for selection of frequency band, radio parameters, polarization, and path type.

```
CHOOSE ANTENNA FEEDPOINT HEIGHT ABOVE
GROUND FROM THE FOLLOWING MENU:


1 =  10'    4 =  40'    7 =  80'
2 =  20'    5 =  50'    8 = 100'
3 =  30'    6 =  60'    9 = 150'


SELECT HEIGHT OF TRANSMIT ANTENNA? 3
SELECT HEIGHT OF RECEIVE ANTENNA? 5


ENTER GAIN OF XMIT ANTENNA (IN DB)? 12
ENTER GAIN OF RCV ANTENNA (IN DB)? 7.5


ENTER TOTAL LOSSES AT TRANSMITTING AND
RECEIVING ENDS OF THE LINK.  INCLUDE
COAX CABLE LOSSES, ETC. (IN DB)?  4
```

fig. 2. Menus for selection of antenna parameters.

The subroutine in **lines 700-740** asks for receiver sensitivity and transmitter power output. You'll either be prompted for an input in dBm or in microvolts and watts, depending upon your preference selected in **lines 70-74**. Your input is converted to both units, which will be displayed later.

The subroutine in **lines 800-860** displays menus on the screen requiring you to select polarization (vertical or horizontal) and type of propagation path (poor soil, good soil, or sea water), also shown in **fig. 1**.

All antenna parameters are input from the subroutine in **lines 900-995**. You must first select the heights of both the receiving and transmitting antennas from the menu (see **fig. 2**). The program includes data for antenna elevations above ground from 10 to 150 feet (3.04 to 45.7 meters) in nine discrete increments. In addition, if you select vertical polarization, an additional option for specifying your antenna at ground level is included. Next you're asked to input antenna gains in dB. Finally, you must input system losses. These would include coaxial cable losses, antenna matching network losses, and antenna losses due to a poor ground radial system, unless you took these into consideration when entering radio set parameters. For example, if you have a 100-watt transmitter and have 6 dB of coax cable and antenna losses, either use 100 watts as your power level and include 6 dB in losses (plus losses at the receiving end, of course), or use 25 watts (actual radiated power) with 0 dB losses.

The main program calculations and outputs occur in **lines 200-335**. First, path loss vs distance and antenna height gain data for your operating conditions are selected based upon your inputs of frequency, polarization, soil type, and antenna heights. An equivalent "path" in dB is calculated in **line 240**. This number is basically the difference in dB between the transmitter power output and receiver sensitivity, with corrections for antenna gains and system losses, plus an equivalent antenna "height gain" for antennas at other than "reference height." Data stored in the pro-

```
GROUND WAVE PROPAGATION AT 50 MHZ
HORIZONTAL POLARIZATION OVER GOOD SOIL

TRANSMITTER POWER OUT:  50     DBM
                        100    WATTS

RECEIVER SENSITIVITY:  -108.9  DBM
                        .8     UV

TRANSMITTING ANTENNA:   12 DB GAIN
                        AT 30 FEET

RECEIVING ANTENNA:      7.5 DB GAIN
                        AT 50 FEET

SYSTEM LOSSES:          4 DB

MAXIMUM EXPECTED RANGE:  66.6 MILES

---------------------------------------
F=NEW FREQ BAND              R=RUN AGAIN
A=MODIFY ANTENNAS            P=PRINTER DUMP
X=MODIFY R/T SENS/PWR        Q=QUIT
N=NEW PATH OR POLARIZATION
```

fig. 3. Typical program output format.

fig. 4. Propagation program list in BASIC for the Commodore 64.

```
2 CL$=CHR$(147):D$="N":LT$=CHR$(157):DN$=CHR$(17)
10 PRINTCL$DN$DN$"   3.5-50 MHZ GROUND-WAVE PROPAGATION
14 PRINTDN$"        PROGRAM  FOR THE COMMODORE 64
16 PRINTDN$DN$DN$DN$"                    V1.0 C 1985 BY
18 PRINTDN$"           LYNN A. GERIG, WA9GFR
20 FORJ=1TO6:PRINT:NEXT
22 PRINT"TO CHANGE BORDER, SCREEN, OR LETTER
24 PRINT"COLORS, PRESS B, S, OR L, RESPECTIVELY.
26 PRINTDN$"TO EXIT TO PROGRAM, PRESS <RETURN>.
30 GETA$:IFA$=""THEN30
32 IFA$="B"THENPOKE53280,PEEK(53280)+1AND15
34 IFA$="S"THENPOKE53281,PEEK(53281)+1AND15
36 IFA$="L"THENPOKE646,PEEK(646)+1AND15:GOTO10
38 IFA$=CHR$(13)THEN50
40 GOTO30
50 PRINTCL$DN$"THIS PROGRAM CALCULATES EXPECTED RANGES
52 PRINT"FOR FREQUENCY BANDS OF 3.5, 7, 14, 28,
54 PRINT"AND 50MHZ.  THE APPROXIMATE DYMANIC
56 PRINT"RANGE IS FOR PATH LOSSES OF 100 TO 200
58 PRINT"DB, COVERING MOST APPLICATIONS FOR RCVR
60 PRINT"SENS OF .2 TO 10 MICRO-VOLTS AND XMTR
62 PRINT"POWER OF .1 TO 1000 WATTS.  PROGRAM
64 PRINT"COVERS ANTENNA HEIGHTS FROM GROUND
66 PRINT"LEVEL TO 150 FEET.
70 PRINTDN$DN$"PROGRAM DEFAULTS TO RCVR SENS AND XMTR
72 PRINT"PWR IN DBM.  WOULD YOU RATHER WORK WITH
74 PRINT"MICRO-VOLTS AND WATTS (Y=YES)";:INPUT D$
76 GOSUB9000:REM READ DATA
100 GOSUB600:REM SELECT FREQUENCY BAND
105 GOSUB700:REM SELECT XMTR PWR & RCVR SENS
110 GOSUB800:REM SELECT PROPAGATION PATH
115 GOSUB900:REM SELECT ANTENNA PARAMETERS

200 REM MAIN PROGRAM CALCULATIONS
205 IF(H1=0ORH2=0)ANDPO=2THENGOSUB900
210 H$=H$(PO,PP,FB):REM DATA FOR SELECTED POLARIZATION, PATH & FREQ
215 FORJ=1TO12:X=6*(J-1):P(J)=VAL(MID$(H$,X+1,3))
220 D(J)=VAL(MID$(H$,X+4,3)):NEXT
225 IFD(12)=999THEND(10)=1050:D(11)=1050:D(12)=1050
230 HX=HG(PO,PP,FB,H1):REM XMIT ANTENNA HEIGHT GAIN
235 HR=HG(PO,PP,FB,H2):REM RCVR ANTENNA HEIGHT GAIN
240 PL=PD-RD+HX+HR+GX+GR-LL:REM PATH IN DB
245 PRINTCL$"GROUND WAVE PROPAGATION AT"F(FB)"MHZ
250 PRINTPO$(PO)" POLARIZATION OVER "PP$(PP)
255 PRINTDN$"TRANSMITTER POWER OUT:"PD;TAB(30);"DBM
260 PRINTTAB(22)PW;TAB(30)"WATTS"
265 PRINTDN$"RECEIVER SENSITIVITY: "RD;TAB(30)"DBM
270 PRINTTAB(22)RMTAB(30)"UV
275 PRINTDN$"TRANSMITTING ANTENNA: "GX"DB GAIN
280 PRINTTAB(23)"AT"H(H1)"FEET
285 PRINTDN$"RECEIVING ANTENNA:    "GR"DB GAIN
290 PRINTTAB(23)"AT"H(H2)"FEET
295 PRINTDN$"SYSTEM LOSSES:        "LL"DB"DN$
300 IFPL<P(1)THENPRINT"RANGE NOT IN PROGRAM:  <"D(1)"MILES":GOTO400
305 IFPL>=P(12)THENPRINT"RANGE NOT IN PROGRAM:  >"D(12)"MILES":GOTO400
320 FORJ=1TO11:X=J+1
325 IFPL>=P(J)ANDPL<P(X)THENDI=D(J)+(D(X)-D(J))*(PL-P(J))/(P(X)-P(J))
330 NEXT:DI=INT(10*DI+.5)/10
335 PRINT"MAXIMUM EXPECTED RANGE: "DI"MILES
400 PRINTDN$LL$
402 PRINT"F=NEW FREQ BAND            R=RUN AGAIN
404 PRINT"A=MODIFY ANTENNAS          P=PRINTER DUMP
406 PRINT"X=MODIFY R/T SENS/PWR      Q=QUIT
408 PRINT"N=NEW PATH OR POLARIZATION";
410 FORJ=1TO10:GETA$:NEXT
412 GETA$:IFA$=""THEN412
413 IFA$="P"THEN430
414 PRINTDN$
415 IFA$="R"THEN100
416 IFA$="Q"THENSYS65126:REM RESTORE
418 IFA$="N"THENGOSUB800:GOTO200
420 IFA$="A"THENGOSUB900:GOTO200
422 IFA$="X"THENGOSUB700:GOTO200
424 IFA$="F"THENGOSUB600:GOTO200
426 GOTO412
430 REM SCREEN-DUMP TO PRINTER
432 OPEN3,3:OPEN4,4:PRINTCHR$(19);:PRINT#4:PRINT#4,LL$
434 FORJ=0TO759:GET#3,A$:PRINT#4,A$;:NEXT:PRINT#4,LL$
436 CLOSE4:CLOSE3:FORJ=1TO5:PRINT:NEXT:GOTO412
```

```
600 PRINTCL$"SELECT FREQUENCY BAND FROM MENU"DN$
602 PRINTTAB(9)" 1 =  3.5 MHZ
604 PRINTTAB(9)" 2 =  7   MHZ
606 PRINTTAB(9)" 3 = 14   MHZ
608 PRINTTAB(9)" 4 = 28   MHZ
610 PRINTTAB(9)" 5 = 50   MHZ"DN$
620 INPUT"WHAT IS YOUR CHOICE";FB
622 IFFB<>1ANDFB<>2ANDFB<>3ANDFB<>4ANDFB<>5THEN600
624 PRINTDN$:RETURN
700 IFD$="Y"THENINPUT"INPUT XMTR POWER (IN WATTS)";PW:GOTO710
702 INPUT"INPUT XMTR POWER (IN DBM)";PD
704 PW=(PD-30)/10:PW=10^PW
706 IFPW>=1THENPW=INT(PW*10+.5)/10:GOTO720
708 IFPW<1THENPW=INT(PW*1000+.5)/1000:GOTO 720
710 PD=10*LOG(PW)/LOG(10)+30:PD=INT(PD*10+.5)/10
720 IFD$="Y"THENINPUT"RCVR SENSITIVITY (IN MICRO-VOLTS)";RM:GOTO730
722 INPUT"RCVR SENSITIVITY (IN DBM)";RD
723 IFRD>0THENPRINT"<1 MW IS A NEGATIVE NUMBER":GOTO722
724 RM=(RD+107)/20:RM=10^RM
726 IFRM>=1THEN RM=INT(RM*10+.5)/10:GOTO740
728 IFRM<1THEN RM=INT(RM*100+.5)/100:GOTO740
730 RD=20*LOG(RM)/LOG(10)-107:RD=INT(RD*10+.5)/10
740 RETURN
800 REM SELECT POLARIZATION & PROPAGATION PATH
805 PRINTDN$"VERTICAL OR HORIZONTAL POLARIZATION
810 INPUT"(V OR H)";PO$
815 IFPO$="V"THENPO=1:GOTO830
820 IFPO$="H"THENPO=2:GOTO830
825 GOTO810
830 PRINTDN$DN$"SELECT PROPAGATION PATH FROM MENU"DN$
835 PRINT" 1 = POOR SOIL
840 PRINT" 2 = GOOD SOIL
845 PRINT" 3 = SEA WATER"DN$
850 INPUT"WHAT IS YOUR CHOICE";PP
855 IFPP<>1ANDPP<>2ANDPP<>3THEN830
860 RETURN
900 REM ANTENNA PARAMETERS
905 PRINTCL$"CHOOSE ANTENNA FEEDPOINT HEIGHT ABOVE
910 PRINT"GROUND FROM THE FOLLOWING MENU:":PRINTDN$
915 IFPO=1THENPRINT"0 =  GROUNDED VERTICAL"DN$
920 PRINT"1 =  10'    4 =  40'    7 =  80'
925 PRINT"2 =  20'    5 =  50'    8 = 100'
930 PRINT"3 =  30'    6 =  60'    9 = 150'"DN$DN$
935 INPUT"SELECT HEIGHT OF TRANSMIT ANTENNA";H1:H1=INT(H1)
940 INPUT"SELECT HEIGHT OF RECEIVE ANTENNA";H2:H2=INT(H2)
945 IFH1<0ORH2<0ORH1>9ORH2>9THENPRINT"NOT IN MENU":GOTO935
950 IFPO=2AND(H1=0ORH2=0)THENPRINT"NOT IN MENU":GOTO935
965 PRINTDN$DN$
970 INPUT"ENTER GAIN OF XMIT ANTENNA (IN DB)";GX
975 INPUT"ENTER GAIN OF RCV ANTENNA (IN DB)";GR
980 PRINTDN$DN$"ENTER TOTAL LOSSES AT TRANSMITTING AND
985 PRINT"RECEIVING ENDS OF THE LINK.  INCLUDE
990 INPUT"COAX CABLE LOSSES, ETC. (IN DB)";LL
995 PRINTCL$:RETURN

9000 RD=7:PRINTDN$DN$DN$DN$,CHR$(18)"READING DATA ";RD;
9005 DIM HG(2,3,5,9):DIMH$(2,3,5)
9010 FORPO=1TO2:REM 1=VERT 2=HORIZ
9015 FORPP=1TO3:REM 1=POOR SOIL 2=GOOD SOIL 3=SEA WATER
9020 FORFB=1TO5:REM 1=3.5 2=7 3=14 4=28 5=50MHZ
9025 FORAH=1TO9:REM 1=10' 2=20 3=30 ... 6=60 7=80 8=100 9=150'
9030 READ HG(PO,PP,FB,AH):REM HEIGHT GAIN IN DB
9035 NEXT:NEXT:RD=RD-1:PRINTLT$LT$LT$RD;:NEXT:NEXT
9040 DATA 0,0,0,0,0,0,0,0,0
9042 DATA -1,-1,0,.5,1,2,3,4,7
9044 DATA 0,1.5,3,5,7,8,10,12,15
9046 DATA 2,6,8,11,12.5,14,16.5,18.5,22
9048 DATA 6,11,14,17,18.5,20,22.5,24,28
9050 DATA 0,0,0,0,0,0,0,0,0
9052 DATA 0,0,0,0,0,0,0,0,0
9054 DATA -.5,-1,-1,-.5,0,1,2,4,7
9056 DATA 0,1,2,3.5,5,6,8,10,13
9058 DATA 1,4,7,9,11,13,15,17,20
9060 DATA 0,0,0,0,0,0,0,0,0
9062 DATA 0,0,0,0,0,0,0,0,0
9064 DATA 0,0,0,0,0,0,0,0,0
9066 DATA 0,0,0,0,0,0,0,0,0
9068 DATA -1,-1.5,-2,-2.5,-3,-3,-2,-1.5,1
9070 DATA 0,2,4,6,7,8,10.5,12,15.5
9072 DATA 0,3,6,7.5,9,11,13,15,18.5
9074 DATA 0,4,8,11,13,14,16,18,22
9076 DATA 0,5.5,9,12,14,15,17,19.5,23
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9078 DATA 0,6,9.5,12.5,14.5,15.5,17.5,20,23.5
9080 DATA 0,4,7.5,10,11.5,13,16,18,21
9082 DATA 0,5,8,11,13,15,17,19,22
9084 DATA 0,6,10,12,14,16,18,20,23
9086 DATA 0,6,10,12,14,16,18,20,23
9088 DATA 0,6,10,12,14,16,18,20,23
9090 DATA 0,6,9.5,12,14,15.5,18,20,23
9092 DATA 0,6,9.5,12,14,15.5,18,20,23
9094 DATA 0,6,9.5,12,14,15.5,18,20,23
9096 DATA 0,6,9.5,12,14,15.5,18,20,23
9098 DATA 0,6,9.5,12,14,15.5,18,20,23
9100 H$(1,1,1)="0990071090121190201290351390541490881591 25
9102 H$(1,1,1)=H$(1,1,1)+"169170179210189250199290209320
9110 H$(1,1,2)="1054.51157.612501313502314503715505516508 8
9112 H$(1,1,2)=H$(1,1,2)+"175120185160195190205230215270
9120 H$(1,1,3)="1112.51214.513100814101315102316103717105 3
9122 H$(1,1,3)=H$(1,1,3)+"181080191105201130211150221180
9130 H$(1,1,4)="1181.81283.11385.514801015801616802517804 0
9132 H$(1,1,4)=H$(1,1,4)+"188058198078208096218120228130
9140 H$(1,1,5)="1231.31332.214300415300716301217301818303 0
9142 H$(1,1,5)=H$(1,1,5)+"193043203058213075223090233110
9150 H$(1,2,1)="099027109045119060129110139150149190159230
9152 H$(1,2,1)=H$(1,2,1)+"169270179310189340199380209420
9160 H$(1,2,2)="105014115023125032135060145090155125165160
9162 H$(1,2,2)=H$(1,2,2)+"175200185225195240205270215300
9170 H$(1,2,3)="1115.712101113102114103215105016107017109 4
9172 H$(1,2,3)=H$(1,2,3)+"181120191140201160211180221200
9180 H$(1,2,4)="1184.21287.513801314802215803516805017806 9
9182 H$(1,2,4)=H$(1,2,4)+"188089198110208130218150228170
9190 H$(1,2,5)="123003133005143010153015163024173037183050
9192 H$(1,2,5)=H$(1,2,5)+"193067203083213100223120233140
9200 H$(1,3,1)="099190109290119380129470139570149650159740
9202 H$(1,3,1)=H$(1,3,1)+"169820179920189999189999189999
9210 H$(1,3,2)="105150115215125280135350145425155500165580
9212 H$(1,3,2)=H$(1,3,2)+"175640185700195780205840215900
9220 H$(1,3,3)="111083121115131150141185151220161260171300
9222 H$(1,3,3)=H$(1,3,3)+"181340191370201410211450221480
9230 H$(1,3,4)="118035128050138070148090158110168130178150
9232 H$(1,3,4)=H$(1,3,4)+"188170198190208210218230228250
9240 H$(1,3,5)="123017133027143040153054163070173085183100
9242 H$(1,3,5)=H$(1,3,5)+"193117203130213150223170233185
9250 H$(2,1,1)="0991.51092.61194.81298.11390151490251590 42
9252 H$(2,1,1)=H$(2,1,1)+"169060179090189125199162209200
9260 H$(2,1,2)="1051.51152.61254.81358.11450151550251650 42
9262 H$(2,1,2)=H$(2,1,2)+"175060185080195115205140215170
9270 H$(2,1,3)="1111.51212.61314.81418.11510151610251710 42
9272 H$(2,1,3)=H$(2,1,3)+"181056191078201100211122221145
9280 H$(2,1,4)="1181.81283.21385.914801015801616803017804 0
9282 H$(2,1,4)=H$(2,1,4)+"188060198080208096218116228136
9290 H$(2,1,5)="1232.41334.11437.215301316302217303218304 5
9292 H$(2,1,5)=H$(2,1,5)+"193060203071213082223100233120
9300 H$(2,2,1)="0990.71091.31192.31290041390071490131590 22
9302 H$(2,2,1)=H$(2,2,1)+"169036179055189080199110209150
9310 H$(2,2,2)="1050.91151.61252.91350051458.81550161650 26
9312 H$(2,2,2)=H$(2,2,2)+"175042185066195090205120215150
9320 H$(2,2,3)="1111.31212.11310041410071510131610211710 35
9322 H$(2,2,3)=H$(2,2,3)+"181050191075201095211120221142
9330 H$(2,2,4)="1181.81283.21385.21489.515801616802617804 0
9332 H$(2,2,4)=H$(2,2,4)+"188058198076208094218116228135
9340 H$(2,2,5)="1232.41334.21437.415301216302017303118304 5
9342 H$(2,2,5)=H$(2,2,5)+"193058203074213090223110233120
9350 H$(2,3,1)="0990.61091.01191.71290031395.51499.51590 17
9352 H$(2,3,1)=H$(2,3,1)+"169028179046189072199108209140
9360 H$(2,3,2)="1050.81151.41252.41354.31457.71550131650 23
9362 H$(2,3,2)=H$(2,3,2)+"175038185059195084205115215150
9370 H$(2,3,3)="1111.21212.11313.81416.81510121610201710 33
9372 H$(2,3,3)=H$(2,3,3)+"181050191070201095211120221140
9380 H$(2,3,4)="1181.71283.01385.41489.415801616802617804 0
9382 H$(2,3,4)=H$(2,3,4)+"188056198076208098218116228130
9390 H$(2,3,5)="1232.41334.11437.215301216302017303218304 5
9392 H$(2,3,5)=H$(2,3,5)+"193060203076213090223110233125
9400 F(1)=3.5:F(2)=7:F(3)=14:F(4)=28:F(5)=50
9405 RD=RD-1:PRINTLT$LT$LT$RD
9410 PO$(1)="VERTICAL":PO$(2)="HORIZONTAL"
9420 PP$(1)="POOR SOIL":PP$(2)="GOOD SOIL":PP$(3)="SEA WATER"
9430 LL$="--------------------------------------"
9440 DIMP(12):DIMD(12)
9450 H(0)=0:H(1)=10:H(2)=20:H(3)=30:H(4)=40:H(5)=50
9460 H(6)=60:H(7)=80:H(8)=100:H(9)=150
9999 RETURN
```

gram assume vertical antennas are at ground level and horizontal antennas are at 10 feet (3.04 meters). In **lines 245-295** all your input parameters are displayed on the screen (see **fig. 3**). In **lines 300-335** a check is made to ensure that the results of your parameters fall within the dynamic range of the program, the expected communications range is calculated based upon the nearest two data points stored, and your expected communications range is displayed on the screen.

One of the features of this program is that you can experiment with changes in a single parameter without having to re-enter all the inputs. **Lines 400-426** print a menu at the bottom of the screen (see **fig. 3**). Would you like to see how much further you could communicate if you increased your transmitter power from 100 to 500 watts? Press "x" on the keyboard, enter new receiver sensitivity and transmitter power, and your new range will instantly be displayed. What about raising that antenna from 30 to 60 feet (from 9.14 to 18.28 meters)? Press "A," answer the questions, and your answer immediately appears. If you have a printer connected, just press "P" and **lines 430-436** will give you a screen dump for a hard copy of all the information.

data format

The propagation curves from which the data in this program were taken assume that both receiving and transmitting antennas are dipoles at 10 feet (3.04 meters) for horizontal polarization and grounded antennas for vertical polarization. In many cases for vertical antennas and in all cases for horizontal antennas, as you raise the height of the antennas, you can communicate over larger distances.

Each antenna elevation has an associated "height gain." For example, for horizontal polarization over *good soil* at 14 MHz, raising the antenna from 10 feet to 30 feet (from 3.04 to 9.14 meters) will give you the same increase in range as increasing your power from 100 watts to 1 kW or as increasing your antenna gain by 10 dB. Hence, a 30 foot (9.14 meter) antenna under these circumstances is considered to have a relative "height gain" of 10 dB.

The data statements in **lines 9040-9098** contain height gains for the various combinations of frequency, polarization, and soil type in this program. The first five lines are for vertical polarization over poor soil, the next five are for vertical polarization over good soil, etc., and the last five are for horizontal polarization over sea water. Each line contains nine numbers which are the height gains in dB for each of the nine discrete heights in the menu. For example, **line 9084** contains data for horizontal polarization over good soil at 14 MHz. The height gain for 10 feet (3.04 meters) is 0 dB (reference height); for 20 feet (6.09 meters), it's 6 dB; for 30 feet (9.14 meters), it's 10 dB . . . and for 150 feet (45.72 meters), it's 23 dB. These data are read into the four-dimensional array HG in **lines 9005-9035** during program initialization, and the proper height gains for the antenna condition you choose in the program are selected in **lines 230** and **235**.

There are 30 pairs of lines from **9100-9392**, one for each combination of polarization (two kinds), soil type (three kinds) and frequency (five bands). **H$(1,1,1)** contains data for vertical polarization over poor soil at 3.5 MHz; **H$(1,1,2)** is for the same at 7 MHz . . . through **H$(2,3,5)**, which is for the second polarization type (horizontal), the third path type (sea water), and the fifth frequency band (50 MHz). Each nonlinear propagation curve of path in dB vs distance in miles is broken into 12 data points, each consisting of three digits for path in dB followed by three digits for distance in miles for that point, and is reconstructed as an 11-segment "piece-wise" linear equation by the program. For example, the first six digits of **H$(1,1,1)** indicate that for 3.5 MHz vertical polarization over poor soil, a path of 99 dB will yield a communications range of 7 miles (11 km). Similarly, the last six characters of **H$(2,3,5)** predict a range of 125 miles (201 km) for a 233-dB path for horizontal polarization over sea water at 50 MHz.

The proper data set for the combination of frequency, path, and polarization chosen is selected in **line 210** of the main program. This is then broken into 12 path and 12 distance values by the character string manipulation in **lines 215** and **220**. In **lines 300-305**, your system path is checked to be sure it's within the program range: if not, a "range not in program" message is printed. In **lines 320-330** your path is compared with each of the 12 path points stored. When it's found to be between the two closest path points, the variable DI is calculated to be the same proportional distance between the associated distance data, and that distance is printed to the screen in **line 335**.

entering the program

Enter the program as listed, taking the normal precautions to SAVE it before you RUN it so that if you make a typing error that could cause a computer lock-up, you'll be able to go back to edit the saved version without having to retype the entire program. The remarks (REM...) are to make the program easy to follow and change. They don't need to be entered.

If you have a Commodore 64 or 128PC, the program will run as LISTed. If you have another brand of computer, you'll want to delete **lines 22-24** and **32-36**, which are machine-specific (or add your own color commands), and change the "SYS65126" in **line 416** to "STOP" or "END." These are the only commands in the program that are machine specific, so the program should be easily converted to run on most computers using BASIC. Some changes might be necessary; for example, some computers won't permit multiple statements on a single line, so new line numbers will have to be added. The program as written requires just under 16K of RAM, but it could be "crunched" by deleting the title screen and REMarks statements.

If you don't want to keystroke the Commodore 64 program yourself, send a check or money order for $8.00 to me at the address shown at the beginning of the article. I'll send you a verified disk containing two copies of the program (1541 format). Add $2.00 for tape or if you live outside the United States. I also have an IBM-PC version available on disc for the same price.)

expected results

In free space, path attenuation changes at a 20 log(F) and a 20 log(D) rate where F is frequency in MHz and D is distance in miles. This means you need four times your present power (or a corresponding 6 dB increase in antenna gain) to double your distance because your radiated power is expanding over an increasing area which is proportional to distance squared. This also means that when your frequency increases by a factor of 10, the signal decreases 20 dB. The atmosphere doesn't really absorb the higher frequencies. A given radiated power will provide the same free-space field intensity (in microvolts per meter or watts per meter squared) at 30 MHz as it does at 3 MHz, for example, but a half-wavelength dipole at ten times the frequency is physically only one-tenth as long and therefore will "capture" only one-tenth as many microvolts (−20dB).

Although free-space attenuation is very predictable [loss in dB = 37 + 20 log(F) + 20 log(D)], actual attenuation is much greater due to the earth's curvature. In addition, some drastic and sometimes unexpected results occur when your antenna is within a few wavelengths of ground — which is usually the case below 30 MHz.

If you're using a vertical antenna at ground level, you can think of your system as if a return current were flowing through the ground, much as return currents flow through the shield of a coaxial cable. If the soil has low conductivity, the signal will be attenuated. For example, the same system that gives you a range of 125 miles (201 km) using a grounded vertical antenna at 3.5 MHz over poor soil will give you a range of 230 miles (370 km) over good soil and 740 miles (1190 km) over sea water. In general, your communications range with vertical polarization will be poor over poor soil and excellent over sea water.

If you place a horizontal dipole close to the ground (in terms of wavelengths), the earth will tend to act as a reflector. Because much of your signal will go "straight up," little will propagate along the horizon; the higher the conductivity of the earth, the more drastic the effect. For the same system parameters at 3.5 MHz referenced in the previous paragraph, if you have a horizontal dipole mounted at only 10 feet (3.04 meters) above ground level, your range will be about 42 miles (67 km) over poor soil, 22 miles (35 km) over good soil, and only 17 miles (27 km) over sea water.

Although the previous two paragraphs might lead you to beleive that vertical polarization is preferable to horizontal polarization for ground wave conditions (it sometimes is), other items should be considered. For example, a horizontal dipole at 3.5 MHz will be very efficient, but a vertical over a poor ground radial system may be less than 10 percent efficient. In addition, as a horizontal antenna is elevated to greater heights, the effects of ground described above will greatly decrease. Raising your 3.5 MHz vertical antenna from ground level to 100 feet (30.48 meters), for example, will have a negligible effect on your expected range. However, moving your horizontal dipole from 10 feet to 100 feet (from 3.04 to 30.48 meters) at this frequency will give "height gains" of 12, 18, and 20 dB over poor soil, good soil, and sea water, respectively.

At the higher frequencies, where antennas are generally mounted several wavelengths above ground, the propagation path is nearly independent of polarization. For example, at 50 MHz, using radio parameters of 100 watts out and 1 microvolt sensitivity, and assuming dipole antennas at 70 feet (21.33 meters) — with no losses for this "ideal" example — the predicted communications ranges fall between 54 and 60 miles (87 to 96 km), no matter what combinations of polarization and soil type you choose.

using the program

No more needs to be said about the mechanics of using the program. Some explanations and precautions, however, are in order.

1. Selection of frequency band, polarization, path type, and antenna height should be straightforward.
2. For transmitter power, use actual output power, not rated input power.
3. For receiver sensitivity, the actual receiver sensitivity can generally be used at the higher frequencies if you live in a "quiet" (QRN-wise) location. However, if you're operating 40 meters, where the background QRM and QRN levels are S6 or S9 or worse, you're kidding yourself if you use 0.2 microvolts, because you might not hear anything below 10 microvolts or so. Disconnect your antenna and listen to the noise level, then connect the antenna. If the background noise doesn't rise, use your receiver sensitivity. If the noise rises, use the background noise level (you can calibrate your S-meter with a signal generator).

4. If you'll be communicating over earth with low conductivity and low dielectric constant (such as dry sand, gravel, or rock), select "poor soil" from the propagation path menu. If you'll be communicating over soil with relatively high conductivity and high dielectric constant (such as cultivated farmland), select "good soil." Maritime mobile operators will obviously select sea water.

5. Antenna gain for horizontal polarization will generally be 0 dB for a dipole or inverted "V." If you're using a beam or directional array, enter the gain (in dB) relative to a dipole.

6. The curves for vertical polarization at ground level assume a grounded whip over a perfect ground radial system. If you have a phased array, enter the gain. If you have a moderate or poor ground radial system (most hams do), performance will be poor. Even with 15 ground radials, efficiencies as low as 50 percent can be expected.[4] For this case, your gain would either be −3 dB, or 0 dB with 3 dB added to other system losses. If you have only a ground rod or a few short radials, your efficiency may be less than 10 percent (−10 dB).

7. The height gains for elevated vertical antennas assume a whip over a good counterpoise (such as a ground plane antenna). Although the theoretical gain of a ground plane antenna is 3 dB above a dipole, the pattern maximum is normally about 30 degrees above the horizon, and the signal is usually down about 6 dB at the horizon (or 3 dB below a dipole level). If you're using a vertical dipole or beam antenna elevated more than a wavelength above ground (such as a 6-meter beam above 20 feet, or 6.09 meters), add 3 dB to the antenna gain. However, the presence of conducting tower and coaxial cables parallel to the driven element usually distort the radiation pattern, so expect actual performance for vertical antennas to be less than predicted.

8. Remember to include losses at both the receiving and transmitting ends of the circuit for total systems losses.

9. As with any "prediction" program, use the results with caution. The curves are based on propagation over average terrain under average conditons. Actual variations of 20 dB or more can be expected. Neither "poor" conditions nor "extended ground wave" conditions will surprise an experienced operator. Expect inferior performance if your antenna is not "in the clear" (i.e. in a jungle, inside an apartment building, etc.) or if your path involves mountainous terrain. Perhaps the most useful purpose for this program is to experiment with antenna height or gain and transmitter power, etc., "on paper" (more accurately, "in RAM") to determine relative system improvements without having to spend a lot of time and money constructing hardware and running comparative tests.

If you have comments or questions, feel free to write to me, but enclose an SASE if you wish a response.

references

1. National Defense Research Committee 15, *Propagation Curves, Report 966-6C*, Bell Telephone Laboratories, Inc., Issue 3, October, 1944 (declassified to "open" status March 8, 1946).

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ham radio

how high should your hf antenna be?

Knowing the desired range determines height

The question, "How high should my antenna be?" is often asked. But the only way to answer that question is by asking another: *how far do you want to communicate?* It's the answer to this question that allows the first to be answered.

Most hams build an antenna and then determine its capabilities and limitations by experiment. They never know whether poor communications should be blamed on the antenna or on propagation. A systems engineer, on the other hand, begins the process of designing a communications link by first determining the required distance for the link and then selecting the proper antenna, which is then built to the height that provides the optimum radiation pattern for the desired communications link. When link quality is poor, the designer can be certain that propagation conditions — not the antenna — are the limiting factor.

skip angle versus distance

The choice of antenna type and height can be readily determined from two simple graphs. First select the distance of the desired communications link. With that value in mind, refer to **fig. 1** to determine the optimum radiation angle or elevation take-off angle.

The graph shown in **fig. 1** is based on the average height of the ionosphere; although this distance varies, the typical Amateur antenna has a broad radiation pattern in the elevation plane, so high accuracy is not required, either for the height of the ionosphere or the height of the antenna.

Typically, we want to be able to select from a broad range of communications distances rather than be limited to only one location. So you'll need to determine the range of communications distances and the resulting range of optimum elevation radiation angles. If the range of radiation angles is too broad, more than one antenna may be required to optimize station performance, as will be shown later.

height versus skip angle

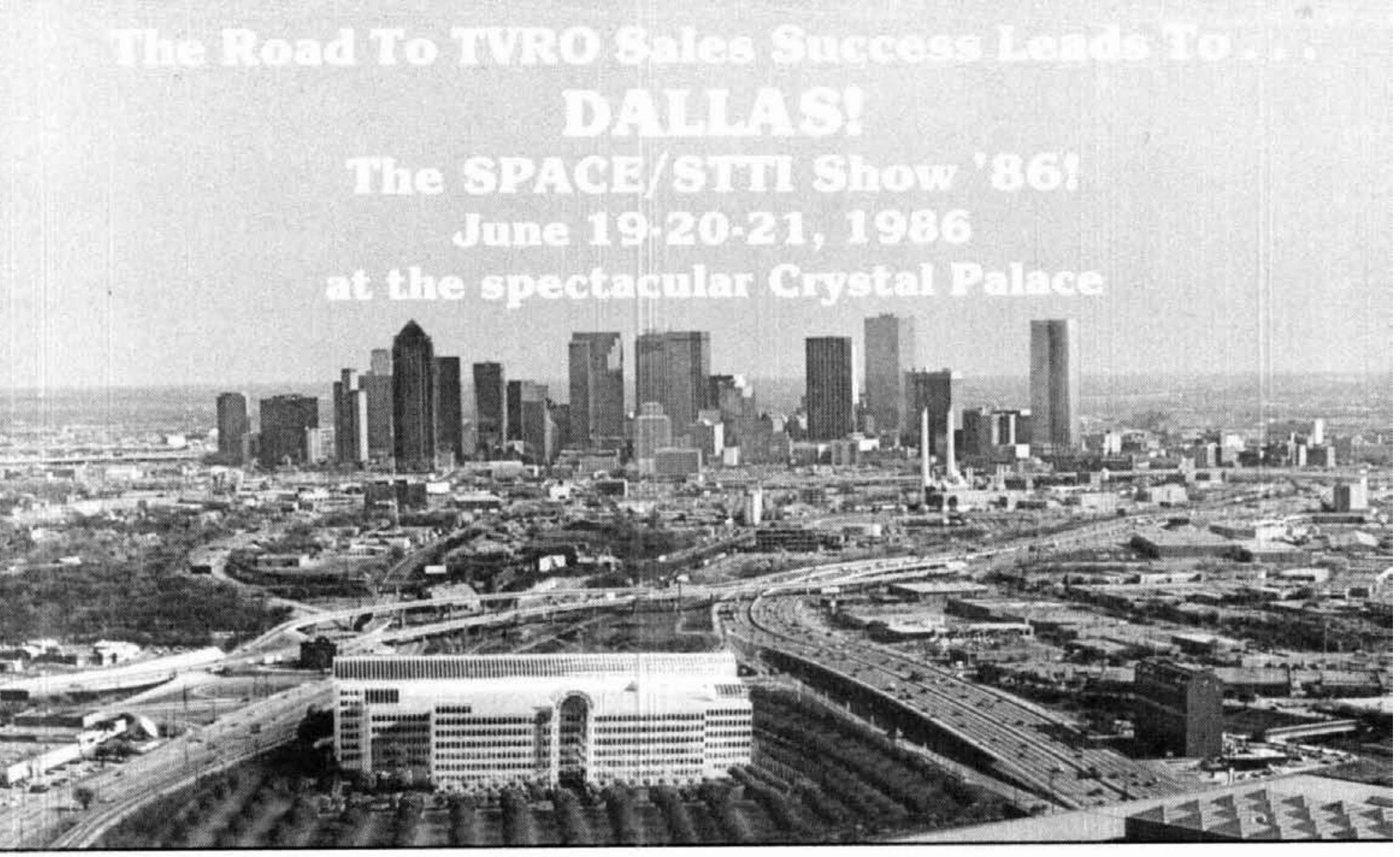
Figure 2 shows a computer-derived graph of antenna height versus skip angle. To allow the graph to be universal, antenna height is shown as a function of wavelength. Therefore, when you find the desired height, the physical height can be determined from the familiar equation of $\lambda = 984/f$, where λ is measured in feet and f is the operating frequency in MHz. For example, if the optimum height 0.75 λ, find λ for your operating frequency by multiplying it by 0.75. This allows the graph to be used at any frequency.

To explain the use of the graph, let us say we determined the distances we wanted to cover to be a range of 10 to 500 miles. From **fig. 1**, this translates to a radiation angle range of 87 to 37 degrees. From **fig. 2** we find the antenna could be anywhere betwen 0.1 and 0.4 λ for 87 degrees and between 0.2 and 0.6 λ for 37 degrees. To cover the desired range we need a horizontal antenna located between 0.2 and 0.4 λ. Since this is probably a good ragchew antenna for 75 meters, this translates to: $\lambda = 984/3.9 = 252$ feet (76.9 meters). Therefore, 0.2 λ = 50 feet (15.4 meters) and 0.4 λ = 101 feet (30.8 meters).

The black area of the curve covers the 3 dB beamwidth of the antenna. At 50 feet the antenna gain would be down 3 dB at a takeoff angle of 37 degrees, and down 3 dB at 87 degrees. The peak of the antenna pattern would be in the center of the black area of the curve.

Understanding the graph may be simplified by relating it to a "standard" antenna pattern. **Figure 3** shows the pattern of a dipole 1.25 λ above ground. If you were to draw a line on **fig. 2** at a height of 1.25 λ, you'd note that it would cross the first black curve at

By Ted Hart, W5QJR, P.O. Box 334, Melbourne, Florida 32902



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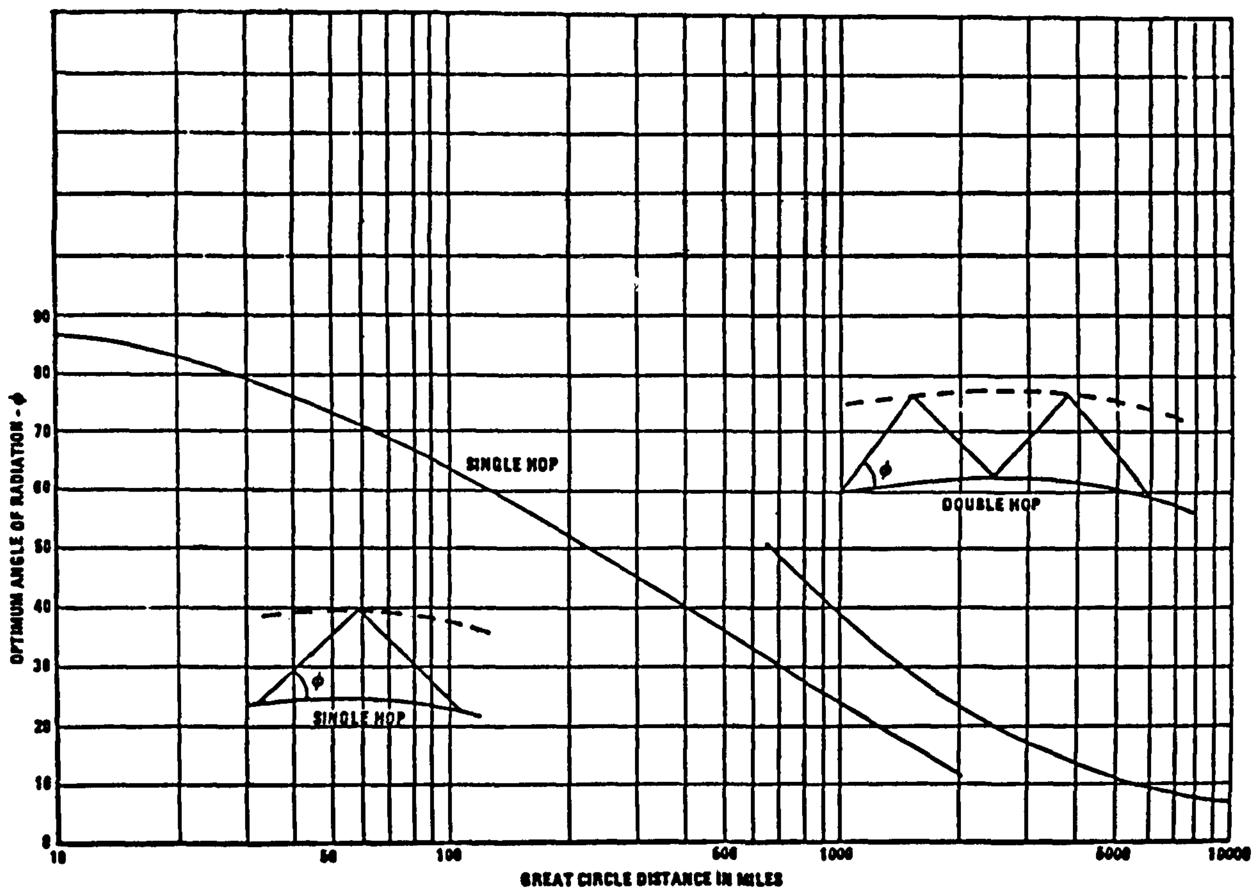


fig. 1. Optimum angle of radiation vs. distance for 1-hop and 2-hop communications based on average height of ionosphere.

5 degrees and 18 degrees (corresponding to the first lobe in the pattern), at 30 degrees and 45 degrees (corresponding to the second lobe), and at 62 degrees and continuing through 90 degrees on the third lobe. Hence, the multiple black areas correspond to the multiple lobes of the antenna pattern, when the antenna is high above ground. The areas between the black areas correspond to the nulls in the antenna pattern.

For a beam antenna, the same curves apply, except that the beam reduces the lobes on the back side because of the front-to-back ratio.

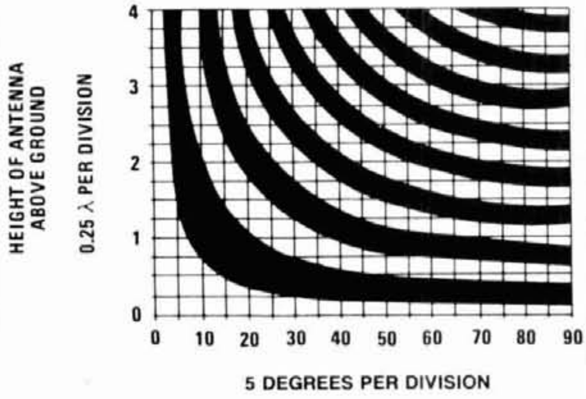
The graph presents only the elevation angles of the various lobes in the antenna, not the relative amplitudes. Typically, one lobe will be predominant in amplitude, with the other lobes at a reduced level. Since very few ham antennas are used at heights above one wavelength, this is a secondary consideration.

The graph also applies to vertical antennas. Normally, Amateurs use verticals only at ground level, but if the vertical were raised to a great height, multiple lobes wold appear in the radiation pattern. Since a vertical is a complement to a horizontal antenna, where one has a lobe the other would have a null in its pattern, asssuming both were at the same height. When using the graph for vertical antennas, simply use the areas that are not dark to derive the pattern.

what are your antenna's characteristics?

By working backwards, you can readily determine the range of communications for your existing antenna. Measure the height of the antenna and draw a corresponding line on **fig. 2**. Determine the elevation angles of the lobe(s), transfer that information to **fig. 1**, and read the corresponding range of communications distances. Again note in particular the nulls in the antenna pattern and the corresponding range. Now you know why you rarely talk to anyone at a distance that corresponds to a null in the antenna pattern. Also note that horizontal antennas close to the ground do not provide signals at low angles; consequently they're not useful for long range communications.* Conversely, vertical antennas don't radiate at high angles and are therefore not useful for short-

*Unless other modes of propagation exist — e.g. ducting, M, N, derived, etc. — Ed.



SKIP ANGLE

ANTENNA HEIGHT VERSUS SKIP ANGLE
USE SOLID AREA FOR HORIZONTAL POLARIZATION,
USE BLANK AREA FOR VERTICAL POLARIZATION

fig. 2. Antenna height vs. skip angle.

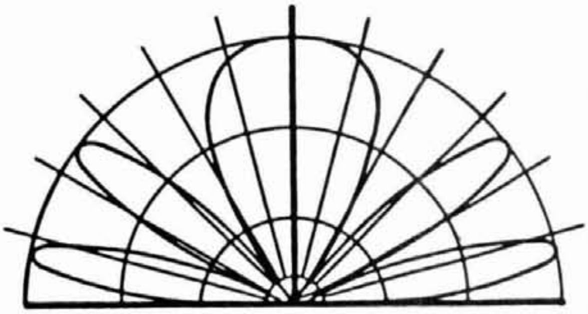


fig. 3. Dipole 1.25λ above ground.

range communications (less than 500 miles). Truly complete Amateur stations have both dipoles and verticals for the low bands.

summary

Figures 1, 2, and **3** were reproduced from my book, *The Rules of The Antenna Game — Alias What Every Ham Must Know About Antennas*, available from the author for $5.95 + $1 for postage and handling. Please address inquiries to Ted Hart, W5QJR, W5QJR Antenna Products, P.O. Box 334, Melbourne, Florida 32902.

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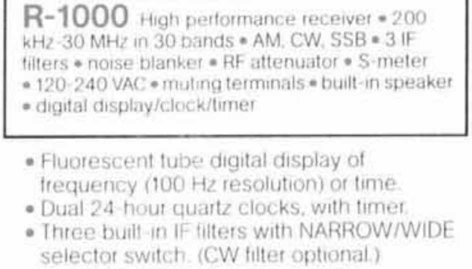

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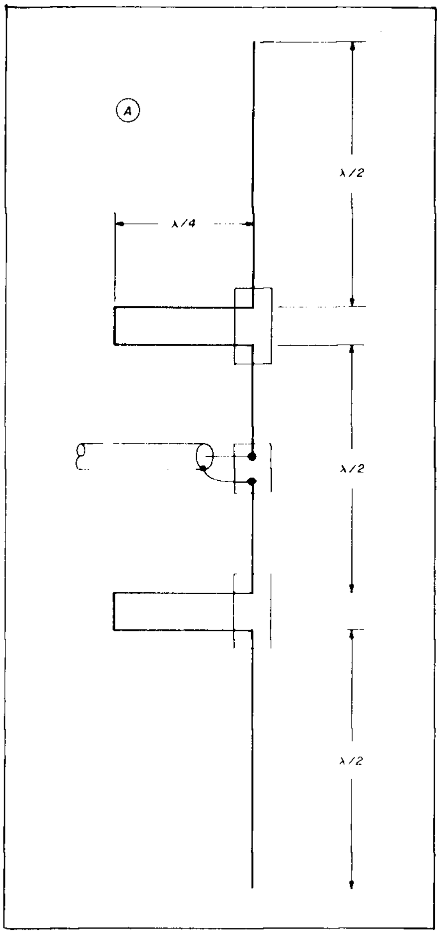
the ham notebook

long 2-meter collinears — a simple way to achieve gain

Depending on the size and construction techniques chosen, it's possible to build vertical or horizontal collinears in as little as one hour — or at most, one day. The cost is low, and gain can be increased by adding elements, one set at a time, to the array. Support can be a rope attached to a tree, a tower, or a building.



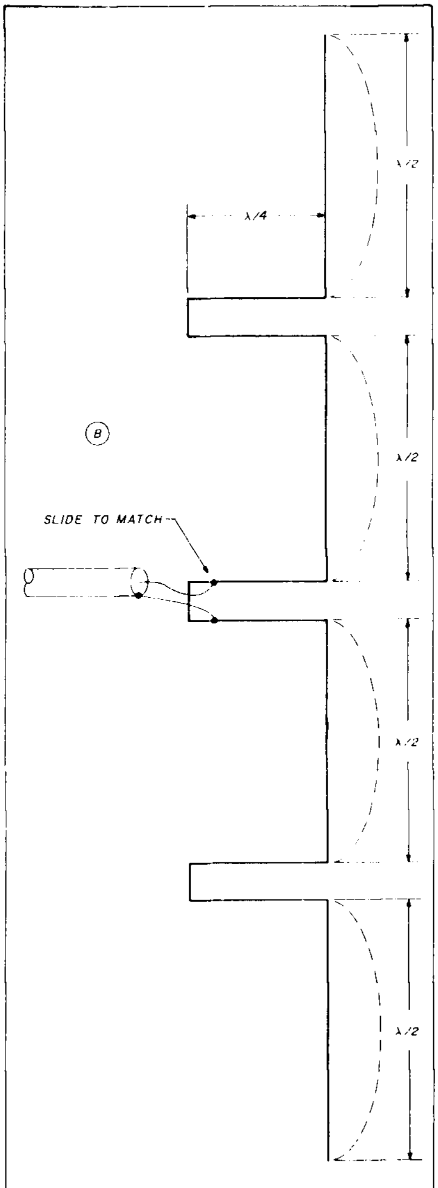


fig. 1. Two examples of half-wave collinears (*A*) 3 section, (*B*) 4 section.

With only moderate variation in gain and SWR, a 2-meter collinear can be cut and matched for the middle of the band and it will work over the entire 4 MHz.

The antenna illustrated in **fig. 1** is a string of half-wave elements laid end-to-end and fed in phase by a series of half-wave delay lines (quarter wave shorted stubs). For use on 2 meters, the antenna is made from No. 12 solid copper wire. PVC pipe is used for insulators.

My antenna is fed with coax. The VSWR is less than 1.5:1 over the entire band at the transmitter. With a ten-element array, I've had contacts with mobile stations 50 miles (80 km) away and constant contacts through repeaters 80 to 100 miles (128 to 160 km) away.

If side-mounted on a tower or pole, three collinears can be phased so that two can be used simultaneously, with an additional 3 to 4 dB gain realized in any six directions.

gain over a dipole

2-element	1.9 dB
3-element	3.2 dB
4-element	4.3 dB
10-element	10.0 dB
20-element	13.0 dB
40-element	16.0 dB

The phasing stub supports are PVC pipe measuring 2.5 inches (6.35 cm) long and drilled 0.5 inch (1.27 cm) from the ends. By changing the dimensions for other bands, this type of antenna can be used horizontally for gain on 432 MHz and 6, 10, and 15 meters, etc. On 6 meters it works especially well for auroral contacts when set up to radiate horizontally, north and south. It's better than a 5-element beam.

The feedpoint impedance is a function of the array.

Figure 2 provides the actual lengths used in a six-section collinear together with construction notes. Provide a loop at both ends for the support rope

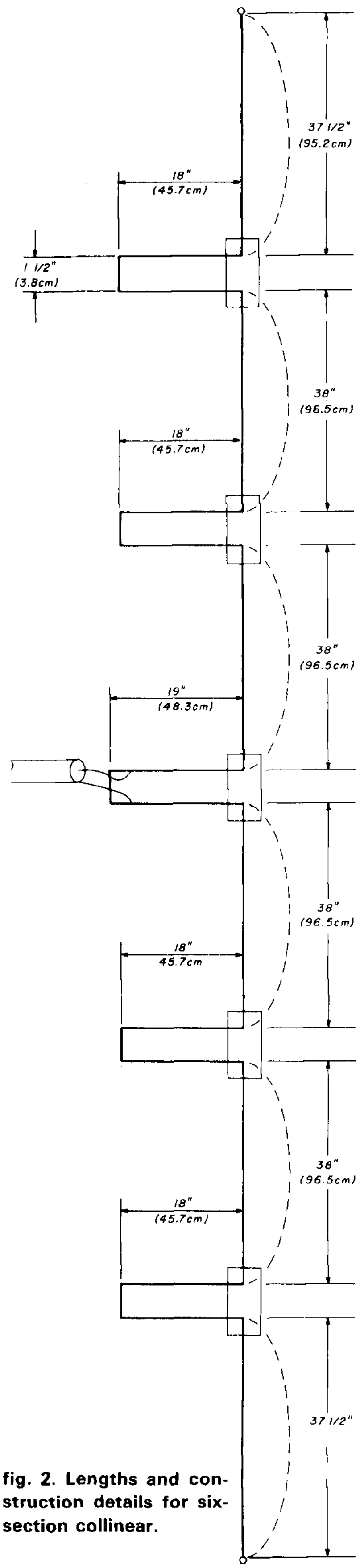


fig. 2. Lengths and construction details for six-section collinear.

or insulator and support wire. Assemble all driven elements, then add the phasing stubs, made from No. 12 or larger stiff copper wire, to be self-supporting for vertical mounting. Slide the coax feed along the driven stub in order to achieve the lowest VSWR. **Figure 3** shows one method of increasing the gain of the "Ringo Ranger" through the addition of a two-section collinear.

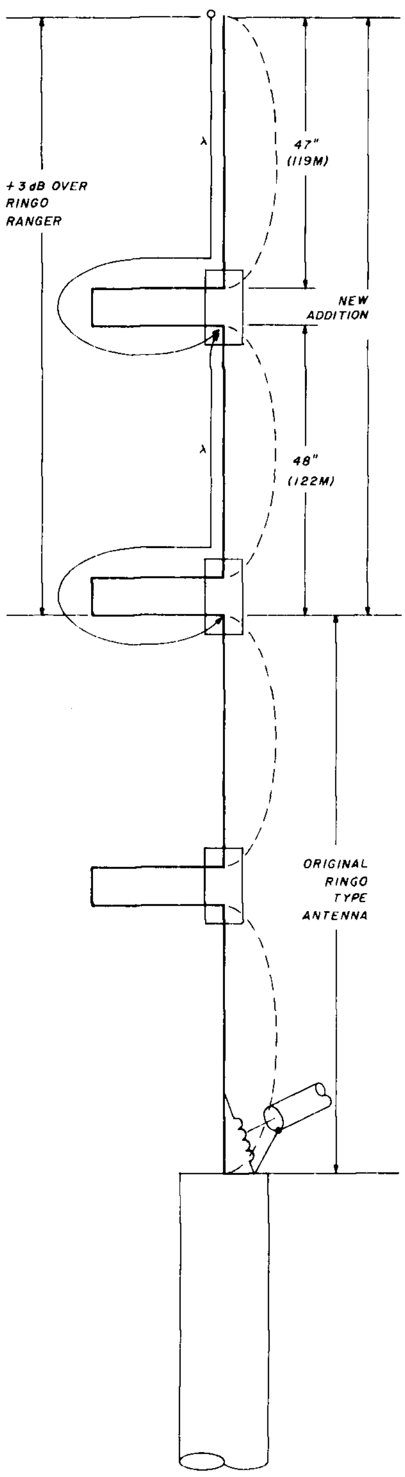


fig. 3. Modifying a Ringo Ranger provides 3 dB more gain.

larger design

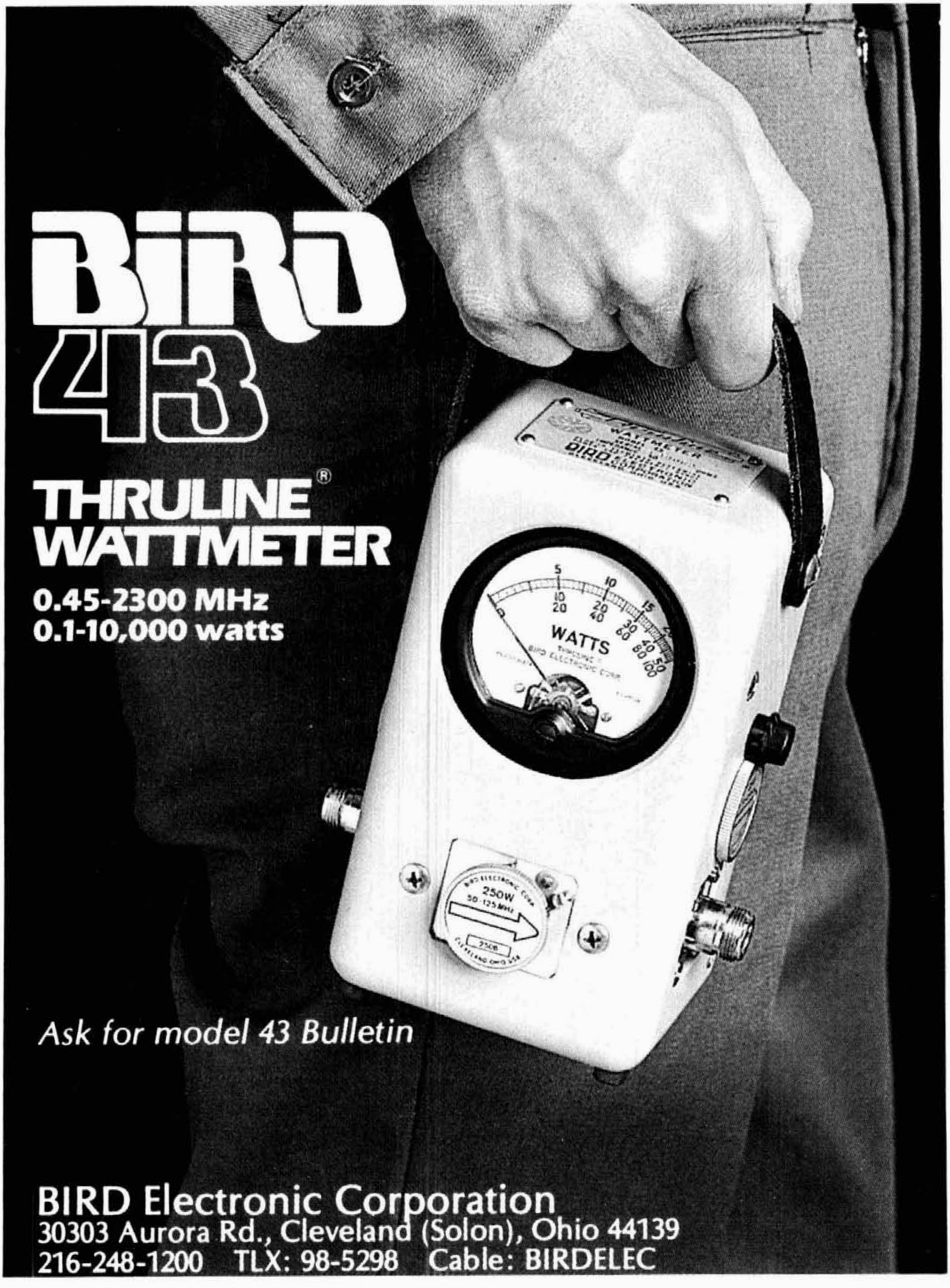
I've built antennas using this design for 435 MHz, 439 MHz, and 2 meters for horizontal operation. My horizontal 2-meter antenna is a 40-element version in an inverted V form, made from No. 22 stranded teflon-coated wire.

acknowledgements

My thanks to WA1YJZ and WA3PGL for the tests and support while I experimented with these antennas over the years.

Please enclose an SASE with any inquiries, which should be addressed to me at R.D. 1, Union City, Pennsylvania 16438.

Leonard E. Shick, WB3AYW



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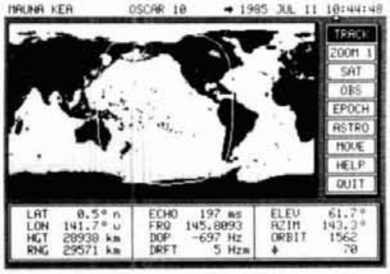

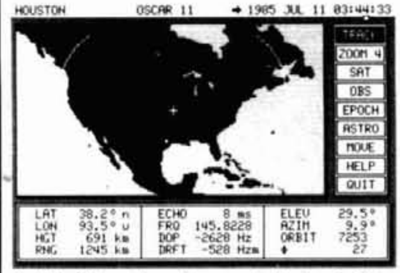

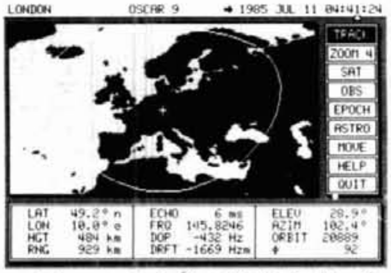

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VHF/UHF WORLD

Joe Reisert W1JR

Yagi facts and fallacies

Surely the Yagi beam is the most commonly used Amateur antenna between 14 and 450 MHz — and rightfully so. It can yield higher gain for its physical size than any other antenna type. Its low profile makes it an excellent choice for those who are either stacking an array for very high gain or desire to operate several bands using the same antenna mast.

Over the past ten years there has been a definite improvement in the gain and especially the radiation pattern of long, high-gain Yagi beams. However, with these improvements there have also been seemingly unexplainable performance failures that have created confusion. Furthermore, pretentious gain claims have been made by some well-intentioned Amateurs.

In light of the above, I'm going to devote this month's column to the Yagi beam. Emphasis will be placed on attaining optimum performance. Certain problem areas will be discussed. I hope this material will be informative and put some of the myths to rest. In addition, it should provide guidance on how to select the proper parameters and obtain optimum performance when designing and building Yagis.

history

First, a few notes on the development of the Yagi-type antenna might be in order. The basic Yagi antenna structure as we know it today is classified as an "end fire" array. It usually consists of a single driven element with a reflector and one or more directors (**fig. 1**). The reflector is used mainly to decrease radiation off the rear of the antenna; the directors primarily determine the shape of the radiation pattern (or gain) in the forward direction.

The Yagi antenna was first developed in Japan during the late 1920s by Dr. H. Yagi and S. Uda.[1] Dr. Yagi published abroad in English, giving rise to the "singular" credit for this type of antenna.[2] His work with Uda on this antenna was published in book form in reference 3.

In the early days the Yagi antenna was typically used with only two to six elements. In the 1950s Kmosko and Johnson published one of the first really long Yagi antenna designs.[4] However, their heuristic ("cut and try") work had somewhat less gain than claimed and the radiation pattern had many sidelobes. These designs used tapered spacing and little or no director length tapering.

Greenblum published what was probably the first cookbook on Yagi designs.[5] However, how his graphs were to be used wasn't completely clear; some missed the point that the elements were through the boom, and the director lengths included the boom correction. The director spacings were not specific (a range of values was given) and some director lengths were also missing on the original charts. Regardlesss of the above, Tilton had great success using Greenblum's designs.[6,7,8]

Ehrenspeck and Poehler showed yet another design approach primarily aimed at decreasing the number of elements in the director structure; patterns were not optimized.[9]

Many years later, Dr. Ehrenspeck suggested that the best design for gain was probably the 0.3 wavelength spaced model.[10] He also said that if two additional directors were added to the front of the structure (as shown in **fig. 2**), that pattern could be improved and the gain increased by up to 1.0 dB.

Other individuals likewise published specific designs, but Amateurs really had to wait until Viezbickie and Reisert published the NBS Yagi designs.[11,12] Unfortunately, the NBS designs covered only six specific boom lengths, 0.4, 0.8, 1.2, 2.2, 3.2, and 4.2 wavelengths. Therefore, one couldn't easily design intermediate or longer boom designs (more on this later).

Hoch published design curves for Yagis of any length up to 47 directors.[13,14,15] His initial work was based on the designs of Greenblum.[5] He was able to improve the patterns and gain as well as account for the boom corrections. Hoch's designs work particularly well with booms 2 through 20 wavelengths long.

However, credit for the really serious work on tying down the optimum element lengths and spacings for Yagi antennas should probably go to Morris.[16] In his PhD thesis, he wrote computer programs to not only determine Yagi antenna patterns but also to optimize the lengths and spacing based on the desired pattern and gain.

Morris's work was followed by that of Chen and Cheng and others in the professional community who had access to large mainframe computers capable of handling the complex current matricies.[17,18] The late Dr. Jim

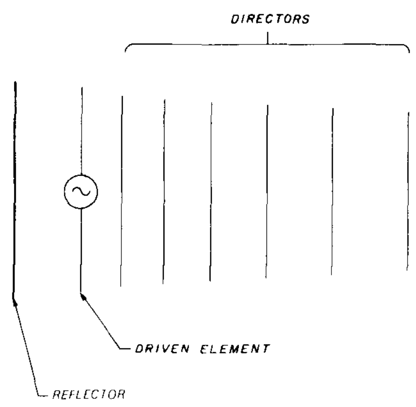

fig. 1. This is a typical Yagi antenna structure.

Lawson, W2PV, published similar work in the Amateur field, although his designs were limited to about 1.75 wavelengths.[19] Finally, Stan Jaffin, WB3BGU, published a program to do Yagi pattern measurement with a home computer,[20] giving the enterprising Amateur all the tools he or she needed to do serious Yagi design and optimization.

facts and fallacies

The above history is brief but necesary for understanding the development of the Yagi. Now let's proceed into the general area of facts and fallacies about it:

1. *The gain of a Yagi antenna is determined by the number of elements.* This is false. Gain is primarily a function of the length of the boom. The number of directors and their length and placement on the boom is a secondary factor that determines whether the gain for a particular boomlength is achieved, as well as the bandwidth, pattern shape and sidelobe levels.

Figure 3 is used to illustrate this point. This graph shows the highest possible gain that can be attained by a Yagi antenna on a specific boomlength (in terms of wavelengths). Note that the gain of a typical well-designed Yagi antenna increases in a logarithmic fashion at about 2.2 dB for each doubling of the boom length. Gain is shown both in dB over a dipole and dB over an isotropic.[23]

Therefore, using the graph in **fig. 3**, it can be shown that the highest possible gain for a 5-wavelength boom Yagi is approximately 15.3 dB over a dipole or 17.45 dB over an isotropic radiator. In reality, it will seldom be possible to attain this gain. If you can get within 0.5 dB of the value shown, consider yourself lucky!

2. *A greater number of directors for a specific boomlength can increase the bandwidth of a Yagi antenna and improve the radiation pattern.* This is true. There are a minimum number of elements needed for each boomlength. Evidence of this was described above in the discussion of the Ehrenspeck and Poehler Yagi designs.

However, if only this minimum number of elements is used, the pattern may have poor sidelobes, the front-to-back ratio may be low, and/or the frequency operating bandwidth narrow. You may ask why the latter item is important, since most weak signal operators operate only over a narrow bandwidth. The reason is that less pattern distortion will be prevalent with lesser element tolerances, weather changes, or structural changes — e.g., if an element loosens or breaks.

3. *Yagi antennas with high gain usually have good front-to-back ratios.* This isn't always true. The maximum gain and highest front-to-back ratio are not always coincidental for a specific boomlength. This means that for some boomlengths, either the gain or the front-to-back ratio may be optimum, but not necessarily coincident.

The NBS Yagis are an example of this phenomenon.[11,12] The 0.8 through 4.2 wavelength models were carefully designed to have both good gain and reasonable front-to-back ratio at the same time. Viezbickie noted that the gain increased similar to that shown in **fig. 3**, but small oscillations above and below the line were noted. He also stated in his report that certain boomlengths had slightly higher gain.

It has since been shown by computer analysis that certain boomlengths naturally exhibit high front-to-back ratio and optimum gain simultaneously.[19]

For the majority of moderate boomlength designs (less than 2 wavelengths), and especially the NBS designs, the optimum boomlength tends to be a multiple of odd quarter wavelengths long (for example, 0.75, 1.25, 1.75 wavelength, etc.). This probably explains why the particular NBS designs were chosen.

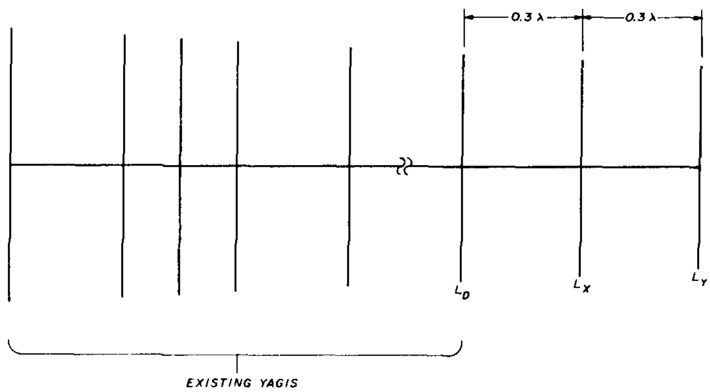

fig. 2. These are suggested improvements to the 0.3 wavelength spaced design of Ehrenspeck and Poehler.[9] L_D is the length of the last director in the original design. L_X is 5 percent shorter than L_D and L_Y is 10 percent shorter than L_D. The pattern is improved and the gain is increased by up to 1 dB.

At my request Stan Jaffin, WB3BGU, ran some examples of my DL6WU designs[15] on his mainframe computer program.[20] The results were quite interesting and I've plotted this data on the graph shown in **fig. 4**. Note that in the DL6WU designs there are also optimum boomlengths, but they seem to be spaced about 2 wavelengths apart. I would recommend using, if possible, the specific boomlengths where the front-to-back ratio is highest.

4. *Tubing and rods of the same diameter have the same electrical wavelength.* This is definitely not true, but this fact appears to have escaped most Yagi designers, especially at the lower frequencies, where tolerances are not as much a problem as they are in the UHF range. The NBS Yagi designs used rods for their elements.[11] Therefore, if you use an NBS design with tubing, the electrical length may not be the same as it would be with an equivalent rod. A UHF design may be slightly off frequency.

This phenomenon was apparently known by those who did the NBS Yagi designs. One document showed that if the end of the element was hemispherical instead of a flush cut, the frequency shifted upwards. The recommended change was to add an overall lengthening factor of 0.4 times the diameter to the element (0.2 times the element diameter to each end of the element).

Steve Powlishen, K1FO, has also noticed this phenomenon and has seen even a chamfer on the end of an element shift the frequency up perhaps 1 MHz or so at 432 MHz. A word to the wise: if you don't use solid rods and/or don't cut the end of the element off flush, check the resonance to see if the frequency shifted upwards!

5. *Scaling elements must be done using the published charts and graphs similar to those of Viezbickie, Reisert, and Hoch.*[11,12,14,15] This is not true. Scaling performed on these charts can be accurate if you don't make any mistakes in the process!

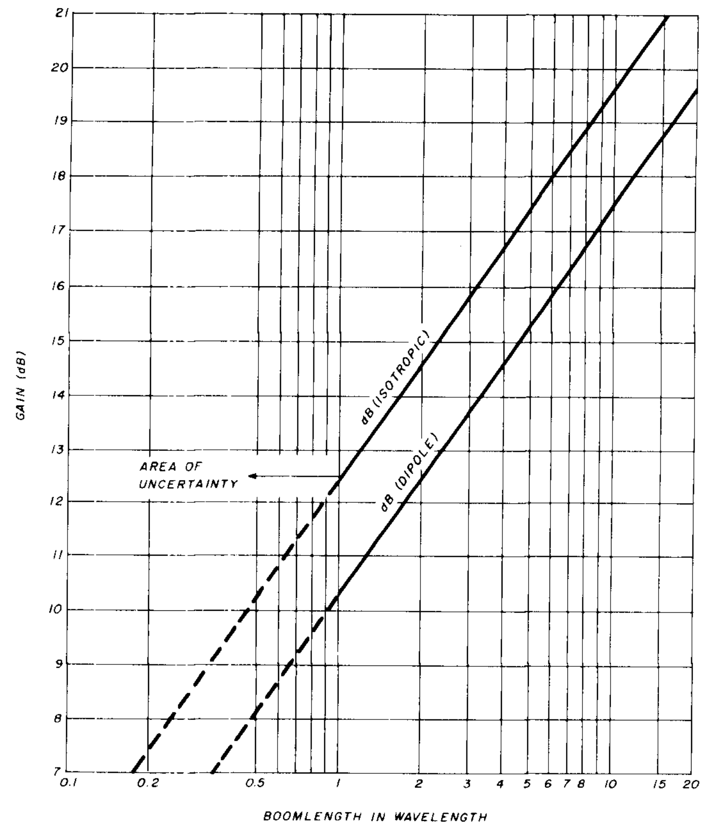

fig. 3. This graph represents the highest possible gain that can be achieved on a conventional (single plane) Yagi antenna. See text for further explanation.

However, scaling can also be done quickly — with probably greater accuracy — on a computer using the methods and equations 8 through 13 proposed by Lawson.[21] These equations can easily be programmed on a personal computer to yield rapid and accurate data without referring to graphs.[22]

6. *The NBS designs are the best Yagi designs available.* This is false. The NBS designs are good and reproduceable. However, they represent only six specific models, as discussed above.

Computer analysis has shown some discrepancies in these antenna designs.[19] Others have found that the patterns and gain don't match the data in the technical note at the design frequency on several of the models. Stan Jaffin, WB3BGU, has shown that if an extra director is placed approximately 0.15 wavelength ahead of the driven element on the 4.2 wavelength design, the gain can be increased by almost 0.5 dB.[20] This has been verified by at least one antenna manufacturer.

The NBS designs are good and reproduceable. If you feel comfortable with them, and if the boomlengths presented fit your needs, by all means use them. Perhaps you should also try the extra director. However, if you add this director to an existing antenna, it will change the impedance match. If the boomlengths of the NBS Yagis are too short, try one of the DL6WU designs.[15]

7. *The best reflector system is the trigonal method proposed by NBS.* This is definitely *not* true. When I first tried this reflector system on a 3.2 wavelength NBS Yagi, the gain dropped by almost 1.5 dB below the same antenna with a standard reflector. Repeated tests showed that the reflector lengths suggested by NBS were definitely too short.

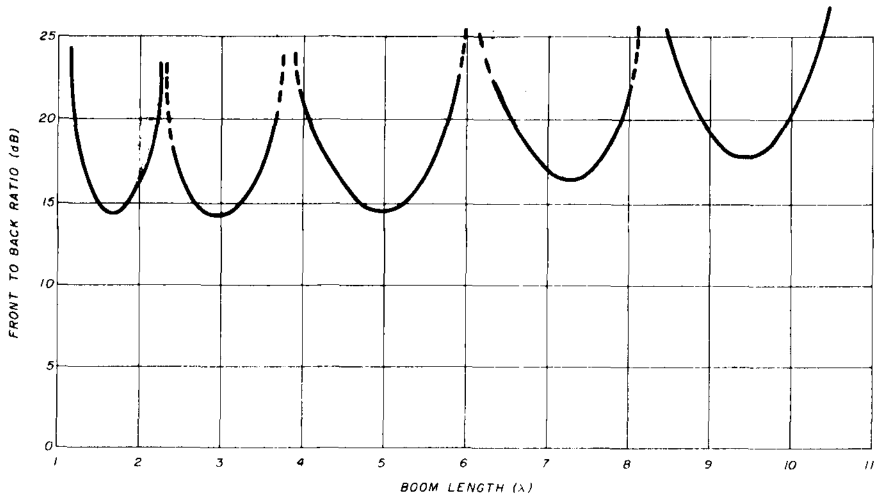

fig. 4. This is tabulated data from computer analyzed front-to-back ratio versus boom-length for the DL6WU Yagi designs.[15] Note the boom lengths where the front-to-back ratio is naturally highest.

I lengthened all three reflectors by 0.007 wavelength, the length needed to make them similar to the existing single reflector. Voila! The gain came back to normal. Repeated measurements showed, however, that the gain of a trigonal reflector system over a single reflector as suggested by NBS was only about 0.1-0.2 dB with perhaps 6 dB better front-to-back ratio. In hardware alone, this represents quite an increase in mechanics and wind load!

Several years later I mentioned this to Stan Jaffin, WB3BGU, and suggested that he could somehow test my theory on his computer program.[20] His tests confirmed my results and showed the same gain changes with the optimum lengthening factor to be 0.009 wavelengths.[24]

8. *The VSWR of an a Yagi is not important.* This is false. Although a moderate (2:1) VSWR would not seem to be important, it can be detrimental at VHF and especially UHF. The reason is that the feedline losses increase, especially if the nominal insertion loss is high (>1dB).

High VSWR can also be a sign that there is something wrong with the design. I once noticed high VSWR on a commercial antenna, only to find that the position of the hole for one of the directors was misdrilled. In addition, if the VSWR on an antenna is low and it changes, this can be an indication of trouble.

Then there's stacking, a typical way to increase gain on VHF and above. A high VSWR may have a very adverse effect when two or more antennas are summed together. Poor matching could divert more power to one of the antennas which would "hog" the power and thus decrease the anticipated gain increase.[25]

9. *Stacking antennas is a good way to increase gain.* This is true. However, the antennas must be properly designed and stacked a certain distance apart to obtain the increased gain. If the spacing distance is too close, the gain increase will be low. Stacking too far apart will increase sidelobes and noise pickup. The basics of stacking are thoroughly discussed in references 25 and 26.

10. *Elements that are insulated from the boom of a Yagi work better than those that are in ohmic contact with the boom.* This is definitely false. There are advantages and disadvantages to either type of mounting.

Insulated elements are less likely to induce boom resonances on other bands, a common problem on HF. While it can be argued that the insulators don't corrode, it can also be proved that the dielectric material in the insulator can get contaminated or deteriorate with age and exposure to the sun and weather.

Mounting elements in ohmic contact with a boom is a technique that has been around for a long time. This method is less likely to produce problems with static buildup and stray HF pickup from the feedline. Usually this technique is easier to use, and if the elements are properly installed without dissimilar materials, the corrosion problem is minimal.

Finally, some of the myths about element mounting have been perpetrated by those who say that antennas with insulated elements are detuned during wet weather. Tests have shown that by pouring water on an existing antenna with and without insulated elements that the detuning effects are about the same for either method *using a similar Yagi design*.

The primary reason for detuning in a Yagi antenna during wet weather is the sensitivity to element diameter. When ice or water is present on an element, its electrical length is changed. The higher the gain and the closer the antenna is operated to its cutoff frequency, the more the detuning effect will be noticed.

11. *Boom corrections are not important since the boom does not detune the element.* This is a serious misconception. The easiest way to envision the electrical characteristics of a boom is that it shorts out part of the elements. Therefore, any elements passing near or through a boom must be *lengthened* to reestablish the intended electrical length.

Fortunately, if too little correction is applied, the frequency of a Yagi is increased. It is well known that a Yagi antenna has a very rapid cutoff above resonance and a slow cutoff below resonance. Hence, if the correction factor is too small, only a slight degradation in performance will be noticed.

Boom corrections seem to be a big


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106	118	130	142	154	166	178	190	202	214	226	238	250	262	274	286	298	310	322	334	346
107	119	131	143	155	167	179	191	203	215	227	239	251	263	275	287	299	311	323	335	347
108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	312	324	336	348
109	121	133	145	157	169	181	193	205	217	229	241	253	265	277	289	301	313	325	337	349
110	122	134	146	158	170	182	194	206	218	230	242	254	266	278	290	302	314	326	338	350
111	123	135	147	159	171	183	195	207	219	231	243	255	267	279	291	303	315	327	339	
112	124	136	148	160	172	184	196	208	220	232	244	256	268	280	292	304	316	328	340	

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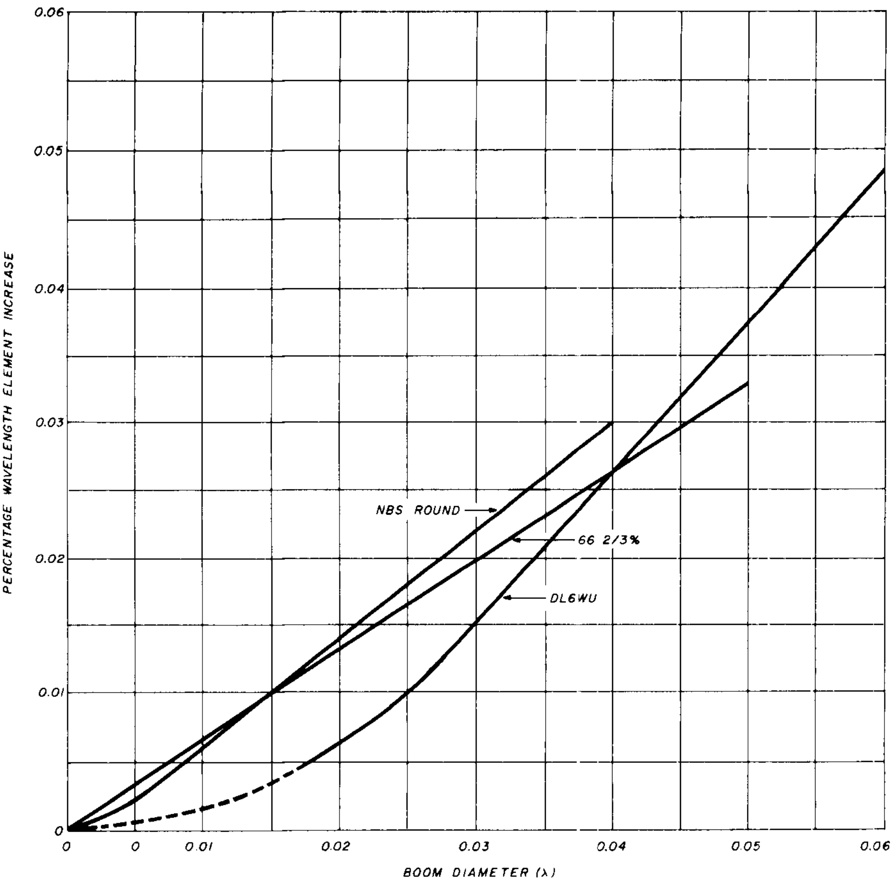

fig. 5. This graph shows three of the most popular boom correction factors. See text for further explanation.

mystery despite the fact that they've been mentioned in the literature for many years. A correction must be made whenever an element passes through or within one radius of a boom with a diameter exceeding 0.0025 wavelengths with respect to the operating frequency (0.2 inches or 5 mm at 144 MHz).

Several different correction factors have been considered. Many years ago a 66 percent correction was recommended for through the boom elements.[5] Later we had the NBS corrections.[11,12] Then DL6WU proposed a correction factor.[13] Unfortunately they don't all agree, but they are close! I have shown these corrections in **fig. 5**.

What if you don't go through the center of the boom or use insulated elements? I have measured some effects on my "backyard" antenna range. For mounting elements on top of the boom a la Cushcraft, the correction seems to be about 0.32 inches (8 mm). Using through the boom insulated elements such as the K2RIW 19-element 432-MHz Yagi seems to be about 40 to 50 percent of the NBS corrections.

Finally, when mounting above the boom, I constructed a sort of pyramid correction factor shown in **fig. 6**. It can be used to estimate the percentage of change based on where the element is mounted with reference to the boom center. For instance, if the element is mounted at least one boom radius above the boom there is no correction, but mounting right on top of the boom would require about a 50 percent correction as opposed to mounting directly through the middle of the boom.

12. *The material used for Yagi elements is important.* This is true. Aluminum is preferred since it's easy to work with, light in weight, and very efficient. Furthermore, aluminum-to-aluminum contacts are recommended. Brass is also usable, but it gets quite brittle after exposure to the weather. Copper is usually too expensive, heavy, and soft. Stainless steel elements, however, are not recommended since the skin effect will definitely lower antenna efficiency, especially above 1000 MHz.

13. *There is nothing wrong with changing an existing design.* This is definitely false unless you really know what you're doing. For example, some Amateurs have tried to second-guess the NBS designs and have invented new variations. A 4.2 wavelength NBS Yagi model at 432 MHz is less than 10 feet (3 meters) long, while standard tubing comes in 12-foot (3.5 meter) lengths. Why throw away the extra 2 feet (61 cm) of tubing, they ask? Just add on a few more elements to the extra tubing.

This approach has always resulted in disaster. The element lengths and spacings for each specific design are carefully chosen to yield a certain phase velocity. Changing a design calls for a new phase velocity. Failing to obtain the correct parameters, or changing elements arbitrarily, will usually decrease gain and distort the antenna radiation pattern.

What this boils down to is the following: if you must redesign an existing design, you can do so only if you have the proper tools at your disposal. These include, but aren't limited to, lots of know-how, an acceptable antenna range, perhaps a computer program, and lots of time and patience. Better yet, start out from scratch, using one of the NBS or DL6WU designs.

14. *Impedance matching is easy.* This is true, but you must know what you're doing. For instance, the length of the driven element in a Yagi isn't critical, but the matching method may be.

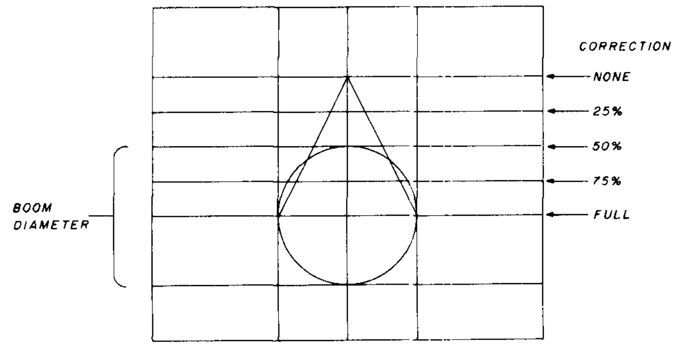

fig. 6. This figure will allow you to approximate boom corrections if an element is not placed directly through the center of a boom. (See text.)

It's been pointed out many times in this column that the Gamma match is especially poor above 150 MHz. Furthermore, Gamma matches often introduce unbalance into the antenna which may cause radiation on the feedline. A folded dipole with a 4:1 half-wave balun is an acceptable feed, but it can be difficult to match if the feed point isn't the proper impedance. I personally prefer the "T" match (without series capacitors) with a built in half-wave balun. It's inherently balanced, easy to tune, and efficient; it also suppresses the possibility of feedline radiation.

15. *Computer-designed Yagi antennas are coming.* This is true. First you'll have to have a computer program. Next, you'll need some antenna savvy on what to do to make a particular Yagi design work.

The NBS and DL6WU designs can be used for starters. Just pencil up a Yagi design. Then tweak the element lengths and spacing on the computer until you get the desired pattern.

I predict that before long, computer designs will be the most promising thing to happen in Yagi design in a long time. You'll be hearing more about this subject in the future. If you're so inclined, review references 19 and 20.

final evaluation

Now comes the fun. You've built that new super-high- gain Yagi and want to know if it plays. First the VSWR has to be matched; the lower the VSWR, the better — but 1.2:1 is more than sufficient.

If you have a radiation plot, your work is easy. Just measure the radiation pattern by the methods described in reference 23 and compare your results to the measured results. If the beamwidth is near the expected value and the sidelobes are down as many dBs as expected, you're probably in good shape.

If the beamwidth is too wide, the sidelobes are better than expected, and/or the first nulls are deeper than expected, the antenna may be tuned too high in frequency. If the beamwidth is too narrow, the sidelobes are worse than expected and/or the first nulls are shallow, the antenna is tuned too low in frequency. You're now on your way.

summary

This month's column was primarily aimed at taking the mystery out of Yagi antenna design and trying to dispel some myths. For those who are timid, the NBS[11,12] or the DL6WU[15] Yagi designs are recommended. If you have a personal computer and can obtain a Yagi program such as MININEC or those mentioned in references 19 and 20, you can "roll your own" without even cutting a piece of tubing!

acknowledgements

I'd particularly like to thank Günter Hoch, DL6WU, Stan Jaffin, WB3-BGU, Steve Powlishen, K1FO, and Dr. Hermann Ehrenspeck for their discussions with me about some of the material presented in this month's column.

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new records?

One of the greatest magnetic storms in recorded history occurred on February 8 and 9, 1986. While the HF bands went dead, numerous auroral contacts were made as high as 432 MHz over some incredible distances. If you had an aurora QSO over a longer distance than shown in **table 4** of this column in the July, 1985 issue, I'd like to hear from you so we can see whether you've set a new aurora record. Forms for authentication are available for an SASE.

A new 9-cm (3456 MHz) world record was made by VK5QR and VK6WG across the great Australian Bight for a distance of approximately 736 miles (1185 km) on January 25, 1986. Soon afterwards, a new North American 13-cm (2304 MHz) overland tropo DX record was made between W4ODW and WB5LUA. Hearty congratulations to all! (Stay tuned for more details.)

important VHF/UHF events:

May 4:	*Predicted peak of the Eta Aquarids meteor shower at 1900 UTC*
May 8:	*ARRL 1296-MHz Sprint Contest*
May 10/11:	*Southern California 6-Meter Club QSO Party (contact N6FSL)*
May 16-18:	*12th Annual Eastern VHF/UHF Conference, Nashua, NH (contact W1EJ)*
May 17:	*ARRL 50-MHz Sprint Contest*
May 24:	*EME perigee*
June 6:	*Predicted peak of the day-time Arietids meteor shower at 0100 UTC*
June 7-8:	*ARRL VHF QSO party*
June 15:	*Predicted peak of the June Lyrids meteor shower at 2100 UTC.*
June 21:	*EME perigee*
June 21:	*Mean date* ± one month for peak of Sporadic-E propagation.

✓ 138


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2N2904 3 for $1.00
2N2904 3 for $1.00
2N2905 3 for $1.00
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12 V.C.T. @ 400 ma. $3.00
12 V.C.T. @ 1 amp $4.00
12 V.C.T. @ 2 amp $4.85
12 V.C.T. @ 4 amp $7.00
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24 V.C.T. @ 1 amp $4.85
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Micro-cassette tape transport for standard MC60 or MC45 micro-cassettes. 3 Vdc operation. Contains: drive motor, belt, head, capstan, pinch wheel and other components. 3 1/2" X 2 1/4" X 5/8"
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50,000 mfd. 40 Vdc 3" x 5 3/4" high $4.50
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86,000 mfd. 30 Vdc 3" x 5 1/4" high $3.50
5,500 mfd. 30 Vdc 1 3/8" x 3 1/2" high $1.00
5,900 mfd. 30 Vdc 1 3/8" x 2 1/4" high $1.00
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CONTACTS: S.P.N.C. 10 amp @ 120 vac Energize coil to open contact... COIL: 13 vdc 650 ohms
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Compact, well-regulated switching power supply designed to power Texas Instruments computer equipment.
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Will charge 4-AA, C, D, or AAA ni-cads or one 9 volt ni-cad at one time.
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STANDARD JUMBO DIFFUSED T 1-3/4
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45¢ EACH 10 FOR $4.20
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Designed to provide a steady + 5 vdc @ 240 ma. from a battery supply of 3.5 to 6.25 volts. 2⁷/₁₆" x 1¹/₁₆ x 1¹¹/₁₆"
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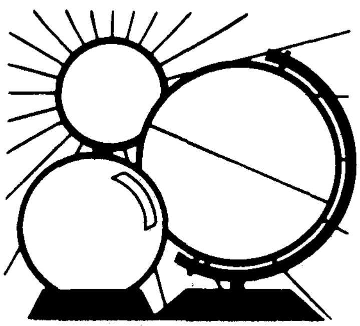

DX FORECASTER

Garth Stonehocker, KØRYW

sporadic-E propagation

From May through September the overhead sun fills the lower ionosphere with ions that support short-skip propagation, even multiple short skips. The geomagnetic field clusters these ions into cloud-like patches known as *sporadic-E.* These patches form a thin layer of intense ionization about 60 miles (100 km) above the Earth.

A patch gives a strong, mirror-like signal reflection over skip distances of 600 to 1200 miles (1000 to 2000 km). Signals remain strong for about half an hour, up to a couple of hours after the onset of the first strong signal.

Station location determines how strongly the sunspot/geomagnetic disturbances affect sporadic-E propagation, with mid-latitudes the least affected and equatorial and polar paths the most affected. The best locations for these E_S openings are in the Northern Hemisphere from June through September and in the Southern Hemisphere during their summer, December through March. The best E_S is on either side of the geomagnetic equator; it's especially good where the geomagnetic equator is furthest from the geographic equator. These special areas are Southeast Asia in the Northern Hemisphere and South America in the Southern Hemisphere, with the former the better of the two.

The highest frequency propagated by E_S occurs at local noon, following the sun across the sky. However, the highest probability of occurrence is near sunrise and again around sunset. These two characteristics of E_S affect short-skip openings differently. Openings on the higher-frequency bands occur around local noontime; the lower bands tend to have openings near sunrise and sunset.

Most of us don't live in the special areas. The maximum E_S frequencies around the mid latitudes are 8 to 9 MHz. With the oblique factor of 5 for a 2000 km maximum-hop, the E_S-MUF becomes 40 to 45 MHz (almost 6 meters). So while the 10 and 6 meter bands have a good probability of opening up, 2 meter openings are rare indeed.

last minute forecast

The second and third weeks of May are expected to be the best for the higher frequency daytime bands, 10 to 30 meters. The solar flux 27-day variation should be maximum during those weeks. The lower frequency bands for daylight, short-skip, and nighttime DX are expected to be best the first and last weeks. Disturbed periods are possible around the 10th and 21st, with MUFs down 15 to 20 percent on the first day of the disturbance.

Of interest to moonbounce DXers, the lunar perigee occurs on the 24th. The full moon occurs on both the 1st and 30th of this month. The Aquarid meteor shower, of interest to meteor-scatter and meteor-burst DXers, peaks between May 4th and 6th, with rates of 10 to 25 per hour for the northern and southern hemispheres, respectively.

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 southeast for a short period before local noon; to the south at noon and to the southwest after noon. Openings will last longer when the solar flux is at a maximum.

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 5000 to 7000 miles (8000 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 to 1500 miles (1600 to 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 lower on days of high solar flux values. In addition, no 30-meter openings will take place during the predawn hours on the morning after these high radio flux values.

Eighty and one-sixty meters will exhibit short skip conditions during daylight hours and lengthen for DX near dark when the QRN isn't bad. Eighty meters will open to the east just before your sunset, swing more to the south as midnight approaches, and end up in the Pacific areas during the hour or so before dawn. (One-sixty opens later and ends earlier.)

MAY

WESTERN USA

	Dir.	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000
PDT		4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00
ASIA FAR EAST	N	20	20	20	20	30	20	20	20	20	20	20	20	20	30	20	20	20	20	20	20*	15	15	15	20*
EUROPE	NE	20	20	20	20	15	15	15	15	15	15	20	20	20	20	30	30	20	20	20	30	30	30	30	30
S. AFRICA	E	20	20	15	15	12	12	10	10	10	12	12	15	20	20	20	20	15	15	20	30	20	20	20	20
S. AMERICA	SE	10	10	10	10	10	10	12	12	12	15	20	20	20	30	20	20	20	20	20	20	15	15	12	12
ANTARCTICA	S	15	15	15	15	20	20	20	40	40	40	40	40	30	30	30	30	30	30	30	20	20	20	15	15
NEW ZEALAND	SW	10	10	10	12	12	15	20	20	20	20	20	20	20	20	20*	15	12	12	10	10	10	10	10	10
OCEANIA AUSTRALIA	W	10	10	10	12	20	30	30	30	30	20	20	20	20	20	20	20*	12	10	10	10	10	10	10	10
JAPAN	NW	15	20	20	20	20	20	30	30	30	20	30	30	30	20	20	20	20	20	15	15	15	15	15	15

MID USA

	Dir.	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000
MDT		5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00
ASIA FAR EAST	N	20	20	20	20	30	30	20	20	20	20	20	20	20	20	20	20	30	20	20	20*	15	20	20	20
EUROPE	NE	20	20	20	20	20	15	15	15	15	15	20	20	20	20	20	30	30	30	20	20	30	30	30	20
S. AFRICA	E	20	20	15	15	12	12	10	10	10	12	12	12	15	20	20	20	20	20	20	30	20	20	20	20
S. AMERICA	SE	10	10	10	10	10	10	10	12	12	12	15	20	20	20	30	20	20	20	20	20	15	15	12	12
ANTARCTICA	S	15	15	15	20	20	20	20	40	40	40	40	40	40	40	40	30	30	30	30	20	20	20	15	15
NEW ZEALAND	SW	10	10	10	12	12	12	20	20	20	20	20	20	20	20	20	20	15	12	12	10	10	10	10	10
OCEANIA AUSTRALIA	W	10	10	10	12	20	30	30	30	30	30	20	20	20	20	20	20	15	12	10	10	10	10	10	10
JAPAN	NW	15	15	20	20	20	20	30	30	30	20	20	20	20	30	30	30	20	20	20	20	20	15	15	15
CDT		6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00

EASTERN USA

	Dir.	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000
EDT		7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00
ASIA FAR EAST	N	20	20	30	30	30	20	20	20	20	20*	15	15	20*	20	20	20	20	20	20	20	20	20	20	20
EUROPE	NE	20	20	20	20	20*	15	15	15	15	20*	20	20	20	20	20	20	30	30	30	30	30	30	20	20
S. AFRICA	E	20	20	15	15	12	12	10	10	10	10	12	12	12	15	20	20	20	20	20	30	20	20	20	20
CARIBBEAN S. AMERICA	SE	10	10	10	10	20	10	10	10	12	12	12	15	20	20	30	20	20	20	20	20	20	15	12	12
ANTARCTICA	S	20	20	20	20	20	20	20	20	40	40	40	40	40	40	40	40	30	30	30	30	30	20	20	20
NEW ZEALAND	SW	10	10	10	10	12	15	20	20	20	20	20	20	20	20	20	20	20	15	12	12	10	10	10	10
OCEANIA AUSTRALIA	W	10	10	10	12	15	30	30	30	30	30	20	20	20	20	20	20	20*	15	12	12	10	10	10	10
JAPAN	NW	15	15	20	20	20	20	30	30	30	20	20	20	20	20	20	20	20	20	20	20	20	20	15	15

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

*Look at next **higher** band for possible openings.

ham radio

HAM RADIO MAY SHOWERS BOOK FLYER

—SOFTWARE—

RF NOTES — IBM-PC

NEW C-64 VERSION AVAILABLE

by John Simmons, W6MDI

RF Notes Vol. 1 is now available for the Commodore C-64 home computer.
Volumes contain programs written by RF consulting engineers that answer a number of very important often asked questions. IBM-PC version written in Basic A and fully menu driven. Graphics card and 128K memory required.

Volume 1

Contains: *dB conversions*, to convert voltage, current or power levels to dB; *dBm conversions*, converts voltages or power levels to dBm and dBm to voltage or power; *VSWR calculations*, calculates VSWR and return loss when both reflected and incident powers are known; *Filter design*, 14 different filter configurations including schematics (6 low pass, 4 high pass, 2 band pass and 2 band elimination circuits; *Basic Microstrip and strip line design*, *Resonant Circuits*, design parallel and series resonant circuits, pi, capacitive and inductive impedance divider circuits.

☐ **E-RF1** IBM-PC	**$59.95**
☐ **E-RF641** Commodore C-64	**$64.95**

Volume II

This program covers: *Attenuator pads*, calculates constants for eleven different pad configurations (all with circuit diagrams.) Inductors, inductance in a single length of wire, single layer coils, both close and wide space wound and Torroidal coil design that gives automatic selection of wire size and torroidal form. Capacitors, calculates self resonant frequencies, determines optimum bypass values and decoupling applications. Impedance Matching Networks, including, L, pi, T and series L configurations.

☐ **E-RF2** IBM-PC **$59.95**

Volume III NEW
BRAND NEW!

Contains: 4 programs that cover: low pass, high pass, band pass, and band reject Butterworth filters (calculates circuit constants for Butterworth filters through the 7th order.) Programs include graphical response curves and all outputs are in schematic diagram form. The schematic outputs and associated circuit constants are determined on the basis of user inputs including source and load resistance.

☐ **E-RF3** IBM-PC **$84.95**

RF-CAD ELECTRONICS DESIGN PROGRAM Version 3.51

by Joe Reisert, W1JR and Gary Field, WA1GRC

For IBM PC and compatable computers

This software package has been written by electronic engineers and contains nearly 40 tested and proven programs that will help the Radio Amateur or engineer design many common types of radio circuitry. Emphasis has been placed upon ease of use. Wherever possible, menus of choices with examples are displayed. Should the user be computer literate, the programs are not copy protected so they can be modified to meet your specific requirements. (full documentation is also provided.) Programs include: Filters, LC, active- LP,HP,BP; Inductor design, torroid, solenoid, straight wire; Matching networks; Crystal oscillators; Microstrip; Transmission lines; Antennas, Yagi-Uda, helix, dish, horn, element scaling; Pi and T attenuators. Also included: Radio Path calculations; FM modulation analysis, Miscellaneous conversions; Geostationary satellite pointing; Moon tracking aids; Receiver noise figure calculations and Spurious receiver response prediction. Requires IBM-PC with at least one floppy drive and 128k of RAM. ©1985.

☐ **RF-CAD** **$39.95**

STAR 1.0 DESIGN PROGRAM

TWO NEW VERSIONS

by Randall Rhea

STAR, S-parameter Two part Analysis Routine, is a professional engineering program designed to help analyze electronic circuits. It is particularly helpful in frequency domain analysis of RF and microwave circuits. To use STAR, you input circuit information by component; inductors, resistors, capacitors, transformers, transmission lines, two port data and several two port manipulations. STAR will then give you S-parameter data for each requested frequency in tabular or plot form. You can also use STAR to optimize component values for maximum circuit performance. This program is definitely not for electronic beginners. Engineers and serious hams, however, will find STAR to be an invaluable design tool.

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AX.25 Protocol

You can get on Packet Radio two ways. One is with a sophisticated "black box." The other is by making your computer act like a "black box" by programming it in a high level machine language code. W4UCH has written a machine language program for the Radio Shack TRS-80 Models 1, 3 and 4 computer (Model 4 works with Model 3 disk while in Model 3 mode). This book has twelve chapters plus seven appendices that take you step by step through the process of setting your computer to first convert the digital information into a useable format and then to decode the information. ©1984, 3rd edition.

☐ **RE-AX**	**Softbound $21.95**
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by Wes Hayward, W7ZOI

LADPAC has been written to help the sophisticated Radi Amateur or electronic engineer design and analyze electronic LADDER circuits. LADPAC consists of five menu driven, interactive programs; general purpose ladder ana sis, low/high and bandpass design, coupled resonator L(filters, lower sideband ladder crystal filters, and a schematic drawing routine. LADPAC will help you: calcul network gain, phase, group delay and return loss; gener either graphic or tabular data output; use Smith chart graphics; optimize multi-element tuning; plus much more LADPAC requires IBM-PC (DOS 2.0) and color graphics card. A dot matrix printer is highly recommended. Also available LADPAC designed to run with the 8087 coprocessor for faster operation. 256K memory.

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☐ **XN-C64** (For Commodore C-64) **$27**

BOOKS

MICRO COOKBOOK Vol. 1 and 2

by Don Lancaster

Learning to use a PC can be a real challenge. However, Don Lancaster has tried to filter out all the gobbledygook and make it as easy as can be. Volume 1 features down-to-earth coverage of fundamentals, number systems, hardware and software logic, mainstream codes and standards, electronic memory and memory devices and other applications. Volume 2 covers address space, addressing, system architecture, machine code programming, I/O and helpful suggestions to common problems.

☐ **21828** Volume 1 ©1982		**$15.95**
☐ **21829** Volume 2 ©1983		**$15.95**
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REPAIR AND TROUBLESHOOTING GUIDES C-64, IBM-PC AND APPLE II

by Robert C. Brenner

If you've been taking care of your ham gear, there's certainly no reason why you can't do much of your own microcomputer servicing. These handy guides give you a real headstart in taking on your "micro" when problems arise. Troubleshooting is clearly illustrated by simple flow charts that are designed to pinpoint failures and correct them. There is also an Advanced Troubleshooting chapter for more complicated systems failures. Clear easy-to-read text and plenty of illustrations.

☐ **22363** Commodore C-64 ©1985	**$18.9**
☐ **22353** Apple II Plus/IIe ©1984	**$19.9**
☐ **22358** IBM-PC ©1985	**$18.9**

CMOS COOKBOOK by Don Lancaster

CMOS is today's state-of-the-art! It's low cost, widely available and uses an absolute minimum of power. It's also fun to work with and very easy to use. The CMOS Cookbook is written to help you use CMOS and is chock full of practical circuits and does not dwell on math or heavy theory. Projects include high-performance op-amps, TV typewriter, digital instruments, music synthesizers, video games and more. ©1977, 1st edition, 414 pages.

☐ **21398** **Softbound $13.9**

IC OP AMP COOKBOOK by Walter Jung

This second edition is broadly updated in terms of device coverage. It includes the latest in state-of-the-art developments such as J Fet and MosFet in both single and multiple formats. This cookbook is edited into three basic parts. Part I introduces the IC op amp and discusses general considerations. Part II covers practical circuit applications. Part III is an appendix consisting of manufacturer's data sheets and other pertinent information. You'll find a wealth of information, as well as over 200 practical circuit applications. ©1980, 2nd edition, 480 pages.

☐ **21695** **Softbound $15.9**

TTL COOKBOOK by Don Lancaster

Despite the advent of CMOS, there is still design work being done with TTL circuitry. This book gives you a broad overview of exactly what TTL is, how it works and is full of design ideas and practical circuits. Areas that receive attention include: flip-flops, clocked logic, counters, counting techniques, noise generators and much more. You also get a complete discussion of practical TTL applications including digital counter, events counter, stopwatch and voltmeter to name just a few. ©1974, 1st edition, 333 pages.

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UNDERSTANDING MICROPROCESSORS
By Don L. Cannon and Gerald Luecke

How microprocessors work and what they can do is something that you need to know. This text starts with an overview of the world of digital electronics and covers the basic concepts of microprocessor systems, how digital ICs provide systems functions, fundamentals of microprocessors, system application with SAM (simplified architecture microprocessor), programming basics and 8 and 16 bit microprocessor applications. Written in an easy-to-read style with plenty of "hands on" projects. © 1984 Second Edition 288 pages.

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UNDERSTANDING DIGITAL ELECTRONICS
By Gene McWhorter

This book tells you all you need to know to understand the basics of digital electronics. You start with a look at how digital electronics systems work and progress through AND, OR, NOT, NAND and NOR gates. You then learn decision making, logic and memory fundamentals. Digital mass storage is explained with information on static, dynamic, RAM and ROM systems. There is much more to this book than can be explained in this short description. You'll have to get one to see how complete it is. © 1984 2nd Edition.

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UNDERSTANDING DATA COMMUNICATIONS
(Includes Packet Information)
By G. Friend, J.L. Fike, H.C. Baker and J.C. Bellamy

This book covers the basic concepts of data transmission and reception, asynchronous and synchronous protocols, error control and networking data communications systems. Data terminals are fully discussed as are message and transmission terminals, modems and interfaces, fiber optics and satellite communications systems. Packet Networks and standards are covered with information on X.25 switching architecture. You also get the recommended X Series standards. A wealth of information. © 1984 1st edition 272 pages.

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UNDERSTANDING COMMUNICATIONS SYSTEMS
By Don L. Cannon and Gerald Luecke

Here's a book that will answer just about any question you have ever had about communications systems. Written in a tutorial style, this book covers basic communications concepts, conversion functions, system techniques, applications and more in 10 complete easy-to-read chapters. The following transmission methods are discussed: AM, FM, PCM, PDM, TDM, TV and Facsimile. Satellite systems are covered in detail. Great text for newcomers to Ham Radio. © 1984 2nd edition 288 pages.

☐ TI-UCS **Softbound $14.95**

UNDERSTANDING DIGITAL TROUBLESHOOTING
By Don L. Cannon

This book has been written to explain the mysteries of repairing digital electronic circuits. Starting with fundamentals like binary/hexidecimal conversions and Ohm's Law, this text progresses thru the most esoteric aspects of digital repair in a logical step-by-step manner. The chapter on troubleshooting fundamentals starts with a review of the most common problems that will be encountered such as opens and shorts and concludes with signal tracing techniques. You also get a full explanation of how to use logic probes and clips. 2nd Edition © 1984 272 pages.

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CONFIDENTIAL FREQUENCY LIST NEW 6th Revised EDITION now includes RTTY stations
by O. P. Ferrell NEW

SWL's around the world know that this is the best reference book to have around. This brand new edition is jam-packed with all the latest frequencies, callsigns and other important information. Inside you'll find listings for aeronautical, military, embassy, VOLMET, INTERPOL, weather and RTTY stations. Also included is a thorough discussion on how to listen to RTTY stations, explanations of the abbreviations used by utility stations, the reasons behind international jamming and much, much more. Every radio enthusiast should have a copy in their shack. © 1986, Revised 6th edition, 336 pages.

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This collection of Packet Radio papers should be in every Packet enthusiasts shack! Written during the formulative years of Packet development, these papers (too numerous to mention them all) cover: theory, practical applications, protocols, software and hardware subjects. You also get a complete up-to-date collection of all published "Gateway", the ARRL Packet Radio newsletter. As big as the ARRL HANDBOOK, this new book is sure to be the ARRL's next best seller! © 1985 over 1000 pages.

☐ AR-CNC **Softbound $17.95**

SOFTWARE FOR AMATEUR RADIO
by Joe Kasser, G3ZCZ

Packed with practical computer applications and tested and debugged programs that can be adapted simply and easily to almost any microcomputer. You get BASIC programming concepts as well as how to interface your comuter to your radio. Programs include: digital communications RTTY, Packet, computer aided design and circuit analysis as well as data base programs for record keeping, logging, and awards. Easy-to-understand explanation of Baudot and ASCII codes and guidance on hardware dependent software ©1984 1st printing 284 pages.

☐ T-1560 **Softbound $15.95**

THE COMPLETE DX'ER
by Bob Locher, W9KNI

DX'ing can be as simple as turning the radio on and searching across a band, or it can be hours spent studying propagation reports, sunspot figures and the DX newsletters looking for tidbits of information. The first part of the book is designed to teach the reader DX'ing fundamentals. Part two is for the "over 200 countries worked" operator and has plenty of handy tips, aids and ideas. Part three is full of more esoteric hints for the "over 300 countries worked" operator. This book tells **all** and should be required reading before anyone starts their quest for DXCC. Even if you don't care about DXCC, Bob's easy-to-read style of writing is most enjoyable reading. ©1984, 1st edition.

☐ ID-DX **Softbound $10.95**

ANTENNA COMPENDIUM
edited by ARRL Staff

This book has more than 20 antenna articles that have never been published before. Subjects covered include: Quads, Yagis, Phased Arrays, Log Periodics, Subsurface Antennas, "The Old Spruce Antenna", as well as discussions on Smith Charts, antenna design, the G5RV multiband antenna and antenna polarization. Great summer reading and full of ideas for Fall '85 antenna projects. ©1985. 1st Edition.

☐ AR-AC **Softbound $9.95**

THE AMATEUR RADIO VERTICAL HANDBOOK
by Cpt. Paul H. Lee, USN (Ret.), N6PL

This is the **only** book dedicated to the vertical antenna and will be of interest to all those using or looking to use the vertical design. Based upon the author's years of work with a number of different vertical antenna designs, you'll get plenty of theory and design information along with a number of practical construction ideas. Included are designs for simple 1/4 and 5/8-wave antennas as well as broadband and multi-element directional antennas. Paul Lee is an engineer and avid ham and is Amateur Radio's resident expert on the vertical antenna. © 1984, 2nd edition.

☐ CQ-VAH **Softbound $9.95**

DX POWER: EFFECTIVE TECHNIQUES FOR RADIO AMATEURS
by Chip Tilton, K5RSG NEW
co-Published by ARRL and TAB Books

If you're a new DX'er, how do you learn all the "ropes" of successful operation? Either you have a special Elmer or you get Chip's new book! This fact filled guide to DX'ing is chock full of advice, tips, hints and the tricks that will put you on the coveted DXCC Honor roll. It's also an insider's view to all the funny, frustrating and tricky maneuvers used by DX'ers around the world. Each band is covered as well as a discussion of equipment, accessories and antennas for your station. Also includes info on QSL'ing, ARRL awards and other helpful information. © 1986 1st Edition, 244 pages.

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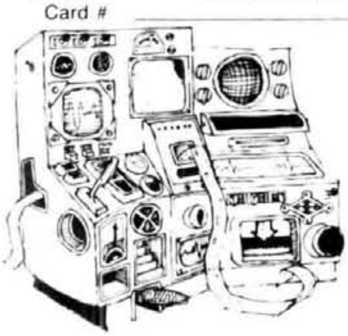

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product REVIEW

Heath HD-1481 remote coax switch

Hams have long known that Heathkit has produced some of the most memorable and valuable pieces of Amateur Radio gear, from transmitters and receivers to simple but useful station accessories.

A few years ago Heath came out with their first remote coaxial switch, the HD-1480. The beauty of this switch was that it allowed you to remotely select five antennas from a single feedline. This represented a significant cost savings in that you'd have to run only one coax line out of the shack to the switch; usually antenna feedlines from this point are much less. It also improved reliability in that instead of dealing with as many as 10 PL-259s (five antenna feedlines at two each) coming out of your shack, you'd have only two connectors.

The HD-1480 used a wafer switch and a stepping motor. Two problems, however, limited the switch's usefulness. The first was that you couldn't remote the switch much more than 200 feet from the shack due to power supply limitations. (Heath did beef up the supply to correct this in all but the longest runs.) The second problem was that the installation required the use of a separate control cable to run the switch, making installation more difficult and adding to the overall expense — control cable isn't cheap.

The new HD-1481 remote coax switch solves these two problems in an interesting and innovative way. The control cable has been eliminated by using the coax itself to carry the switching instructions — but more on how this is done later. You can remote the switch almost any distance away from the control unit because there's very little voltage drop in the heavy conductors used in coaxial cable. Installation is greatly simplified and consequently less expensive.

description

The remote coax switch comes in two units. There's the switch that you remote at the antenna site and the power supply/control unit that goes in your shack. The only interconnection necessary is the coaxial cable.

The remote unit uses two heavy-duty 24-volt DPDT relays as a switch. The unit is weather protected by a high strength black plastic cover, and all openings are sealed with silicone to ensure weatherproofing. It mounts via a single U-clamp arrangement.

The power supply/control unit includes a 24-volt power supply and a rotary switch that selects the appropriate polarity voltage to make the switch work.

theory of operation

I'm sure that by now you've either figured out how you can select four antennas with this switch or that you're fully confused. Fear not. Here's how it's done:

In switch position 1, no voltage is applied to the coax and Antenna 1 is selected. In position 2, the 24-volt AC is rectified to produce a positive 24-volt DC voltage. This is injected into the coax and energizes Relay 2 at the remote switch end and Antenna 2 is selected. In position 3, this is reversed: negative 24 volts is injected into the coax, energizing Relay 1 and routing the RF to an unenergized Relay 2 and Antenna 3. Finally, Antenna 4 is selected by sending AC to two diodes in the remote switch that energizes both relays. Sounds simple, doesn't it?

construction

Typical of a Heathkit, the instruction manual is clearly written, explained, and fully illustrated to minimize confusion and troubles during construction. I have the impression that Heath has gone to considerable time and expense making the manual easier to use than the ones that accompanied its kits of 10 to 15 years ago. (Maybe this is a sad commentary on the level of technical awareness of the average Ham nowadays?) The circuit diagram along with the exploded drawing should be more than enough to allow completion of this project with a minimum of fuss and trouble.

After completing a couple of tests you're ready to install the remote switch, a few antennas, and presto — that's it!

use

I've installed the switch out at my 160-vertical, which is located over 200 feet from the house. For starters, I've installed 80-and 40-meter antennas and have had no problems using either low or high power switching between any of the three antennas.

Heath includes self-adhesive labels so you can mark the antenna by both band and design, a neat extra touch.

I expect that this switch will give the average user thousands of hours of reliable use with few, if any, problems.

For more information, contact Heathkit, Benton Harbor, Michigan 49022.

—N1ACH

NEW products

new IC-751A base station transceiver

The ICOM IC-751A 100-watt HF base station trasceiver and general-coverage (100 KHz-30 MHz) receiver incorporates the high performance features of the IC-751 with new, improved features requested by hams worldwide. This newly-designed, top-of-the-line HF transceiver includes the following:

- •All modes (USB, LSB, AM, FM, CW, RTTY) are built-in
- •100 duty cycle transmitter
- •105 dB dynamic range
- •12 volt operation
- •Electronic keyer unit is included*
- •FL-32A 9 MHz at 500 Hz CW factory-installed filter
- •QSK up to 40 WPM
- •New LED annunciator
- •32 memories
- •Thermo-sensor for improved stability
- •New 9MHz notch filter
- •New AGC and improved noise blanker
- •CW sidetone for code practice
- •Low-noise receiver

Optional filters include the FL-52A CW 455 KHz at 500 Hz, FL-53A CW-N 455 KHz at 250 Hz, FL-63A CW-N 9.0106 MHz at 250 Hz, FL-33 AM 9.010 MHz at 600 Hz, and CR-64 high-stability 30.72 MHz crystal filters.

The IC-751A will be available in April 1986 and will be displayed in the ICOM booths at the Dayton Hamfest (April 25-27).

For details, contact ICOM America, Inc., 2380 116th Avenue NE, Bellevue, Washington 98004.

Circle #317 on Reader Service Card.

current probe

The new MFJ-206 Antenna Current Probe determines the current distribution and RF radiation pattern of antennas, transmission lines, ground leads, building wiring, guy wires, enclosures, shields, etc. It monitors RF currents by sensing the magnetic field around a current-carrying conductor. It uses an electrostatically shielded ferrite core tuned circuit, and FET RF amplifier, and an operational amplifier meter circuit for excellent sensitivity and selectivity.

It can be used to adjust an antenna for maximum efficiency, gain, and F/B ratio to improve

DX, and to determine whether a ground system is effective so you can radiate more power. You can also use it to determine the best place to mount a mobile antenna on a vehicle for a stronger signal and eliminate RFI by pinpointing leaky shielding. It can even be used as a sensitive tuned field strength meter.

The MFJ Antenna Current Probe is powered by a 9-volt battery and covers 1.8 to 30 MHz in five ranges. It includes a telescoping antenna for the field strength meter, and sensitivity and tune controls are provided. Also included are an on/off switch, a power LED indicator, and an internal meter zero adjust.

The retail price of the MFJ-206 is $79.95.

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

Circle #316 on Reader Service Card.

antenna traps

G2DYM Aerials, makers of the well-known Anti-TVI trap dipoles, has announced the availability of new traps for 10 and 15 meters. A 6-inch length of aluminum tubing at the end of each trap facilitates the construction of two- and three-element rotary tribanders, rotary tribander dipoles, and trap verticals, either quarter or half-wave in height.

Prices are as follows: 10 and 15-meter traps, $16 plus $5 shipping; kit of four traps for rotary dipole, $54 plus $8 shipping; kit of eight traps for 2-element tribander, $105 plus $10 shipping; kit of twelve traps for three-element tribander; and kit of two traps for vertical, $27 plus $6 shipping.

For information, contact G2DYM Aerials, Uplowman, Tiverton, Devon, England EX16 7OH.

Circle #315 on Reader Service Card.

buying, installing marine electronics

In his new book, *The Straightshooter's Guide to Marine Electronics, Motor Boating & Sailing Magazine* columnist Gordon West speaks frankly buying and installing marine electronics gear.

According to West, "More and more mariners are doing their own installation of marine electronics. In my book I tell them where to get the best deal, how to buy the equipment, and finally, how to install it so it meets the criteria to be covered under a manufacturer's warranty. I also talk about the necessary FCC licensing as well as steps to avoid electrolysis."

Topics covered include depth sounders, hand-held and 25-watt VHF radios, marine SSB radios and ham radios; VHF and MF direction fiders, LORAN equipment, satellite navigational receivers, and automatic pilots, among others.

Personally autographed copies are available from Gordon West Radio School, 2414 College Drive, Costa Mesa, California 92626 for $9.95 plus $3.00 postage and handling.

Circle #314 on Reader Service Card.

cable and connector guide

Nemal Electronics international has published a comprehensive guide for the selection of electronic wire, cable, and connector products. The 32-page guide contains detailed specifications and illustrations of over 550 items, along with cable construction and performance charts, and a complete tooling cross reference.

Among the 32 product categories listed are fiber optic cables and connectors, plenum cables, satellite control cables, and numerous RF and data connector types. Nemal's new cable and connector selection guide is available for $4.00 (credited with a $50.00 order).

For information, contact Nemal Electronics, 12240 NE 14th Avenue, North Miami, Florida 33161.

Circle #313 on Reader Service Card.

replacement mic for discreet communication

Ace Communications, Inc. has introduced the IECS-200 Inter-Ear Communication System. The IECS-200, which replaces any HT's speaker microphone, allows the user to speak as well as listen through the earpiece, protecting the privacy of communications.

NEW products

The IECS-200 measures only 2 x 2.9 x 0.9 inches. Housed in a durable metal case, it can be clipped to the belt or holstered. Custom hybrid audio processing circuitry provides natural audio reproduction for various applications such as law enforcement, military service, and construction.

For information, contact ACE Communications, Inc., 22511 Aspan Street, Lake Forest, California 92630-6321.

Circle #312 on Reader Service Card.

146 and 440 MHz mobile antenna

Austin's new 19-inch Model 500C antenna is designed using state-of-the-art technology currently being used in the cellular radio field. Ruggedly built with a low design profile, it takes advantage of several patent-applied-for techniques that enhance its radiation efficiency. The antenna uses the standard Motorola vehicle mount (not supplied).

On 146 MHz, it uses the vehicle body as a ground plane and is a 1/4 wave vertical with an elevated feedpoint. This technique brings the main lobe down to 16 degrees above the horizon; this lower angle of radiation improves the antenna's ability to get into distant repeaters. The standard 1/4 wave vertical has a main radiated lobe of 60 degrees above the horizon (the 5/8 wave is 22 degrees). Overall bandwidth is around 20 MHz; the antenna is rated at 100 watts.

On UHF, the 500C operates independently of the vehicle and is a 1/2 wave element. Tuning of the 1/2 wave stainless steel whip is achieved in the re-entrant cavity.

The retail price is $49.95; the Motorola MAG Mount is priced at $39.95.

For information, contact Austin Custom Antennas, P.O. Box 357, Sandown, NH 03873.

Circle #311 on Reader Service Card.

new Yaesu duplexer

Yaesu Electronics has announced the release of the new AD-2 Duplexer for the FT-2700RH Dual-Band FM Transceiver and FT-726R VHF/UHF All-Mode Transceiver. The AD-2 provides for semi- or even full-duplex VHF/UHF cross-band operation with a single 2-meter/70 centimeter dual-band antenna. The single antenna serves for both transmitting (on one band) and receiving (on the other band), *simultaneously*. Band-to-band isolation of more than 50 dB assured minimum receiver interference between bands. At high power (up to 50 watts), there is minimal insertion loss of transmitted power or received sensitivity.

specifications:

pass bands:	140-150 MHz and 400-450 MHz
maximum power:	50 watts
insertion loss:	VHF less than 0.3 dB; UHF less than 0.5 dB
impedance:	50 ohms
VSWR:	less than 1.2:1
receive isolation:	50 dB

For details, contact Yaesu Electronics Corporation, 17210 Edwards Road, Cerritos, CA 90701.

Circle #310 on Reader Service Card.

newsletter index

After serving the owners of Yaesu equipment for 14 years, Milt Lowens, N4ML, has announced the termination of the publication of the *FT Newsletter*, the official journal of the International Fox-Tango Club, which he organized in January 1972. All of the back-issues of the Newsletter have been republished in calendar-year volumes, mostly in booklet form; each has its own index.

To simplify the task of selecting the volumes most appropriate to individual needs, Fox Tango has also published a comprehensive 32-page cumulative index covering the years 1976 through 1985 in detail, and summarizing the years 1972 through 1975. Most articles are grouped according to model number (FT-101, FT-757, etc.); within such groupings, newsletter articles are listed chronologically by year and page; by topic (such as user report, modifications, etc.); and by title and author's call sign.

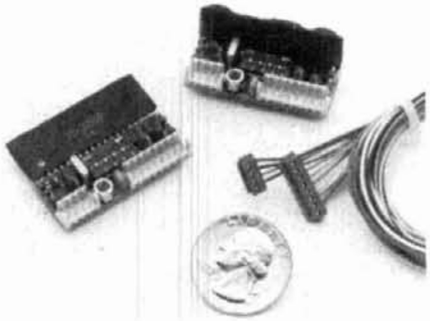
The price of the index (including a rebate certificate creditable towards the purchase of newsletter volumes) is $4.00 postpaid in the United States and Canada (elsewhere, $5.00).

For information, contact Fox Tango Corporation, Box 15944, West Palm Beach, Florida 33411.

super-small encoder-decoder for portables

Communications Specialists, Inc., of Orange, California has announced availability of their TS-32HB Super-Microminiature Programmable Encoder-Decoder for handhelds. The TS-32HB comes in two different configurations to take advantage of the limited space available in the newer super-small handheld radios. The TS-32HBH measures 1.5 x 0.65 x 0.65 inches. The TS-32HBL, lower in profile, measures just 1.5 x 1.2 x 0.4 inches.

Programming the 32 available CTCSS EIA tones is done through a five-position DIP switch mounted on the board, and installation is simplified by the use of two plugs with color-coded cables attached. A crystal-controlled clock oscillator allows excellent stability under all conditions, and sensitivity is rated at 6 mV RMS for use with the lowest output receivers. Decode bandwidth is ±1.5 Hz. The TS-32HB provides an adjustable sinewave output and encodes with an accuracy of ±0.1 Hz maximum at −40



degrees C to +85 degrees C. Output level is 6v P-P across 10k.

Priced at $64.95, the TS-32HB is in stock for immediate delivery and is covered by a full one-year warranty. A catalog is available on request.

For details, contact Communications Specialists, Inc., 426 West Taft Avenue, Orange, California 92665-4296.

Circle #307 on Reader Service Card.

Commodore/ICOM interface

Microcomputer Electronics Corporation has announced the release of the new MEC 71α, a computer control interface for Commodore 64/128 computers and ICOM R71A and 751. The MEC 71α is easy to use; screen menus guide the user through operation of the system. Features include UTC time dispay, frequency display/control with 10 Hz resolution, mode display/control including narrow filter status, and single-page viewing of ICOM's 32 internal memories. Full control of the ICOM's 32 internal memories, frequency stepping with selectable steps, and complete VFO and memory control, including VFO/memory exchange, are included.

The MEC 71α is designed to be used with the ICOM EX-309 module, available at low cost from any ICOM dealer. The ICOM EX-309 is easy to install in the radio. The MEC 71α plugs into the expansion port of the 64 or 128 computer and a cable exiting from it plugs into connector provided with the ICOM EX-309 module.

The MEC 71α includes a 90-day warranty and a comphrehensive user's guide for detailed information on system operation.

The MEC 71α, priced at $199, is designed and manufactured by Microcomputer Electronics Corporation and is distributed by the Electronic Equipment Bank, 516 Mill Street, Vienna, Virginia 22180.

Circle #308 on Reader Service Card.

infra-red sensing digital thermometers.

North American SOAR has announced the release of four infra-red sensing digital thermometers.

Model TX-700L is a general-purpose, handheld, battery-operated portable instrument that can measure an object's temperature with a 6-inch (150mm) spot size at a distance of 16 feet (5 meters). Model TX-700S uses an LED as a spot marker, making aiming easy and sure.

NEW products

Models TX-710L and TX-710S are monitor versions (i.e., no pistol grip) of the TX-700.

The TX-700 Series units are small in size, light in weight, and easy to use. These units measure an object's temperature without touching and are highly accurate with resolution to 0.1 degree C. A Data Hold function is trigger activated and readings are viewed on a large 3-1/2 digit LCD in approximately half a second. The TX-700 Series has a high-low limit set capability with alarm output; it also has an analog signal output. An automatic "low battery" indication appears in the LCD readout when the battery's voltage falls below operating level. The TX-700L/S can be AC operated using an adapter provided. The price of the TX-700L is $1470.00 and the TX-700S is $1495.00.

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

Circle #306 on Reader Service Card.

simplex autopatch and HF base station control system

The Com-Shack 64 has been designed to give the ham shack a new dimension in user control. The full-featured simplex auto-patch and HF remote base operate under control of the Commodore 64 computer. A clear digitized human voice announces your call sign and alerts you to an incoming call. All parameters such as timing windows and time-out controls are adjustable from a user-friendly menu. A real-time menu displays all system parameters. Call waiting and last number memory features are included. The autopatch works on any phone line in either tone or pulse mode. A Yaesu 757 and a VHF/UHF transceiver are all that are required to complete the setup.

A fast-scan and a slow-scan mode provide remote tuning on all bands. The hardware interface board plugs into the I/O port of the Commodore 64 or 128. All hardware and cables and connectors are supplied along with a program

✓ 121

NEW products

disk and instruction manual. Easy to install, the system is priced at $229.95

The Com-shack 64 is available from Engineering Consulting, 583 Candlewood St., Brea, California 92621.

affordable tool kits

Jensen Tools, Inc. has introduced a new economical line of electronic/electrical tool kits for students, hobbyists, and in-house service departments. While not as comprehensive as the professional Jensen line, the new Telvac kits include tools for most service needs and come in a choice of attache or zipper-style cases.

The tool selection includes more than 30 standard tools for servicing electronic and electrical equipment as well as for model building. Tools are supplied in single-pallet attache-style cases of wood/vinyl or aluminum/vinyl construction, or in a heavy-duty zipper pouch case.

Telvac Kits are ideal for those seeking a highly functional and attractive kit at a minimum investment. For more information, contact Jensen Tools Inc., 7815 S. 46th St., Phoenix, Arizona 85044.

Circle #304 on Reader Service Card.

new commercial license materials

In response to popular demand, Ameco Publishing has rewritten two Commercial Radio Operator Question and Answer License Guides for two popular commercial exams: the General Radiotelephone Operator's License and the Marine Radio Operator's Permit.

For preparing for the General Radiotelephone exam, *The Commercial Radio Operator Q&A License Guide for Element 3* (Cat. No. 9-01, $5.95) contains over 270 questions taken from the latest FCC syllabus. Detailed answers, written in Ameco's proven, easy-to-understand style, are included.

For preparing for the Marine license, the revised *Commercial Radio Operator License Guide for Elements 1 and 2* (Cat. No.8-01, $5.95) contains all the information needed to pass the

NEW products

examination, plus additional charts and handy reference material.

Ameco also recommends its Commercial Radio Operator Theory Course (Cat. No. 15-01, $8.95). More than 450 pages long, it contains 21 lessons and 600 FCC-type multiple choice questions. The book is a complete course in commercial radio; no previous technical background is required.

For details, contact Ameco Publishing Corp., 220 East Jericho Tpke., Mineola, New York 11501.

Circle #303 on Reader Service Card.

Yaesu newsletter

International Radio, Inc., publishers of the ICOM and Kenwood *Newsletters* for the last five years, has now added the *Yaesu Owners' Newsletter*, formerly a Fox Tango publication, to its list of monthly publications. Founded by Milt and Ida Lowens approximately 13 years ago, *The Yaesu Newsletter*, like its companion publications, functions as a worldwide owner's information exchange. Each of the three newsletters features information gathered from readers, manufacturers or their agents, the IRI Service Laboratory, and Amateur Radio magazines around the world.

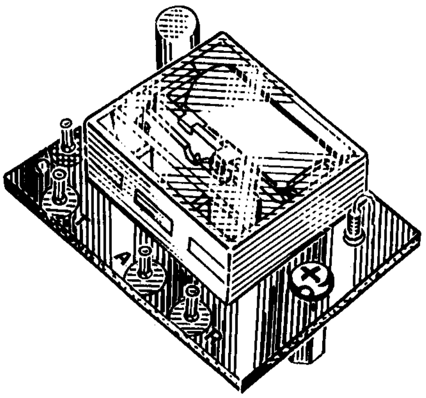
Back Issues of the Fox Tango *Yaesu Newsletter* are available from 1972; a cumulative index covering the years 1972 through 1985 is also available. Back Issues of the IRI *ICOM Newsletter* and *Kenwood Newsletter* are available from 1980; cumulative indices are also available.

For information on these publications, send an SASE to International Radio, Inc., 1532 S.E. Village Green Drive, Suite L, Port St. Lucie, Florida 33452.

Circle #301 on Reader Service Card.

new T/R relay module

Hamtronics, Inc. has recently developed a low-loss transfer relay module for use with 50-ohm coaxial cables at frequencies up to 1000 MHz. The special shielded relay, with gold-plated contacts for high reliability and long life, is mounted on a stripline PC board with solder terminals. The relay module, which measures only 1-1/8 x 1-5/8 inches, is easy to mount and connect. In a typical application, it would be wired to adjacent modules with miniature coax. To interface with larger cables, it's usually wired to appropriate connectors on the rear panel of the cabinet. Handy for T/R switching of devices such as the Hamtronics transmitter and receiver



modules, band switching of transmit and receive converters, selection of antennas, switching test equipment paths, etc., the TR Relay Module is rated to switch RF up to 25 Watts with a VSWR of only 1.3:1. Special rounded contacts and shielding between ports provides an isolation of 55 dB at VHF and 48 dB at UHF. The maximum usable frequency is 1000 MHz. Transfer time is a fast 15 mSec, which makes it useful in applications such as packet radio or simplex autopatch. Operating power is 13.6 VDC at only 40 mA, and on-board relay coil transient suppression is provided. Standoffs are provided for mounting the relay module.

The price of the TR Relay Module is only $24 in kit form and $34 assembled.

For information on the TR Relay Module and a 40-page catalog, contact Hamtronics, Inc., 65-F Moul Road, Hilton, New York 14468-9535. (Enclose $1 to receive your catalog by return first class mailing. For overseas mailing, please send $2.)

200-watt linear amp

Microwave Modules Ltd., of Liverpool, England, has announced the availability of a combination 200-watt linear amplifier, the MML 144/200-S, with selectable input levels and a GaAsFET receive preamplifier for 144-MHz operation. This design provides an output power level of 200 watts that is fully compatible with 3-watt 144-MHz handheld transceivers or multimode transceivers having either 10 or 25 watts output. The input power level is manually switch-selectable to suit the transceiver in use, making this product appropriate for use with mobile, portable, or base station equipment. RF VOX and a manual PTT are provided.

The receive preamplifier uses one of the latest dual-gate GaAs FETs in a noise-matched configuration. Conversion gain is deliberately set at only 12 dB in order to achieve strong signal handling capability while maintaining an overall noise figure of below 1.5 dB. The unit is housed in a durable extruded aluminum enclosure measuring 13-3/16 x 6-15/16 x 3-13/16.

The MML 144/200-S is available from the "PX" Shack, Belle Mead, New Jersey 08502 and other Microwave Module dealers.

Circle #320 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance.** No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

RADIO FREQUENCY SPECTRUM CHART made specifically for Amateur, shortwave listeners, and scanner enthusiasts. 16" x 20" FULL COLOR poster suitable for framing. Only $4.50 plus $1.50 s&h. Schools and others please write for quantity discount. Rover Printer, KB6DYM, 2135C Columbia, San Diego, CA 92101.

DX ANTENNAS FOR 160-10 METERS. Small size, broadband, high performance. Also, antenna parts, Beverage insulators, wire and cable. Low prices and fast service. SASE for catalog. W1FB, Oak Hills Research, POB 250, Luther, MI 49656.

CABLE TV CONVERTERS & EQUIPMENT: Plans and parts. Build or buy. SASE for information. C & D Electronics, PO Box 1402, Dept. HR, Hope, AR 71801.

WANTED: Anything made by Kinemetrics True Time, Inc. Receivers, WWV clocks, time code readers, manuals, incomplete assemblies, etc. C.K.Barber, 3112 Ursula Street, Aurora, CO 80011.

IBM-PC RTTY/CW. CompRtty II is the complete RTTY/CW program for the IBM-PC and compatibles. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! 10,000 character transmit/receive buffers. Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Now with WRU (simple mailbox). Ideal for MARS and traffic handling. Requires 128k PC, XT, AT, PCjr, PC-DOS, serial port, RS-232C TU $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 7373 Jessica Drive, North Syracuse, NY 13212.

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THE GOOD SAM HAMS invite RV operators to check in the Good Sam Ham net 14.240 *Sundays 1900Z also 3.880 Tuesdays at 2359Z. Net control N5BDN, Clarksville, IN*

OLD RADIO transcription discs wanted. Any size, speed. W7FIZ, Box 724 HR, Redmond, WA 98073-0724.

RTTY-EXCLUSIVELY for the Amateur Teleprinter. One year $10.00. Beginners RTTY Handbook $8.00. PO Box RY, Cardiff, CA 92007.

IMRA, International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 2-3 PM Eastern. Eight hundred Amateurs in 40 countries. Brother Frey, 1 Pryer Manor Road, Larchmont, New York 10538.

RUBBER STAMPS: 3 lines $4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

SELL RK4D32 Raytheon Transmitting tubes only $35.00 each. Inquire on others. Wanted Morrow BR 560 receiver with supply. Morrow SSB Transmitter, AC supply. M. Levy, 101 East Driftwood No. 26, Fredericksburg, TX 78624. Tel 512-997-2534.

WANTED: Western Electric tube manual. Also would like to contact groups specialized in home-brewing tube type audio equipment. Doug Yumoto, AG8L, 8258 Niles Center Road, Skokie, IL 60077. (312) 982-9683 (home) (312) 764-9186.

DISCOUNT CATV CONVERTERS/DECODERS and video accessories. Solar cells for remote power and battery charging applications. Send for free information and prices — it could save you big money on your next purchase of these and other CATV items. Easy View, PO Box 221, Arlington Heights, Illinois 60006. (312) 952-8504. Ask for Rudy Valentine.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. Daily Electronics, PO Box 5029, Compton, CA 09224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. Hein Specialties, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

BRAND NAME 5.25" COMPUTER DISKS. 10 disks in polypak/SSDD $7.99 DSDD $8.99 includes sleeves, ID labels, tabs. Send check or money order to Micro-Applications, Inc., 915 E. Sheridan, Des Moines, IA 50316. Shipping add $1.50 for 1-5 items; $3.00 for 5 or more items. COD orders add $2.00. IA residents add 4% sales tax.

FAMOUS "FLORIDA SKIP" 2 meter repeater map. Now in its 5th printing. Fully up-to-date, with all the latest repeater listings and frequencies. Designed and edited by Bill Tucker, W4FXE. Available for just $.25 plus business size SASE to: FLORIDA SKIP, PO Box 501, Miami Springs, FL 33266

PRINTED CIRCUIT BOARDS and kits for QST articles. Call or write for information. A&A Engineering, 7970 Orchid Drive, Buena Park, CA 90620. (714) 521-4160.

PACKET/ASCII/BAUDOT/CW for IBM-PC. SASE to: Emile Alline, 773 Rosa, Metairie, LA 70005.

CABLE TV CONVERTERS/DESCRAMBLERS. Guaranteed lowest prices in US. Jerrold, Hamlin, Zenith — Many others. Lowest dealer prices! Orders shipped within 24 hours! Mastercard, VISA, COD accepted.Free Catalog — call (80) 345-8927 only Pacific Cable Co., Inc., 7325-1/2 Reseda Blvd,#1012, Reseda, CA 91335. (818) 716-5914.

CHASSIS and cabinet kits. SASE K3IWK, 5120 Harmony Grove Road, Dover, PA 17315.

WANTED: Heath Curve Tracer IT-3121 kit/assembled. Mission School needs 10 units. Call Manila, P.I. 832-1773 or write Mission POB 1651 MCC Makati MM, P.I.

2 METER AMP KITS: 8877 legal limit kit $395. 3CX800A7 900W kit $325. Also HV power supplies, CX600N relays, parts and EME newsletter. SASE for catalog. 2 Meter EME Bulletin, 417 Staudaher St., Bozeman, MT 59715.

RIW-19 432 MHz beams by K3IPW. SASE for information.

COMING EVENTS

Activities — "Places to go . . ."

CALIFORNIA: Flea Market/Boneyard Sale. Foothill College, Los Altos Hills. March-Sept. 2nd Saturday of every month 7 AM Sellers. 7:15 AM buyers. Talk in 145.27( ) or 147.570 simplex. FCC exams (408) 255-9000.

ILLINOIS: The Starved Rock Radio Club Hamfest, June 1, Princeton. Same place as last year. SASE please for complete registration materials, map, etc. SRRC, W9MKS, RFD 1, Box 171, Oglesby, IL 61348 (815) 667-4614

NEW HAMPSHIRE: Deerfield. The Hosstraders will present their Spring Tailgate Swapfest, Saturday, May 10 at Deerfield, NH Fairgrounds. Admission $2 per person; no extra charge for sellers. Friday night camping at nominalfee, but no entry before 4 PM Friday. Profits benefit Shriners' Hospital. Last year's gift: $11,754.46. Talk-in 146.40-147.00. New England's biggest Hamfest is sponsored by Bob, W1GWU, Joe, K1ROG, and Norm, WA1IVB. For map SASE to WA1VIB, RFD Box 57, West Baldwin, ME 04091.

RHODE ISLAND: The RI Amateur FM Repeater Service which operates the 146.16/76, 146.34/94 and 222.16/223.76 repeaters in RI, will hold their annual Spring Flea Market and Auction, Saturday, May 17, American Legion Fairmount Post 85, 870 River Street, Woonsocket. Flea market opens 9 AM and spaces are $5.00 each. Auction 12 Noon to 5 PM. Free admission. Food and beverages available. Talk in on 34/94 and 52 simplex. For information: Rick Fairweather, K1KYI, Box 591, Harrisville, RI 02830 (401) 568-3468 from 7-9 PM.

GEORGIA: The 1986 Atlanta Hamfestival, sponsored by the Atlanta Radio Club, July 19 and 20, Georgia World Congress Center. Over 150 exhibitors. Forums and a huge, air-conditioned flea market. For further information SASE to: Atlanta Hamfestival, POBox 77171, Atlanta, GA 30357.

ILLINOIS: The Western Illinois Amateur Radio Club will hold its 1986 Tri-State Swapfest in conjunction with a Flyln Breakfast sponsored by the Experimental Aircraft Association. May 18, Haerr Field, Taylor, Missouri (5 miles west of Quincy, IL). 9 AM to 3 PM. Tickets $1.00 each; 6/$5.00. Tailgate flea market spaces $2.00 advance, $3.00 at the gate. VEC exams offered for all license classes. Talk in on 147.03 repeater. For more information: Western Illinois ARC, PO Box 3132, Quincy, IL 62301.

NEW YORK: The 27th annual Southern Tier Amateur Radio Club's Hamfest, Saturday, May 3, Treadway Inn, Owego. Flea market opens 8 AM. Tech and non-tech talks. Vendor displays. Refreshments. 6:30 PM dinner by advance tickets only. Talk in on 22/82, 16/76 or 146.52 simplex. For further information SASE to PO Box 7082, Endicott, NY 13760.

MASSACHUSETTS: The Hampden County Radio Association will hold its annual Flea Market, Sunday, May 4, rain or shine, West Springfield Elks Lodge covered pavillion, Morgan Road. 9 AM to 3 PM. Admission $1.00. Tables $5.00 each. Dealer displays $5.00 per vehicle. Food and refreshments available. For more information contact Steve Nelson, WA1EYF (413) 596-8216.

INDIANA: The 40th annual WVARA Hamfest sponsored by the Wabash Valley ARA, Sunday, June 1, Vigo County Fairgrounds, Terre Haute. For more information SASE to WVARA, PO Box 81, Terre Haute, IN 47808.

NEW HAMPSHIRE: The 12th annual Eastern VHF/UHF Conference, May 16-18, Rivier College, Nashua. Friday night hospitality room. Saturday rap sessions. New this year — a series of tutorial presentations for the newcomer to VHF/UHF. To preregister send $13.50 to David Knight, KA1DT, 15 Oakdale Avenue, Nashua, NH 03062 before May 5. Registration at the door $20.00. Saturday night banquet $14.00 payable by May 5. A special registration fee of $10.00 is available for the first-timer. Dormitory housing available at the college for a modest fee. Contact Lewis D. Collins, W1GXT, 10 Marshall Terrace, Wayland, MA 01778 (617) 358-2854 6-10 PM EST.

MASSACHUSETTS: The Northern Berkshire Amateur Radio Club's annual Spring Flea Market, Sunday, May 18, Dalton American Legion, Route 9, Dalton. Admission $1.00. Starts at sunrise. YLs and kids free.

ARIZONA: The Cochise Amateur Radio Association (CARA) will hold its 1986 Hamfest, May 2-4, Club's Training Facility, Moson Road and Rt. 90, Sierra Vista. No charge for tailgaters. Talk in on 146.52 and 146.16/76. Ham exams May 4. For more information: Don Morgan, W7ACI, (602) 458-5293 or CARA, PO Box 1855, Sierra Vista, AZ 85636.

MARYLAND: The Maryland FM Association's annual Hamfest, Sunday, May 25, Howard County Fairgrounds, West Friendship, 30 miles west of Baltimore. 8 AM to 4 PM. Inside tables $7.00 by advance registration only. At the door $10.00 if available. Donation $3.00. Talk in on 146.16/76, 222.16/223.76 or 449.1/444.1 MHz. For tables or information: Michael Cresap, W3IP,1921 Pometacom Drive, Hanover, MD 21076. (301) 551-3567 6-10 PM.

COLORADO: The Pikes PeakRadio Amateur Association's Swapfest Saturday, May 17, 8 AM, Rustic Hills Mall, Palmer Park and Academy Blvd, Colorado Springs. Free admission. Table rentals $8.00 advance, $10.00 at the door. Talk in on 146.37/97. VE testing on site. For information or reservations call Al, N0CMW (303) 473-1660 or write PPRAA Swapfest, PO Box 16521, Colorado Springs, CO 80935.

CONNECTICUT: The Pioneer Valley Radio Association's annual Flea Market, May 4, 9 AM to 3 PM, East Hartford High School (formerly Penney High) 869 Forbes Street, East Hartford. Free parking. Dealer tables $8.00, setup 8 AM. General admission $2.00. Talk in on 146.19/79. Amateur radio exams given by the Newington Amateur Radio League VE team. Walk-ins accepted. For information or table reservations: Dave Rose, KW1V, 13 Long Crossing Rd, East Hampton, CT 06424. (203) 267-8993.

OHIO: The Athens County ARA's 7th annual Hamfest, Sunday, May 18, 8 AM to 3 PM, City Recreation Center, East State Street. Admission $3.00 advance and $4.00 at the gate. This year the focus will be on the use of computer technology in ham radio. A special feature will be a live demonstration of packet radio. Those wishing to take license exams send completed form 610 and check for $4.25 payable to ARRL/VEC by April 15 to John Cornwell, NC8V, exam coordinator, 101 Coventry Lane, Athens, Ohio 45701. Advance registration requested but walk-ins will be accepted. Free flea market space for those bringing own tables. Talk in on club repeater 146.34/.94. For reserved flea market space: Sam Stewart, KA8NIE, 116 Franklin Avenue, Athens, Ohio 45701 (614) 592-5330. For further information or advance tickets write Carl J. Denbow, KA8JXG, 653 Morris Avenue, Athens, Ohio 45701.

OHIO: Portage Hamfair sponsored by the Portage ARC, Sunday, May 18, 7:30 AM to 4 PM, Randlph Fairgrounds, Randolph. Tickets $3.00 advance, $3.50 at the gate. Indoor/outdoor flea market spaces $2.00; with 8' table and one chair $6.00. For information or tickets (216) 274-8240.

KENTUCKY: The Northern Kentucky ARC's "Ham-O-Rama '86", June 7 and 8, Best Western Vegas Convention Center, Erlanger (8 miles south of Cincinnati). Admission for both days $5.00. Children under 13 free. Open to public 8 AM. Indoor/outdoor flea market. Contact AF4Y or WD4PBF at gate for flea market spaces and prices. Major vendors contact Joe Dunnett, WA4WNF at (606) 371-2255 for additional information or write NKARC, PO Box 1062, Covington, KY 41012. Talk in on 147.855/.255 and 147.975/.375.

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

PENNSYLVANIA: The Delaware County Amateur Radio Association is sponsoring their 7th annual Hamfest, June 8, Drexel Hill Middle School, State Road and Penn Avenue, Drexel Hill. Doors open 8 AM. Setups 7 AM. Admission $3.00. Indoor tables with electricity available by reservation $3.00 per space. Outdoor tailgating. Novice through Extra license exams starting 10 AM. Food and refreshments available. Talk in on W3UER, 147.96/36 C/L 224.5 MHz and 146.52 simplex. For registration/information: Hamfest, DCARA, PO Box 236, Springfield, PA 19064 or contact Barbara, N3DLG (215) 535-1616.

ILLINOIS: The Six Meter Club of Chicago is having its 29th annual Hamfest, Sunday June 8, Santa Fe Park, 91st and Wolf Road, Willow Springs, IL. (SW of downtown Chicago). Advance registration $2.00. At the gate $3.00. Swapper's Row. Gates open 6 AM. Plenty of parking, picnicking, displays in pavilion, refreshments. AFMARS meeting. Talk in K9ONA 146.52 or K9ONA/R 37-97. Advance tickets from Val Hellwid, K9ZWV, 3420 South 60th Court, Cicero, IL 60650.

NEW YORK: The Rochester Hamfest and Atlantic Division ARRL Convention, sponsored by the Rochester Amateur Radio Association, May 16, 17 and 18, Monroe County Fairgrounds, Rochester. Tickets $5.00 advance; $7.00 at the gate. Huge outdoor flea market $5.00 per space. Special indoor flea market for non-commercial exhibitors. For tickets: Hamfest Tickets, 174 Croydon Rd, Rochester, NY 14610. For information: Rochester Hamfest, 300 White Spruce Blvd, Rochester, NY 14623 or phone (716) 424-7136. Talk in on 146.28/88.

NEBRASKA: The Ak-Sar-Ben Amateur Radio Club Auction, May 18, Radial Social Hall, 1516 NW Radial Highway, Omaha. Equipment check-in 8 AM. Auction begins 9:15 AM. Talk in on 146.34/.94. For information: Greg Zimmerman, N0BTN (402)895-5219.

MICHIGAN: The Wexaukee Amateur Radio Association's 26th annual Swap Shop, Saturday, May 17, Wexford Civic Arena, jct. of N. Mitchell and 13th Street. 8 Am to 2:30 PM. Admission $2.50. Food and refreshments available. Talk in on WD8RZL 97/37. For more information: Wexaukee ARA, PO Box 163, Cadillac, MI 49601.

NORTH CAROLINA: The Durham FM Association will hold its annual Hamfest & Computerfest, Saturday, May 24, lower level of South Square Mall, Durham, 8 AM to 4 PM. Admission $4.00 at the gate. Covered flea market. Tables will be available. Free parking. Talk in on 147.825/225. For more information: D⁶F⁶M⁶A⁶, PO Box 8651, Durham, NC 27707 or Mick, W4ZUS at (919) 544-3556.

OHIO: The Sandusky Valley ARC's annual Hamfest, May 18, American Legion Home, 2000 Buckland Avenue, Fremont. Advance tickets $2.50; at the door $3.00. 8' table space $6.00. Free trunk space space, free parking. Talk in on 52 simplex or 146.31/91. For tickets or more info SASE to Pat D. Keating, WB8KWD, 615 Lime Street, Fremont, Ohio 43420.

NEW YORK: LIMARC sponsors ARRL outdoor Hamfest, Sunday, May 18, NY Institute of Technology, Northern Blvd, Rt. 25A, 1 mile east of Glen Cove Road, Old Westbury. General admission for hams $3.00. 9 AM to 3 PM. Sellers car space $5.00. 7:30 AM, no reservations. Call Hank, WB2ALW nights for additional info or LIMARC Infoline (516) 796-2366.

PENNSYLVANIA: The 32nd annual Breezeshooters Hamfest, Sunday, June 1, 9 AM to 5 PM, White Swan amusement Park, Rt. 60 near Greater Pittsburgh International Airport. Free admission and flea market. Family park. Registration $2.00 each. 3/$5.00, 7/$10.00. Covered vendors area by advance registration. Mobile talk in on 28/88 and 29.000 MHz. For more information: William Hall, Sr, K3VSL, 3103 Wainbell Avenue, Pittsburgh, PA 15216 (412) 531-4827.

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

NORTH CAROLINA: Raleigh, the City of Oaks and the Raleigh Amateur Radio Society presents the 14th annual RARS Hamfest, NC State ARRL Convention and Computer Fair, Jim Graham Building, NC State Fairgrounds, Hillsborough Street. Advance registration $3.50 until April 7. $5.00 at the door. Flea market space, one table and 2 chairs (ours only) $6.00 each. FCC exams by pre-registration prior to April 1. Contact John Johnson, WM4P direct. Free welcoming party in Graham Building Saturday night, 7 - 10 PM. Wouff Hong Ceremony. Talk in 04/64 and 28/88. For more information: Rollin Ransom, NF4P, 2447 Fairway Drive, Raleigh, NC 27603. (919) 779-5021.

MASSACHUSETTS: The MIT UHF Repeater Association and the MIt Radio Society offer monthly Ham Exams. All classes Novice to Extra. Wednesday, May 21, 1986,7 PM, MIT Room 1-134, 77Mass Ave, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann (617) 253-5820/646-1641 or Craige Rodgers at 225-6616. Exam fee $4.00. Bring copy of current license, 2 forms of picture ID and completed form 610 (available from FCC in Boston. 223-6609).

OPERATING EVENTS

"Things to do . . ."

ARMED FORCES DAY: In recognition of the 37th anniversary of this event, Amateur Radio Station W4ODR, located Northside aboard Naval Air Station Memphis, Millington, Tennessee, will be operated by sailors and Marines on Saturday, 17 May from 1400Z to 220Z. For information on W4ODR, NAS Memphis contact: Station Custodian, Chief Petty Officer Bob Donan, KA4FAL, (901) 872-2007.

QRP ARCI Spring CW Contest, April 19 to April 20. For information Eugene Smith, KA5NLY, Chairman, POBox 55010, Little Rock, AR 72225.

UNION ELECTRIC Ham Radio Club will operate KA0AWS on May 18 from 1800-2300 UTC to honor all the employees of Union Electric Co, the utility serving parts of Missouri, Illinois and Iowa. Send contact number and large SASE (39 cents) for certificate to: KA0AWS Henry G. Schaper, Sr. 241 Tapestry Drive, St. Louis, MO 63129.

NATIONAL 6 MTR INVITATIONAL NET Activity Day Contest, 1400Z May31 to 2400Z June 1. Exchange call, SIN No. and grid squares. Send contest logs by July 1, 1986, to Lisa Lowell, KA0NNO, POB 249, Ft. Lupton, CO 80621

ST. CHARLES ARC will operate WB0HSI from the annual Lewis and Clark Days Festival, St. Charles, MO, 1300-2100Z, May 17-18. For certificate, send large SASE to St. Charles ARC, PO Box 1429, St. Charles, MO 63302.

ARMADILLO COUNTY, TEXAS will become county number 3,077 from March 2 through December 31, 1986. Governor Mark White will proclaim that any Amateur Radio Operator operating along the Texas Independence Trail during that time frame may broadcast that s/he is in Armadillo County, Texas.

W.I.N.O., the Wireless Institute of Northern Ohio, an organization sponsored by the Lake County ARA, will commemorate Ohio Wine Month operating a special events station, KO8O, from a winery in Madison, Ohio, Saturday, June 7 and Sunday, June 8. A special certificate is available from KO8O WINO Weekend, 7126 Andover Drive, Mentor, Ohio 44060. Please send legal sized SASE.

ARMED FORCES DAY The US Naval Reserve Readiness Command will operate special event station W4NUS (Navy United States) from the battleship USS North Carolina at Wilmington, NC. May 17 1400Z to 0200Z. QSL to: USS North Carolina, Box 417, Wilmington, NC 28406. SASE not required for your special QSL.

OWENSBORO ARC will operate K4HY from 0000Z May 10 to 0530Z May 11 to celebrate their International BBQ Festival. 7245 phone. Certificate for SASE via N4EKG, 1615 East 23rd Street, Owensboro, KY 42301.

SCHOLARSHIP AWARD: The Atlanta Radio Club is pleased to announce its 1986 scholarship awards program. Two sums of $1250.00 each will be awarded to the winners. Applicants must be licensed Radio Amateurs graduating from high school and entering an accredited college or university as Freshmen for the first time in 1986. Judging is based on school grades, citizenship, ham radio achievements and financial need. For application blanks write: Phil Latta, W4GTS, 259 Weatherstone Parkway, Marietta, GA 30067.

THE FOUNDATION FOR AMATEUR RADIO, INC., a non-profit organization with headquarters in Washington, DC, plans to award 21 scholarships for academic year 1986-87. Licensed Radio Amateurs may apply for these awards if they plan to pursue a full-time course of studies at an accredited university, college or technical school. For additional information and application form send letter prior to May 31, 1986 to FAR Scholarships, 6903 Rhode Island Avenue, College Park, MD 20740.

Derby and District Amateur Radio, incorporating Derby Wireless Club 1911, will be celebrating its 75th anniversary during 1986. The Society plans at least one event per month throughout the year each from a different location with the City of Derby. The callsign to listen for will be GB3ERD.

1986 marks the 50th anniversary of the Greater Cincinnati Amateur Radio Association. A number of special events are planned. Watch for announcements here.

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Invitation to Authors

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THE GUERRI REPORT

by Ernie Guerri, W6MGI

major advances in fiber optic systems —

Throughout the world intensive work is being done to tap the potential offered by fiber optic communications and data transmission systems. The progress has been rapid and impressive; in the United States and Japan, vast optical networks are taking shape that will handle much of the national communications load by the early 1990s.

The development of critical components has been key to this progress. The use of single-mode fibers has reduced transmission losses to the region of 2 dB/km. Single-mode fibers have very small core diameters, which means that the light doesn't reflect off the core walls and cause corresponding losses. Other key components include transmitting and receiving illumination and detection semiconductors, low-loss fittings and couplers, and integrated optical signal processors and data switches.

The bandwidths and data rates associated with fiber optic systems are dazzling, with several hundred MHz being common. These systems offer the further advantages of being small, lightweight, low in power radiation, EMP resistant, and very difficult to intercept or tap.

During the past several months, researchers at GTE have published work that shows just how fast this technology is progressing. The GTE investigators have fabricated a laser diode with a cavity only 0.2 square microns. This small geometry has demonstated switching rates of 20 Gigabits per second, and would theoretically allow data transmission rates 5 million times greater than a conventional phone line. This remarkable component was fabricated from Indium Phosphide (InP), a successor of sorts to GaAs.

As if all of this weren't enough, extensive work is being done to develop RF-to-optical converters, optical switches, and other devices aimed at eliminating the electronics altogether. Just when we thought that electronics was the way to go!

thanks for the memories

One form or another of electronic memory has found its way into nearly every type of consumer and industrial product: microwave ovens that store the cooking time for many foods in a permanent memory . . . scanners, Hi-Fi receivers, VHF-UHF transceivers and HTs, and so on — not to mention the proliferation of memory types and sizes available for computer applications.

Basic memory these days generally consists of CMOS structures organized in various binary configurations. The largest of these arrangements has typically been 256K x 1, used in advanced microcomputers like the IBM, Apple, and HP machines. These, in turn, are organized into even larger grouping — up to 1 Megabyte (1 million x 8 bits). Toshiba has recently announced the limited availability of its TC511000 series of 1 Mbit (1 million x 1) CMOS memories. Since most computers use a memory structure that calls for 9 bits (8 data bits plus 1 check bit), it will now be possible to have 1 Mb of random access memory using only 9 ICs. It has just recently become possible to break the so-called 640K computer memory barrier with bank-switched cards that allow well over 1 Mb of memory in microcomputers that nominally can address only 1 Mb of memory. The new Toshiba chip will help make possible IBM PC-type computers with processing power that is today associated with machines costing over $200,000.

Other types of memory devices have made equally impressive strides. Floppy disks capable of storing over 6 Mb have been tested and are about to become available. Hard disks with 20 to 50 Mb are now common adjuncts for microcomputers, and industry sources say that within two years, 100 Mb drives will be "standard" on many advanced PCs. Plug-in expansion cards containing 20 Mb hard disks are now available at prices comparable to the cost of a single 360K floppy drive a few years ago. On the horizon are optical disks similar to those used in audio CD players; some are now available as permanent back-up for computer data. These devices can be written only once, but have over 100 Mb of capacity and are quite cost-effective for this application. Good progress is being made on much larger optical disks, with storage capacities up to 1 Gb, and the ability to read as well as write. Optical memories offer the prospect of being able to hold all the data that a single user may ever need, on a single disk!

ultra-small transistor

Scientists at Arizona State University report that they have fabricated an operating transistor with a gate length of only 150 atoms. This is less than 1/10th the size of the average microwave GaAs FET. The device was made using a special very narrow electron beam to form the etching mask. Since frequency response is closely related to the dimensions of the gate, it is expectd that devices with such small geometries will provide good gain and low noise well into the millimeter (above 30 GHz) region.

ham radio

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READER SERVICE #		PAGE #
201	ADN	45
216	Advanced Computer Controls, Inc	13
208	Advanced Receiver Research	34
167	AEA	85
153	AEA	99
149	AEA	101
144	AEA	102
133	All Electronics Corp	117
115	Alpha Delta Communications, Inc	130
143	Aluma Tower Co	102
103	Amateur Wholesale Electronics	143
*	American Electronic Labs, Inc	42
147	Amidon Associates	101
187	AMSAT	66
141	ARRL	102
124	ARRL	127
184	Astron Corp	68
127	Azotic Industries	125
*	Barker & Williamson	78
*	Barry Electronics	126
150	Bird Electronic Corp	98
151	Bird Electronic Corp	98
157	Bomar Crystal Company	94
193	Brincomm Technology	54
166	Buckmaster Publishing	84
*	Butternut Electronics	113
*	Caddell Coil Corp	76
160	CCIE	92
162	CDC	88
120	Coaxial Dynamics, Inc	128
156	Colorado Comm Center	94
138	Communications Concepts, Inc	113
107	Communications Specialists	140
112	Computer Smythe	133
102	Connect Systems, Inc	144
155	CTM	96
218	Cushcraft Corp	11
134	Data World	114
171	DCC Data Service, Inc	76
*	Dick Smith Electronics	85
108	Digimax Instruments Corp	138
173	Digitrex	79
223	Doppler Systems	31
163	Down East Microwave	88
122	EEB	129
113	EGE, Inc	132
*	Engineering Consulting	27
194	ESS	54
164	Exmet	84
105	Fair Radio Sales	142
203	Fluke Mfg. Co	43
152	Fox International, Inc	99
*	Fox Tango Corp	132
*	Gem Quad Products	97
202	GLB Electronics	45
186	GLB Electronics	67
172	GLB Electronics	79
154	GLB Electronics	96
183	Gordon West Radio School	71
135	H.L. Heaster, Inc	114
217	Hal Communications Corp	10
165	Hall Electronics	84
214	Ham Radio Outlet	14, 15
*	Ham Radio's Bookstore	9, 26, 66, 96, 100, 101, 114, 116, 120, 122, 123, 130, 133, 138
*	The Ham Station	99
*	Hamtronics, NY	115
*	Hamtronics, PA	137
109	Hamtronics, PA	139
139	Harrison Radio	108
221	ICOM America, Inc	Cover II
174	J.S. Technology, Inc	79
195	Jensen Tools, Inc	54
145	Jun's Electronics	100
220	Kantronics	1
197	Kendecom/MCS	52
*	Trio-Kenwood Communications	2, 5, 7, 93, Cover IV
131	Kepro Circuit Systems, Inc	116
192	Larsen Antennas	59
178	Luxor (North America) Corp	72, 73
169	Madison Electronics Supply	80
207	Elaine Martin, Inc	34
179	Glen Martin Engineering	70
116	MCM Electronics	131
106	The Meadowlake Corp	142
219	MFJ Enterprises	8
188	Micro Supply Organization	60
190	Micro Systems Institute	59
158	Milliwatt Books	94
226	Minds Eye Publications	139
212	Mirage/KLM	24
140	Mirage/KLM	107
111	Mosley Electronics	137
176	Multibotics, Inc	78
213	N&G Distributing Corp	20
129	Nemal Electronics	120
132	Nuts & Volts	116
215	P.C. Electronics	12
211	Pac Comm Packet Radio Systems, Inc	29
136	Pacific Rim Communications	114
121	Pro Search	129
180	Processor Concepts	70
175	Propagation Publishing	79
159	The PX Shack	92
117	QEP's	131
137	QSKY Publishing	114
206	R&L Electronics	34
209	Radio Amateur Callbook	30
123	RadioKit	126
205	Radyx Satellite Systems, Ltd	37
130	Ramsey Electronics, Inc	121
177	Redipart	77
210	RF Parts/Westcom Eng	31
170	Rhode Island School	76
198	Robot Research, Inc	51
114	Roensch Microwave	132
125	Satellite Super Savers	127
146	Silicon Solutions, Inc	101
168	Sommer	83
*	Spec Com	128
185	Spectrum International, Inc	66
126	Spi-Ro Distributing	125
*	STTI	90
128	STV/OnSat Magazine	120
104	Sultronics	142
191	Synthetic Textiles, Inc	59
199	TDP Electronics	46
181	TechMart	70
119	Technical Development Systems	131
189	Tel-Com	58
196	Telewave, Inc	55
*	Ten-Tec	44
182	Transverters Unlimited	71
118	Unity Electronics	131
*	University Microfilm Int	94
225	Vanguard Labs	139
204	Varian	38
110	W9INN Antennas	139
142	Webster Communications	102
200	Wenzel	45
148	Western Electronics	101
222	World Tech Products	58
101	Yaesu Electronics Corp	Cover III

PRODUCT REVIEW/NEW PRODUCT

312	Ace Communications, Inc	125
303	Ameco Publishing Corp	130
311	Austin Custom Antennas	126
307	Communications Specialists	127
308	EEB	127
*	Engineering Consulting	128
*	Fox Tango Corp	127
315	G2DYM Aerials	125
314	Gordon West Radio School	125
*	Hamtronics, NY	132
317	ICOM America, Inc	124
301	International Radio, Inc	132
304	Jensen Tools, Inc	130
316	MFJ Enterprises	124
313	Nemal Electronics	125
306	North American Soar Corp	127
321	The PX Shack	133
310	Yaesu Electronics Corp	126

*Please contact this advertiser directly.

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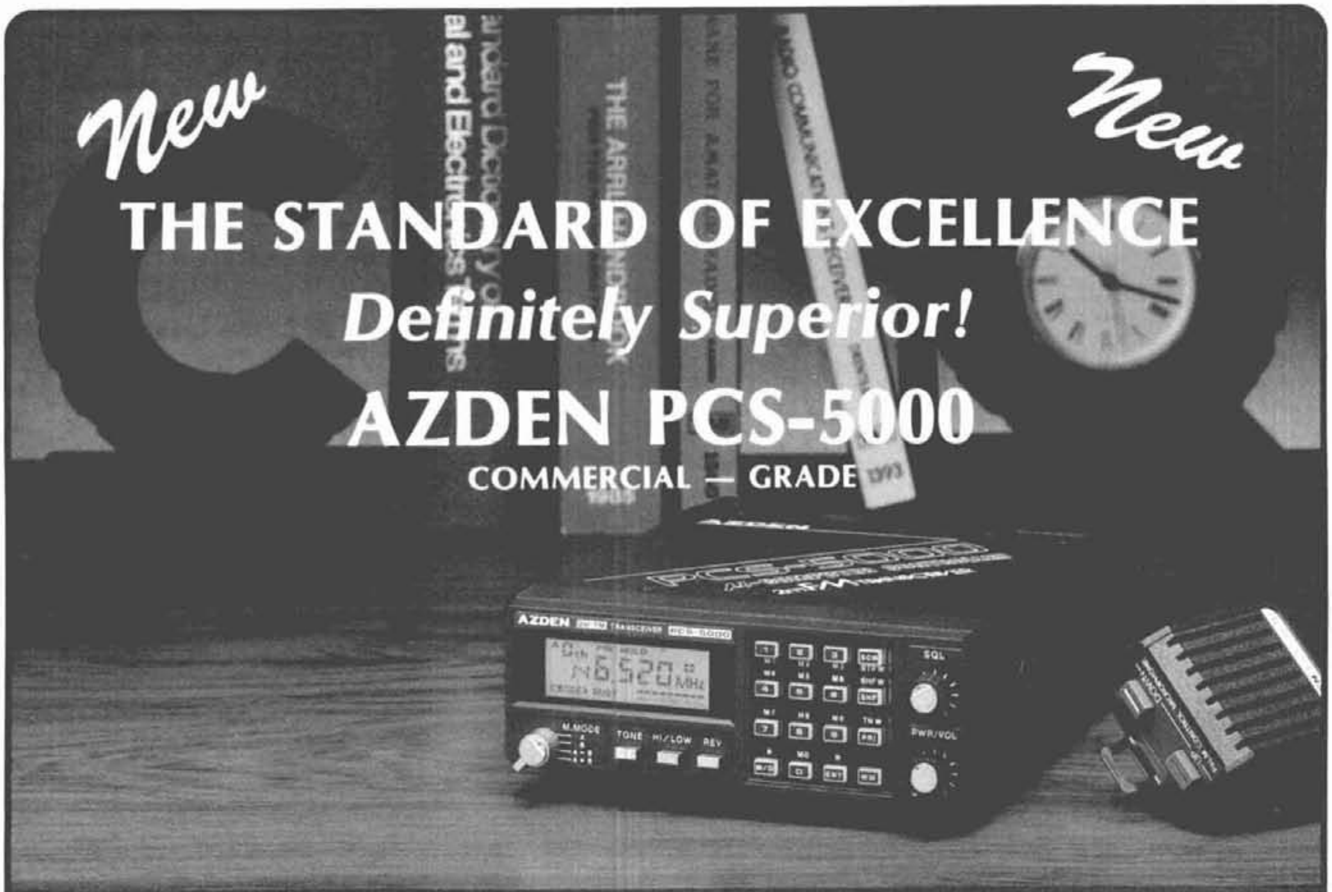

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- Your patch should sound just like your home phone.
- There should not be any sampling noises to distract you and rob important syllables. The best phone patches do not use the cheap sampling method. (Did you know that the competition uses VOX rather than sampling in their $1000 commercial model?)
- A patch should disconnect automatically if the number dialed is busy.
- A patch should be flexible. You should be able to use it simplex, repeater aided simplex, or semi-duplex.
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- A patch should not become erratic when the mobile is noisy.
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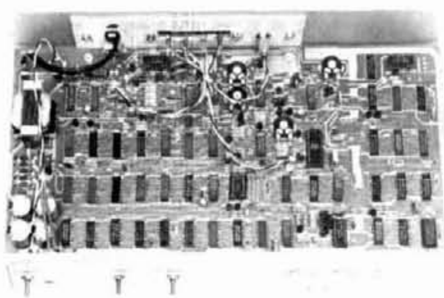

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And working the DX has never been easier with dual VFOs, single-button VFO/memory swap for split-frequency operation, eight memories, and push-button quick memory and band scan.

The 757 also lets you listen from 500 kHz to 30 MHz with its high-performance general coverage receiver. The transmitter covers 160 through 10 meters, including the new WARC bands, with 100 watts output on sideband, FM and CW.

CW buffs will enjoy the delights of full QSK operation. Plus the massive heatsink and duct-flow cooling system allow continuous RTTY operation for up to 30 minutes. Use the FP-757HD heavy-duty power supply option for continuous-duty applications.

And of course, there's the 757's highly attractive price. It's the perfect way to get all the HF performance you desire, with money left over to apply toward other ham gear. Perhaps a power supply for base station use. An antenna or antenna tuner. Or whatever else makes your operation complete.

So ask your dealer today about Yaesu's FT-757GX. The most celebrated HF price/performer on the air.

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