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.

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See the IC-735 at your authorized ICOM dealer. For superior performance and innovative features at the right price, look at the ultra compact IC-735.
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 Packet 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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For more information contact your local Kantronics dealer or write:

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- MB-430 mobile mounting bracket  
- YK-88C/88CN 500 Hz/270 Hz CW filters  
- YK-88S-885N 2.4 kHz/18 kHz SSB filters  
- MC-60A/80/85 desk microphones  
- MC-5s (8p) mobile microphones  
- HS-41/67/7 headphones  
- SP-40/50 mobile speakers  
- MA-5VP-1 HF 5 band mobile helical antenna and bumper mount  
- TL-322A 2 kw PEP linear amplifier  
- SM-220T station monitor  
- VS-1 voice synthesizer  
- SW-100A/200A/2000 SWR/power meters  
- TU-8 CTCSS tone unit  
- PG-2C extra DC cable

Complete service manuals are available for all Kenwood transceivers and most accessories. Specifications and prices are subject to change without notice or obligation.
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May 1986
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, YU7PFR1), 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

May 1986
220: Kenwood Style!

The first comprehensive 220 MHz FM transceiver

TM-3530A

- 25 watts of 220 MHz FM—Kenwood style!
- Features include built-in 7-digit telephone number memory, auto dialer, direct frequency entry and big LCD.
- All this makes the TM-3530A the most sophisticated rig on 220 MHz!
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- Rugged, high-impact case

- 16-key DTMF pad, with audible monitor
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- New 5-way adjustable mounting system
- High performance GaAs FET front end receiver
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TM-3530A optional accessories:

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

- MC-60A/MC-90/MC-95 desk mics.
- MC-48 extra DTMF mic. with UP/DOWN switch
- MC-42S UP/DOWN mic
- MC-55 (8 pin) mobile mic. with time-out timer
- SP-40 compact mobile speaker
- SP-50 mobile speaker
- SW-200B SWR/power meter
- SW-100 compact SWR/power meter

Kenwood

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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 1986 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 Severeely 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 bedrooms.” As the report above demonstrates, this bill’s threat to a citizen’s privacy that they were running a business rather than disposing of personal equipment. Though swap Meet 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 nets’ 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 28. The third party traffic problem had arisen in the form of a Notice of Proposed Rule Making. Most of the comments filed in response to the proposal (SK 5038) 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.

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 (SK 5038) 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 EXAMINATION 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 URE 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.

WASHINGTON INTERNATIONAL COORDINATOR’S ASSOCIATION IS THE NEW NAME tentatively chosen for the “Pacific Area Coordination Association” announced in last month’s PressStop. 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” ACTIVITIES 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 nets’ activities, does not herald any FCC change in direction or indicate the beginning of a nationwide FCC effort.

THE 12TH ANNUAL EASTERN VHFE/UHFE 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, K1ATF, 150 Oakdale, Nashua, NH 03052 can provide details.
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.

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:
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- VB-2530 2m 25 W RF power amp
- ST-2 base stand/charger
- MS-1 mobile stand/charger
- PB-26 Ni-Cd battery
- 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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This may be the world's most popular 3 KW roller inductor tuner because it's small, compact, reliable, matches virtually everything and gives you SWR/Wattmeter, antenna switch, dummy load and balun—all at a great price!

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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. New antenna switch! Front panel mounted. Select 2 coax lines, direct or through tuner, random wire/balanced line or tuner bypass for dummy load. New airwind inductor! Larger more efficient 12 position airwind inductor gives lower losses and more watts out. Run up to 300 RF power output. Matches everything from 2.8 to 30 MHz, dipole, inverted vee, random wires, verticals, mobile, mobile whips, beams, balanced and coax lines. Built-in 4:2 balun for balanced lines. 1000 V capacitor spacing. Black 11 3 x 7 inches. Works with all solid state or tube rigs. Easy to use anywhere.

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2 KW COAX SWITCHES

MFJ-1702 $19.95

MFJ-1702 $19.95. 2 positions. 60 dB isolation at 500 MHz. Less than 2.0 dB loss. MFJ-1701 $29.95

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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 airwind 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

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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, mobile, camping operation. Tunes 1.8-30 MHz. 2 x 3 x 4 inches. MFJ-1331 is available for $29.95.

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8 May 1986
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, Hantsshire, 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:*  

CN2AO DJ0IA DL0WU EA8ADP G2PU  
G3WMZ G4AMN GW4OFQ I5NPH JA1FRE  
JF1IST K1MEM K2FV K3Z0 K5UR  
KG7D LA7ZQ N1ACH N4AR N4RJ  
N4SU NW5K N6KXP N7CKD O6EMBG  
OH1RY Q28BV PA3DFU SM4CAN SM6EHY  
SP3GEM T15EVL VE2H0 VE3GMV VE7B5  
VK6LK W1FV W1NH WB2ITR W2JB  
W3BGN W4DR W6NLZ W6RJ YU7PR  
2L4BO 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

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

* 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.
that's changed to some extent with the challenge and achievement remain. The full-sized availability of commercial Yagis for 80 meters, but the 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.

Beavers, 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, 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 call signs are provided. Though most Beverages preferably are installed over low conductivity soil, OZ8BV proves that they still perform over salt water with his four interconnected 200-meter-long antennas.

The full size element Yagi is installed “in the clear” and accounts for OH1RY’s strong signal from Finland.
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.

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-

![Fig. 6. VE2HQ's homemade Yagi uses linearly loaded elements but still is quite large.](image-url)
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                | JAIFRE               |
| 3 element Yagi, short el | 10-15                | Function of freq.    |
| 3 element Yagi, full size | 30                   |                      |
| 2 element Yagi,wire   | 8-12                 | Yukish design        |
| 4 element Vert, phased array | 30                   | WINM                 |
| 4 element Vert, phased array | 15-45  | SIMEN               |
| 2 element Vert, phased array | 20-30                | HFV                  |
| Delta loop, 2 element driven | 15-20  | Great F/S           |

| Table 7. Rotators |
|-------------------|-------------------|-------------------|
| Description       | Height            | Station            |
| Rohn 45           | 180               | EABHOF             |
| Rohn 90 plus 10/1 mast | 150          | NARJ               |
| Westover S-100     | 160               | JAIFRE             |
| Trumex T-20        | 120               | WALTZ              |
| Homestead 50 on 60 microwave tower | 110 | VE2VCD             |
| Heights            | Height            | Station            |
| Create 15-15       | 90                | JP1380             |
| Trumex Skyneedle   | 90                | M300               |
| Pole               | 70                | DXBA               |
| Buildings          | 50                | YUKFRR             |
| Self-supporting    | 40                | 11546              |

May 1986
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.

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,
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-
at 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 groundbus 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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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.¹

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 | Salty: Conductivity: 4.64 mS |
| Frequency: 3.75 MHz | Dielectric constant: 20 | Dielectric constant: 81 |
| Rocky soil: Conductivity: 2 mS | Dielectric constant: 14 |

**Table 9. Ground systems**

<table>
<thead>
<tr>
<th>Radials</th>
<th>Length</th>
<th>Gnd rods</th>
<th>Length</th>
<th>Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>125’</td>
<td>3</td>
<td>8’</td>
<td>K32D</td>
</tr>
<tr>
<td>2</td>
<td>131’</td>
<td>3</td>
<td>8’</td>
<td>VE3BMV</td>
</tr>
<tr>
<td>3</td>
<td>135’</td>
<td>4</td>
<td>10’</td>
<td>4X4NJ</td>
</tr>
<tr>
<td>63</td>
<td>65’</td>
<td>4</td>
<td>8’</td>
<td>SP3GEM</td>
</tr>
<tr>
<td>50</td>
<td>62’</td>
<td></td>
<td>6.6</td>
<td>VK6LK</td>
</tr>
<tr>
<td>20</td>
<td>75’</td>
<td></td>
<td>6.6</td>
<td>VE7BS</td>
</tr>
<tr>
<td>125</td>
<td>65’</td>
<td></td>
<td>6.6</td>
<td>NW5HK</td>
</tr>
<tr>
<td>90</td>
<td>80’</td>
<td></td>
<td>6.6</td>
<td>W36GN</td>
</tr>
<tr>
<td>320</td>
<td>80’</td>
<td>500</td>
<td>6.6</td>
<td>WINH</td>
</tr>
<tr>
<td>100</td>
<td>130’</td>
<td>4</td>
<td>6.6</td>
<td>H5UR</td>
</tr>
<tr>
<td>65</td>
<td>130’</td>
<td></td>
<td>6.6</td>
<td>N4RQ</td>
</tr>
<tr>
<td>3</td>
<td>250</td>
<td></td>
<td>6.6</td>
<td>N4RQ</td>
</tr>
<tr>
<td>400</td>
<td>70-1000</td>
<td>50</td>
<td>6.6</td>
<td>SMAH6Y</td>
</tr>
<tr>
<td>496</td>
<td>65’</td>
<td></td>
<td>6.6</td>
<td>W4DR</td>
</tr>
<tr>
<td>15</td>
<td>65’</td>
<td>3</td>
<td>6.6</td>
<td>DJ01A</td>
</tr>
<tr>
<td>300-360</td>
<td>50-130</td>
<td></td>
<td>6.6</td>
<td>W1FW</td>
</tr>
</tbody>
</table>

**Table 10. Reflection coefficient vs soil type and takeoff angle**

<table>
<thead>
<tr>
<th>Soil</th>
<th>Angle</th>
<th>Polarization</th>
<th>Amplitude</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocky</td>
<td>15</td>
<td>Horizontal</td>
<td>118% of max</td>
<td>290 deg</td>
</tr>
<tr>
<td>Pastoral</td>
<td>15</td>
<td>Horizontal</td>
<td>97%</td>
<td>165 deg</td>
</tr>
<tr>
<td>Salty</td>
<td>15</td>
<td>Horizontal</td>
<td>98.75%</td>
<td>91 deg</td>
</tr>
<tr>
<td>Rocky</td>
<td>15</td>
<td>Vertical</td>
<td>17%</td>
<td>75.50 deg</td>
</tr>
<tr>
<td>Pastoral</td>
<td>15</td>
<td>Vertical</td>
<td>6.2%</td>
<td>25.52 deg</td>
</tr>
<tr>
<td>Salty</td>
<td>15</td>
<td>Vertical</td>
<td>96%</td>
<td>2.10 deg</td>
</tr>
<tr>
<td>Rocky</td>
<td>45</td>
<td>Horizontal</td>
<td>4.2%</td>
<td>6.24 deg</td>
</tr>
<tr>
<td>Pastoral</td>
<td>45</td>
<td>Horizontal</td>
<td>99.75%</td>
<td>0.14 deg</td>
</tr>
<tr>
<td>Salty</td>
<td>45</td>
<td>Horizontal</td>
<td>99.75%</td>
<td>0.14 deg</td>
</tr>
<tr>
<td>Rocky</td>
<td>45</td>
<td>Vertical</td>
<td>51%</td>
<td>13.44 deg</td>
</tr>
<tr>
<td>Pastoral</td>
<td>45</td>
<td>Vertical</td>
<td>98.6%</td>
<td>8.85 deg</td>
</tr>
<tr>
<td>Salty</td>
<td>45</td>
<td>Vertical</td>
<td>98.6%</td>
<td>8.72 deg</td>
</tr>
</tbody>
</table>

**Fig. 8.** To gain an appreciation of the type of tower needed to handle low-band rotaries, examine VE2HO’s new 160-foot structure ready to support his three-element Yagi.

**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.

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
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 maintenance. What periodic maintenance 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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computer-aided design
of long VHF Yagi antennas

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 Ile 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
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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

fig. 4. Program to input data files.
The program shown in Fig. 3 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


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.)

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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.

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...
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.

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.

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<tr>
<td><strong>3-year warranty</strong></td>
<td>3-year warranty</td>
<td>3-year warranty</td>
</tr>
</tbody>
</table>

* Suggested U.S. list price effective November 1, 1985
** Patent pending

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*Stuart D. Cowan is recognized as one of the world’s foremost authorities in ham radio. He is an author of Handbooks for Radio Amateurs, CB Operators, Shortwave Listeners, Kit Builders, Experimenters, and Students. He and Bill Orr (W6SAI) worked together in propagation studies on the new 10, 18, and 24MHz bands as authorized by the FCC. Experiments also included satellite communication. In the experiments he used Ten-Tec equipment for three years on cw and ssb “without a single problem or failure.”

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<table>
<thead>
<tr>
<th>Model</th>
<th>CM-1</th>
</tr>
</thead>
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<tr>
<td>Frequency</td>
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</tr>
<tr>
<td>Output Drive</td>
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</tr>
<tr>
<td>Aging Rate</td>
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<td>Temperature</td>
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<td>Warm-Up Time</td>
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<td>Power Requirements</td>
<td>9 V Adapter Included</td>
</tr>
<tr>
<td>Size</td>
<td>4.6&quot; x 4.8&quot; x 1.6&quot;</td>
</tr>
</tbody>
</table>

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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, Amateure, 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 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.

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

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

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.
sensitivity

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

\[ E_s (dB) = 20 \log \frac{e_{OUT}}{e_{IN}} \cdot \frac{1}{2} \cdot \frac{C_A}{C_{IN} + C_{OUT}} \]

where the factor 1/2 arises because of a given \( \mu V/m \) 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 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
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.

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**Table 2.** Series filter resonance of readily available inductors.

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

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
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 Engineering 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.

**references**


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More Details? CHECK - OFF Page 142

May 1986 55
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.

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 goal 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) 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-

By Bill Myers, K1GQ, Box 501, Hollis, New Hampshire 03049
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. 2. H-plane radiation pattern.](image)

![fig. 3. E-plane radiation pattern.](image)

![fig. 4. Coaxial matching sections.](image)

![fig. 5. Measured standing wave ratio.](image)

![fig. 6. Feedpoint switch.](image)
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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:

\[ 10 \log \left( \frac{78^\circ}{65^\circ} \right) \approx +0.79 \text{ dBd} \]

Gain improvement in the H-plane is:

\[ 10 \log \left( \frac{360^\circ}{90^\circ} \right) \approx +6.0 \text{ dBd} \]

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

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 \( 0.83\lambda_o \) 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:

\[ 0.659 \times \frac{\lambda_o}{2} \leq 0.33\lambda_o \]

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

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

\[ 0.695 \times \frac{\lambda_o}{2} \leq 0.35\lambda_o \]

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

\[ 0.82 \times \frac{\lambda_o}{2} = 0.41\lambda_o \]

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

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* “Colagi” is a registered trademark of Sinclair Radio Laboratories.
fig. 1. Dipole through 24 element Yagi -3dB beamwidth vs. directive gain.

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
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:

\[ 10 \log \left\{ \frac{32,000}{42 \cdot 46} \right\} - 2.15 = 10.04 \text{ dBi} \]

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

\[ 10 \log \left\{ \frac{32,000}{20 \cdot 46} \right\} - 2.15 = 13.26 \text{ dBi} \]
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.

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
spacing between 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...
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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°, 30°, 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 half 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:

\[
10 \log \left( \frac{32,000}{18 \times 10} \right) = -2.15 = 20.3 \text{ dBd}
\]

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 2.5λ₀. 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 -3 dB 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.

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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 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 (fEXP) 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
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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 λ/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:

\[ \text{Change} = \left( \frac{f_{\text{EXP}}}{f_R} \right) \times 100\% \]

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 reac-
tance 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.

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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 \( X/f \) 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 feed lines 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.

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 armamentarium.

reference

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"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 K4Klfs illuminating article1 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:

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

(1)

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

This equation can be solved for $Z_L$, yielding:

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

(2)

Recalling the rule of complex algebra

$$a + jb = \frac{ac + bd}{c^2 + d^2} + \frac{j \cdot bc - ad}{c^2 + d^2}$$

(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:

$$\text{SWR} = \frac{1 + G}{1 - G}$$

(4)

where $G$ is the reflection coefficient

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

(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:

$$\text{SWR at load} = \text{SL} = \frac{A + B}{A - B}$$

(6)

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

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

where

$$A = \frac{S_I + 1}{S_I - 1}$$

(7)

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

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

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
ous sources. The ARRL Antenna Book2 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 $y = \log\text{(attenuation)}$, $x = \log\text{(frequency)}$, $m$ 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 $Z_o$.

Although the concept is straightforward, a brief
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fig. 1. "Transline Plus" program performs transmission line calculations.

READY.

10 REM WRITTEN BY GARY MYERS K9CZB
20 PRINT"(CLR)"
30 FOR J=1 TO 5:PRINT: NEXT J
40 PRINTTAB(10)"**TRANSLINE PLUS**"
50 PRINTTAB(12)"A PROGRAM FOR"
60 PRINTTAB(4)"TRANSMISSION LINE CALCULATIONS"
70 L=LOG(10)
80 PRINT: PRINT"FREQUENCY (MHz): F"
90 PRINT: PRINT"TRANSMISSION LINE TYPE:""'
100 PRINTTAB(5)"A - RG59"
110 PRINTTAB(5)"B - RG69"
120 PRINTTAB(5)"C - MINI B"
130 PRINTTAB(5)"D - RGB/213"
140 PRINTTAB(5)"E - RG11"
150 PRINTTAB(5)"F - RGB FOAM"
160 PRINTTAB(5)"G - OTHER"
170 GETC$: IF C$="THEN170"
180 IF C$="A" THEN POK1558, 31: L=53.5: GOTO 7000
190 IF C$="B" THEN POK1598, 31: L=73.6: GOTO 7010
200 IF C$="C" THEN POK1642, 31: L=50: GOTO 7020
210 IF C$="D" THEN POK1681, 31: L=50: GOTO 7030
220 IF C$="E" THEN POK1719, 31: L=75: GOTO 7030
230 IF C$="F" THEN POK1762, 31: L=50: GOTO 7040
240 IF C$="G" THEN POK1799, 31: GOTO 2060
250 GOTO 170
260 PRINT: INPUT"LINE LOSS (DB/100)": LD
270 PRINT: INPUT"LINE IMPEDANCE": L: GOTO 3100
280 LP=INT(L/10)/10
290 IF INT(L/100)/100=0 THEN LF=LP+.1
300 PRINT: PRINT"MATCHED LOSS": LF:" DB/100"
310 PRINT: INPUT"VELOCITY FACTOR": VF
320 PRINT: PRINT"WANT TO CALCULATE A 0-SECTION (Y/N)?"
330 GETC$: IF C$="Y" THEN 3320
340 IF C$="N" THEN 3710
350 QL=(246.067VF)/LF: GL=INT(QL/100)+100
360 PRINT: PRINT"MATCHED LOSS": LF:" DB/100"
370 PRINT: INPUT"LINE LENGTH (FEET)": LL
380 AL=INT(L/10)+10
390 IF INT(L/100)/100=0 THEN AL=AL+.1
400 ML=(L/100)+100: MF=INT(M/10)+10
410 IF INT(M/100)/100=0 THEN MF=MF+.1
420 PRINT: PRINT"MATCHED LOSS": MF:" DB/100"
430 B=((L/100)/20)+100: EA=B+5.7
440 BP=INT(BA): BA=INT(10*BA)/10
450 IF EA-BF=1 THEN BF=BF+1
460 PRINT: PRINT"ELECTRICAL LENGTH":; BF:" DEGREES"
470 IF C$="Y" THEN 540
480 PRINT: INPUT"LOAD RESISTANCE": BR
490 PRINT: INPUT"LOAD REACTANCE": EX
500 GOSUB 1270
510 PRINT: INPUT"INPUT RESISTANCE": IR
520 PRINT: INPUT"INPUT REACTANCE": IX
530 GOTO 800
540 PRINT: PRINT"DESIGNATE KNOWN QUANTITY:""'
550 PRINTTAB(5)"A - INPUT IMPEDANCE"
560 PRINTTAB(5)"B - LOAD IMPEDANCE"
570 PRINTTAB(5)"C - INPUT SWR"
580 PRINTTAB(5)"D - LOAD SWR"
590 GETC$: IF C$="N" THEN 5910
600 IF C$="A" THEN 750
610 IF C$="B" THEN 780
620 IF C$="C" THEN 1000

May 1986
630 IFD$="D" THEN 1080
640 GOTO 590
650 PRINT: PRINT "TRY AGAIN (Y/N)?"
660 GOTO$: IFD$="THEN660"
670 IFD$="Y" THEN PRINT "(CLR)" : FOR J=1 TO 8: PRINT: NEXT: J: GOTO 70
680 PRINT "(CLR)" : FOR J=1 TO 8: PRINT: NEXT
690 PRINTTAB(13) "75 DE K/2CB": END
700 LA= .5376*LOG(F)/L+LOG(.42)/L: LO= 101+LA: GOTO 80
710 LB= .4586*LOG(F)/L+LOG(.4)/L: LO= 101+LB: GOTO 80
720 LC= .3979*LOG(F)/L+LOG(.4)/L: LO= 101+LC: GOTO 80
730 LD= .515*LOG(F)/L+LOG(.21)/L: LO= 101+LD: GOTO 80
740 LF= .52*LOG(F)/L+LOG(.15)/L: LO= 101+LF: GOTO 80
750 PRINT: INPUT "INPUT RESISTANCE": BR
760 INFUP "INPUT REACTANCE": BX
770 GOSUB 1200
780 PRINT: PRINT "LOAD RESISTANCE":; RA; " OHMS"
790 PRINT: PRINT "LOAD REACTANCE":; XB; " OHMS"
800 NF= (BR-LI) 12+BX 12
810 NF= (BR-LI) 12+BX 12
820 F=SQR(NF/DP)
830 SW=(1+F)/(1-F): SW=INT(SW*10)/10
840 PRINT: PRINT "VSWR":; SW
850 GOSUBI 1200
860 GOTO 650
870 PRINT: INPUT "LOAD RESISTANCE": RL
880 INPUT "LOAD REACTANCE": XL
890 NS= (RL-LI) 12+XL 12
900 DS= (RL-LI) 12+XL 12
910 G=SQR(NS/DS)
920 SW=(1+G)/(1-G): SW=INT(SW*100)/100
930 PRINT: PRINT "VSWR AT LOAD":; SW
940 GOSUB 1200
950 BR= RL; EX= -XL; GOSUB 1200
960 RA= INT(RA*10)/10; XB= COLLECT AND
970 PRINT: PRINT "INPUT RESISTANCE":; RA
980 PRINT: PRINT "INPUT REACTANCE":; XB
990 GOTO 650
1000 PRINT: INPUT "INPUT SWR":; SI
1010 AS= (SI+1)/(SI-1)
1020 BS= 1010 (ML/10)
1030 SW= (AS+BS)/(AS-BS); SW=INT(SW*10)/10
1040 PRINT: PRINT "VSWR AT LOAD":; SW
1050 CS= (SW-1)/(SW+1)
1060 GOSUB 1170
1070 GOTO 650
1080 PRINT: INPUT "LOAD SWR":; SW
1090 GOSUB 1120
1100 PRINT: PRINT "VSWR AT INPUT":; SI
1110 GOTO 650
1120 BS= 1010 (ML/10)
1130 CS= (SW-1)/(SW+1)
1140 SI= (BS+CS)/(BS-CS); SI=INT(10*SI)/10
1150 IFD$="D" THEN I170
1160 PRINT: PRINT "VSWR AT INPUT":; SI
1170 LT= (1010/L)*LOG((BS+CS)/(BS-CS))/(BS+CS)
1180 PRINT: PRINT "TOTAL LINE LOSS":; LT; " DB"
1190 RETURN
1200 IF COS(B)=OTHEN=1.57
1210 BB=TAN(B)
1220 D= (LI+ 8BB) 12 + (BB+BB) 12
1230 NA= BR 12 (LI+BB12) 1RA= (LI+NA)/D
1240 RA= INT(RA*10)/10
1250 NB= (BX-(L1+BB12) 1LI+BB12) 1BB 12 1BB 12; XB= (LI+NB)/D;
1260 RETURN
1270 RA= INT (LI+BB12) 1BB 12+BB 12); RA= INT (RA*10)/10
1280 XB= (LI+BB12) 1BB 12+BB 12); XB= INT (XB*10)/10
1290 RETURN
1300 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.) 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. 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 860 means a SHIFTed CLR/HOME key; this shows on the screen as a reversed video heart symbol.

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 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.

references

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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

CHOOSE ANTENNA FEEDPOINT HEIGHT ABOVE GROUND FROM THE FOLLOWING MENU:

1 = 10’
2 = 20’
3 = 30’
4 = 40’
5 = 50’
6 = 60’
7 = 80’
8 = 100’
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. 1. Menus for selection of frequency band, radio parameters, polarization, and path type.

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, 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-

fig. 2. Menus for selection of antenna parameters.

fig. 3. Typical program output format.
fig. 4. Propagation program list in BASIC for the Commodore 64.

2 CLS:CHR$(147):DL="N":LT=CHR$(157):DN=CHR$(17)
10 PRINTCL*WINS" 3.5-50 MHZ GROUND-WAVE PROPAGATION
14 PRINTD*: "PROGRAM FOR THE COMMODORE 64
16 PRINTD*: "V.1.0 C 1985 BY
18 PRINTD*: "LYNN A. GERIG, WAY8FR
20 FORJ=1TO6:PRINTNEXT
22 PRINT:TO CHANGE BORDER, SCREEN, OR LETTER
24 PRINT:COLORS, PRESB R, B, OR L, RESPECTIVELY.
26 PRINT:TO EXIT TO PROGRAM, PRESB <RETURN>.
30 GETA:IFA=""THEN30
32 IF=4="B":THENPOKE$280,PEEK$(33280)+1AND15
34 IFA="g":THENPOKE$3281,PEEK$(33281)+1AND15
36 IFA="L":THENPOKE$46,PEEK$(46)+1AND15:GOTO10
38 IFA=CHR$(13):THENSO
40 GOTO30
50 PRINTD*:"THIS PROGRAM CALCULATES EXPECTED RANGES
52 PRINT:FOR FREQUENCY BANDS OF 3.5, 7, 14, 28,
54 PRINT:50MHZ. THE APPROXIMATE DYNAMIC
56 PRINT: RANGES 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 PRINTD*:"PROGRAM DEFAULTS TO RCVR SENS AND XMTR
72 PRINT:POWER IN DB. WOULD YOU RATHER WORK WITH
74 PRINT:"MICRO-VOLTS AND WATTS (Y=N):""INPUT DB
76 GOSUB3900:REM READ DATA
100 GOSUB6400:REM SELECT FREQUENCY BAND
105 GOSUB7000:REM SELECT XMTR PWR & RCVR SENS
110 GOSUB8000:REM SELECT PROPAGATION PATH
115 GOSUB9000:REM SELECT ANTENNA PARAMETERS

200 REM MAIN PROGRAM CALCULATIONS
205 IF(H1=0ORH2=0)ANDP=2THENGOSUB900
210 H=H*(PO,PP,FB):REM DATA FOR SELECTED POLARIZATION, PATH & FREQ
215 FORJ=1TO12:X=64,J-1,P,J=VAL(MID$(H,x+4,3))NEXT
220 D(J)=VAL(MID$(H1,x+4,3)):NEXT220
225 IF(D(J)-999THEN(10)+1050:D(J)=1050)+D(J)-1050
230 H=H*:PO,PP,FB):REM XMT ANTENNA HEIGH T GAIN
235 H=H*:PO,PP,FB):REM RCVR ANTENNA HEIGH T GAIN
240 PRINT:"PWR=RD-HX+HR*GR-LRE PATH IN DB
245 PRINTCL*WINS"GROUND WAVE PROPAGATION AT"P(J)="HZ
250 PRINTP0S(PD)" POLARIZATION OVER "PPH
255 PRINTD*:"TRANSMITTER POWER OUT=PD TAB(50)"DBM
260 PRINTP2P(22):PRINTTAB(30)"WATTS"
265 PRINTD*:"RECEIVER SENSITIVITY =RD TAB(30)"DBM
270 PRINTP2P(22):PRINTTAB(30)"DBM
275 PRINTD*:"TRANSMITTING ANTENNA =GX"DB GAIN
280 PRINTP2P(22):"AT"H(1):FEET
285 PRINTD*:"RECEIVING ANTENNA =GR DB GAIN
290 PRINTP2P(22):"AT"H(2):FEET
295 PRINTD*:"SYSTEM LOSSES ="DB DBM
300 IFP=1THENPRINT "RANGE NOT IN PROGRAM: ""D(1)""MILES"GOTO400
305 IFP=1THENPRINT "RANGE NOT IN PROGRAM: ""D(1)""MILES"GOTO400
320 FORJ=1TO11:X=J+1
325 IFP=1THENPRINT "RANGE NOT IN PROGRAM: ""D(1)""MILES"GOTO400
330 PRINT"MAXIMUM EXPECTED RANGE: ""D(1)""MILES"
400 PRINTD*:"NEW FREQ BAND R=RUN AGAIN
404 PRINTA:"MODIFY ANTENNA R=PRINTER DUMP
406 PRINTA:"MODIFY R/T BENS/PWR Q=QUIT
408 PRINTA:"NEW PATH OR POLARIZATION M=RECALCULATE
410 FORJ=1TO11:GETA:NEXT
412 GETA:"IFA=""THEN412
413 IFA="*":THEN430
415 PRINTD*:"R=THE1N00
416 IFA="*:THENSBY85126:REM RESTORE
418 IFA="*:THENSGOUB8000:GOTO200
420 IFA="*:THENSGOUB8000:GOTO200
422 IFA="*:THENSGOUB8000:GOTO200
424 IFA="*:THENSGOUB8000:GOTO200
426 GOTO412
430 REM SCREEN-DUMP TO PRINTER
432 OPEN3,3,OPEN4,4:PRINTCHR$(199)+PRINT$4:PRINT$4,LLL
436 CLOSE4:CLOSE3:FORJ=3TO5:PRINT$:NEXT:GOTO412

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HOT ROD ANTENNA

...
Program 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 (46.72 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 com-
puters 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 believe 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. 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 conditions. 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


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 \( \lambda = \frac{984}{f} \), where \( \lambda \) is measured in feet and \( f \) is the operating frequency in MHz. For example, if the optimum height 0.75 \( \lambda \), find \( \lambda \) 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 between 0.1 and 0.4 \( \lambda \) for 87 degrees and between 0.2 and 0.6 \( \lambda \) for 37 degrees. To cover the desired range we need a horizontal antenna located between 0.2 and 0.4 \( \lambda \).

Since this is probably a good ragchew antenna for 75 meters, this translates to: \( \lambda = \frac{984}{3.9} = 252 \) feet (76.9 meters). Therefore, 0.2 \( \lambda = 50 \) feet (15.4 meters) and 0.4 \( \lambda = 101 \) feet (30.8 meters).

The black area of the curve covers the 3 dB beam-width 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 \( \lambda \) above ground. If you were to draw a line on fig. 2 at a height of 1.25 \( \lambda \), you'd note that it would cross the first black curve at

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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 would 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, assuming 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.*
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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, W50JR Antenna Products, P.O. Box 334, Melbourne, Florida 32902.
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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.

<table>
<thead>
<tr>
<th>gain over a dipole</th>
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<tbody>
<tr>
<td>2-element</td>
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<tr>
<td>3-element</td>
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<tr>
<td>4-element</td>
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<tr>
<td>10-element</td>
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<tr>
<td>20-element</td>
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<tr>
<td>40-element</td>
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</tbody>
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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.
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May 1986
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.

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.

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Yagi facts and fallacies

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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. Dr. Yagi published abroad in English, giving rise to the "singular" credit for this type of antenna. 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. 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 design. 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 corrections. Hoch’s work on tying down the optimum element lengths and spacings for Yagi antennas should probably go to Morris. 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 matrices.
bling of the boom length. Gain is shown both in dB over a dipole and dB over an isotropic. 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 boom length 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 boom length. 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 boom length. This means that for some boom lengths, 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. 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 boom lengths had slightly higher gain.

It has since been shown by computer analysis that certain boom lengths naturally exhibit high front-to-back ratio and optimum gain simultaneously. For the majority of moderate boom length designs (less than 2 wavelengths), and especially the NBS designs, the optimum boom length 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.
At my request Stan Jaffin, WB3BGU, ran some examples of my DL6WU designs on his mainframe computer program. 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. 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 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).

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. These equations can easily be programmed on a personal computer to yield rapid and accurate data without referring to graphs.

6. The NBS designs are the best Yagi designs available. This is false. The NBS designs are good and reproducible. However, they represent only six specific models, as discussed above. Computer analysis has shown some discrepancies in these antenna designs. 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. This has been verified by at least one antenna manufacturer.

The NBS designs are good and reproducible. 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.

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.
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. His tests confirmed my results and showed the same gain changes with the optimum lengthening factor to be 0.009 wavelengths.

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.

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.

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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. Later we had the NBS corrections. Then DL6WU proposed a correction factor. 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.
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.

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 NBS11,12 or the DL6WU16 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.

references

10. Personal conversation between Dr. H. W. Ehrenspeck and J. Reisert.
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 W40DW and WB5LUA. Heartily 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 N6FL)
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 daytime 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.

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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 Eₖ openings are in the Northern Hemisphere from June through September and in the Southern Hemisphere during their summer, December through March. The best Eₖ 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 Eₖ 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 Eₖ 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 Eₖ frequencies around the mid latitudes are 8 to 9 MHz. With the oblique factor of 5 for a 2000 km maximum-hop, the Eₖ-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 Eₖ.

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

*Look at next higher band for possible openings.
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Belden Nema Per Per
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8237 1100B RGB/U Poly 96% 39.00 .44
8241 1500B RG59/U Poly 96% 13.00 .15
8267 1130B RG213/U Poly 96% 53.00 .59
9269 1600B RG62A/U Poly 96% 15.00 .17
8218 1450B RG174/U Poly 96% 12.00 .14
9913 1180 Low Loss 50 Ohm 46.00 .58

OTHER QUALITY CABLES

Nema Per Per
No. Description 100 ft. ft.
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1130 RG213/U Mil Spec. 96% Shield 34.00 .36
1140 RG214/U Mil Spec. - Silver 155.00 1.65
1705 RG1428/U Teflon - Silver 140.00 1.50
1310 RG117/US 8" 50 Ohm Dbl. Stol. 80.00 .85
1470 RG223/U Mil Spec. - Silver 80.00 .85
BC682 2-18 Ga. 6-22 Ga. 19.00 .21
8C1820 2-16 Ga. 6-20 Ga. Heavy Duty 34.00 .36
FXA12 Smooth Alum. w/black jacket 79.00 .89
FCL12 Copper (EQ. Heliax LDF) 150.00 1.69

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Also includes CTCSS (PL) tone chart, VHF/UHF and Repeater Advisory committee addresses, special mode repeaters (packet and ATV), band plans, repeater operating practices, ARRL Frequency Coordinators, and Special Service Clubs.

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NEW 35 MHz DUAL TRACE OSCILLOSCOPE
A heavy duty and accurate scope for service as well as production use. Features include:
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- Excellent sensitivity
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- Hold off
- ALT trigger
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3500 Dual Trace Oscilloscope $4,999.95 includes 2 high quality probes

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Ideal for field/mobile applications, this scope can display up to 15 MHz signals or up to 2 hours on a single charge. Features include:
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- Front panel trace rotator
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2500 Portable Oscilloscope $4,499.95 includes 2 high quality probes

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CT-70 7 DIGIT 525 MHZ COUNTER $1,199.95
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DM-700 DIGITAL MULTIMETER
Professional quality at a hobbyist price. Features include:
- 21 different ranges and 5 functions
- 3.5 digit, 1 inch LED display
- Automatic decimal placement
- Auto polarity

DM-700 Multimeter $1,199.95

PR-2 COUNTER PREAMP
The PR-2 is ideal for measuring weak signals from 10 to 100 MHz. With 29 dB gain...wire connections...great for shifting RF...ideal receiver for TV and FM...$4,499.95 wired includes AC adapter

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More Details? CHECK - OFF Page 142
RF Notes — IBM PC

PACKET TRAFFIC SOFTWARE

AX75 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. SUCHA has written a

machine language packet radio program for the Radio

Shack TRS-80 Models 1, 3, and 4 computer (Model 4 works with

3 disk while in Model 3 mode). This book has twelve chap-

ters plus seven appendices that take you step by step

through the process of setting up your computer to first con-

vert the digital information to a useable format and then to

convert it to a usable format. 1984 3rd edition

Softbound $21.95

NAME VALUE

RE-AX Model 1 Disk $29.00

RE-MI Model 3 Disk $29.00

No Documentation included

RE-ML Model 5 Disk $29.00

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CODEPAC.COM for IBM-PC

Here is a really different code practice program for your

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BOOKS

RF CAD ELECTRONIC DESIGN PROGRAM

Version 3.5.1

by Joe Reisert, W1JR and Gary

Field, WATIGC

For IBM PC and compatibles

This software package has been written by elec-

tronic engineers and is based in part on

eleven different pad configurations (all with circuit

diagram). Inductors, inductance in a single layer of wire,

single layer coils, both wide and narrow spaced and

Toroidal coil design, automatic selection of wire

diameter and toroidal form. Capacitors, calculations of

resonant frequencies, determines optimum bypass values and de-

coding applications, impedance matching networks,

including, L, L T, and L T 7 connectors.

E-RF2 80-PC $59.95

E-RF 80-PC $59.95

RF CAD $48.95

RE-AX Model 1 Disk

No Documentation included

RE-MI Model 3 Disk

No Documentation included

RE-BD special book

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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.

It shows how to design a circuit and does not offer math or heavy theory. CMOS Cookbook is arranged into high-

performance op-amps, TV, LED, digital instruments, music synthesizers, video games and more

1987 1st edition, 164 pages

Softbound $13.95

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 amplifiers such as J Fet and Field effect transistor amplifiers. The IC Op Amp Cookbook is edited into three

easy to use parts. Part 1 introduces the IC op amp and design considerations. Part II covers practical circuit

applications. Part III is an appendix 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

Softbound $15.95

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 latches, counters, counting techniques, noise generators and

much more. You also get a complete discussion of practical TTL applications including digital computer, printer

counters, stepper motor and voltmeter to name just a few.

1974, 1st edition, 332 pages

Softbound $12.95

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Have a name — but need the Call Sign?

Traveling and want to meet local Hams?

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by Name and Call, 593 pages

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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 IC-751A base station transceiver**

The ICOM IC-751A 100-watt HF base station transceiver and general-coverenge (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
- OSK up to 40 WPM
- New LED annunciator
- 32 memories
- Thermo-sensor for improved stability
- New 9 MHz 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 2-25).

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

**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 #1316 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 70H.

Circle #315 on Reader Service Card.

buying, installing marine electronics


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, handheld and 25-watt VHF radios, marine SSB radios and ham radios; VHF and MF direction finders, LORAN equipment, satellite navigation 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.
The IC-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 #12 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 #11 on Reader Service Card.

new Yaesu duplexer

Yaesu Electronics has announced the release of the new AD-2 Duplexer for the FT-2700H 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.
VSWR: less than specifications.

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-32BHL, 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 ± 0.1 Hz maximum at ± 40 degrees C to ± 85 degrees C. Output level is 6 v p-p across 10 k.

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 #310 on Reader Service Card.

Commodore/ICOM Interface

Microcomputer Electronics Corporation has announced the release of the new MEC 71x, a computer control interface for Commodore 64/128 computers and ICOM R71A and 751. The MEC 71x is easy to use; screen menus guide the user through operation of the system. Features include UTC time display, 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 71x 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 71x plugs into the expansion port of the 64 or 128 computer and a cable exiting from the radio plugs into the expansion port of the MEC 71x module.

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

The MEC 71x, 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 an accuracy of ± 0.1 Hz maximum at ± 40 degrees C to ± 85 degrees C. Output level is 6 v p-p across 10 k.

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.

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

Circle #310 on Reader Service Card.
Measure Up With Coaxial Dynamics
Model 85A Termination Wattmeter

A direct-reading instrument for servicing 50 ohm communication systems and maintaining them at peak operation.

The Model 85A features:
- Dry load no coolant required.
- Replaceable connectors, interchangeable without affecting instrument calibration.
- Four power ranges easily switchable — 0-3/15/50 and 150 watts full scale.
- Accuracy ± 5% OFS
- Temperature Compensated

Contact us for your nearest authorized Coaxial Dynamics representative or distributor in our world-wide sales network.

COAXIAL DYNAMICS, INC.

Service and Dependability...A Part of Every Product

COAXIAL DYNAMICS, INC.

15201 Industrial Parkway
Cleveland, Ohio 44135
216-287-2233 1-800-COAXIAL
Telex: 98-0830

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 a 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 1306 on Reader Service Card.

simplex autopatch and HF base station control system

The Con-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.
The Model DX-A combines the tremendous firepower of the quarter wave sloper with the wide bandwidth of a half wave dipole. Simple to install, quick to tune. Proven longhaul DX performance.

- Installs like an inverted-V dipole. One leg for 80 meters (67') and the other leg for 160/40 meters (55'). Fed with a single 50 ohm coax. 50-239 connector provided on mounting bracket.
- Configuration provides wide bandwidth on all three bands. Typically 70 kHz on 160 meters, 200 kHz on 80 meters and full band on 40 meters. Much wider than most other loaded slopers, dipole, or verticals. Tuner usually not required.
- Model DX-A also operates on 30-17-12 meters. VSWR of less than 2.5:1. Easily matched with a tuner.
- High-power operation. Rated at 1500 watts P.E.P. output. No traps to break down. A single "ISO-RES" isolator-resonator is used in the 160/40 meter leg.
- Current lobe up high for maximum radiation and excellent DX performance. Can be installed from 25 to 40' high.
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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 Mit 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 34952.
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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 strip line 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.
Now there's a brand new magazine for the technically sophisticated microcomputer enthusiast who likes to build, customize and explore micro hardware at the chip and board level.

The publishers have recruited an outstanding staff of senior editors with more than twenty years of engineering, software and diagnostic experience in the microcomputer field. Computer Smyth is produced quarterly in Peterborough, New Hampshire, home of ten other microcomputing publications and a total of more than twenty internationally circulated publications.

Computer Smyth's primary interest is hands-on construction, modification and expansion of micros. We see the IBM PC phenomenon as a giant magnet or vacuum, dragging hardware and software talent into a vortex of activity that ignites and overshadows the line of new CPUs and peripheral hardware enhancements that are becoming available. We believe 32-bit architecture is the proper and exciting growth direction for micros and too little talent is being invested in that opportunity.

Computer Smyth's editors are also determined to cover all opportunities including the rich offerings of the IBM lines as they appear and especially to evaluate the so-called clones. We believe magazines are hard-copy networks—or extensions of the central nervous systems of those who read them and interact with each other through them. The inter-stimulus factor accelerates each participant's learning curve, produces new combinations of ideas and new answers, and defines fresh problems. We are content and idea centered—not just a sales medium for consumer goods.

Who reads Computer Smyth? We're looking for the intelligent, technically curious and adventurous computer buff who isn't afraid to take the back off the case, who likes new experiences and digs into any device, unsatisfied until all its mystery is dispelled and its potential is fully in hand. Our reader is a craftsman who enjoys building, even while finding the adventure just a little scary.

Our first-year line-up included: The S84 computer, a brand new Z80 system with exceptionally powerful peripheral possibilities and a plain English description of each and every capability of the machine and its operating system, an X/Y chart/plotter you can build for under $60 that will teach you a lot about how these devices work; a neat, powered wire-wrap tool for two hours of your time and a little more than the price of the tool's bit; an RGB color to composite converter board; Ed Scott's three part series on his 68000 computer; Ken Barbier on printer interfaces; a multiplex plotter upgrade; a Data Destroyer (for super clean disks) a review of the DTC XT clone; an RMN converter, and an audio module for the Atari 8000.

Coming up in 1986: a switched power supply; an EPROM programmer, a safe, active circuit tracing tool; a silicon disk; how to identify and find microchips; how to buy a superplus keyboard; and builder reports on four single-board computers: Z80, 68010, PC and XT.

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ins accepted. For information or table reservations: Dave Rose, K1WV, 13 Long Crossing Rd, East Hampton, CT 06424 (203) 267 8993.

OHIO: The Athens County ARA’s 7th annual Hamfest, Sun- day, May 15, 1 0 AM to 3 PM. Contact P.O. Box 101, Athens, OH 45701. Advance registration $6.00. Children under 10 free. Open to the public 10 AM. Free flea market in city park. Contact: Fred Whorton, K9ONAIR, 337-9544.


ARLINGTON: The Arlington County ARA’s annual Hamfest, Sunday, May 15, 10 AM to 4 PM. Contact: Dick Suttles, W5PWA, 7201 Church Street, Arlington, VA 22204. Advance registration $3.00.

WASHINGTON: The Seattle Tables of Brier ARRL District 7-1 annual Hamfest, Sunday, May 15, 10 AM to 4 PM. Contact: Bill Street, W7GSW, 17135 NE 104th Street, Kirkland, WA 98034. Advance registration $3.50.

MINNESOTA: The retired Hamfest in Rochester, Minnesota, held on Sunday, May 15, 9 AM to 1 PM. Contact: Bob Johnson, W8ECO, 3521 1st Street SE, Rochester, MN 55901. Advance registration $7.00.

MONTANA: The University of Montana annual Hamfest, Saturday, May 14, 10 AM to 1 PM. Contact: Ken Cook, K9MUD, 2025 Main Street, Missoula, MT 59802. Advance registration $4.00.

NEW YORK: The Lakeview (North Shore) ARS’s annual Hamfest, Sunday, May 15, 10 AM to 4 PM. Contact: Howard Viner, K2LII, 286 Lakeview Avenue, Great Neck, NY 11024. Advance registration $3.00. Children under 10 free. Free flea market in city park. Contact: John Street, W2XJN, 1000 Lakeview Avenue, Great Neck, NY 11024. Advance registration $3.00.

DELAWARE: The Annual ARRL Delaware Chapter Hamfest, Saturday, May 14, 10 AM to 4 PM. Contact: Gene Mancuso, K9ONAIR, 3401 South Street, New Castle, DE 19720. Advance registration $2.00.


THE KANSAS CITY AREA: The Kansas City ARS’s annual Hamfest, Sunday, May 15, 10 AM to 4 PM. Contact: Bill Street, W7GSW, 17135 NE 104th Street, Kirkland, WA 98034. Advance registration $3.50.

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Significant changes for 1986 mandate that all hams get both the North American and International Callbooks. **DX'ers and Contesters note** — Having both books is the only way you'll have all Foreign Amateur listings.

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1985

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*ham radio* welcomes manuscripts from readers. If you have an idea for an article you'd like to have considered for publication, send in a free copy of the *ham radio* Author's Guide. Address your request to *ham radio*, Greenville, New Hampshire 03048 (SASE appreciated).
The SS-32HB is a new hybrid sub-audible encoder plucked from Communications Specialists' Hothouse. It has grown through a cross of the time tested SS-32, the subminiature SS-32M and space age micro circuitry. This programmable 32 tone encoder measures a scant .5 x 1.0 x .15 inches; no small wonder it allows the addition of continuous tone control to a bunch of hand held transceivers that lack space.

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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 demonstrated 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 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 expected 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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MICROCOMPUTER CONTROL: Gives you the most advanced operating features available.
UP TO 11 NONSTANDARD SPLIT: COMPARE this with other units!
20 CHANNELS OF MEMORY IN TWO SEPARATE BANKS: Retains frequency, offset information, PL tone frequency,
DUAL MEMORY SCAN: Scan memory banks separately or together. ALL memory channels are tunable independently.
COMPARE!
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DISCRIMINATOR CENTERING (AZDEN EXCLUSIVE PATENT): Always stops on frequency desired when scanning.
PRIORITY MEMORY AND ALERT: Unit constantly monitors one memory channel for signals, alerting you when channel is occupied.

LITHIUM BATTERY BACKUP: Memory information can be stored for up to 5 years even if power is removed.
FREQUENCY REVERSE: Allows you to listen to repeater input frequency.
ILLUMINATED KEYBOARD WITH ACQUISITION TONE: Keys are easily seen in the dark, and actuation is positively verified audibly.
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THINGS TO LOOK FOR (AND LOOK OUT FOR) IN A PHONE PATCH

- One year warranty.
- A patch should work with any radio, AM, FM, ACSEB, relay switched or synthesized.
- Patch performance should not be dependent on the TR speed of your radio.
- 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.
- A patch should allow you to manually connect any mobile or HT on your local repeater to the phone system for a fully automatic conversation. Someone may need to report an emergency!
- A patch should not become erratic when the mobile is noisy.
- You should be able to use a power amplifier on your base to extend range.
- You should be able to connect a patch to the MIC and EXT, speaker jack of your radio for a quick and effortless interface.
- You should be able to connect a patch to three points inside your radio (VOL high side, PTT, MIC) so that the patch does not interfere with the use of the radio and the VOL and SQ settings do not affect the patch.
- A patch should have MOV lightning protectors.
- Your patch should be made in the USA where consultation and factory service are immediately available. (Beware of an inferior offshore copy of our former PRIVATE PATCH II.)

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The telephone is the most powerful mode of communications... PRIVATE PATCH III gives you full use of your home telephone from your mobile and HT radios!

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Suddenly the utility of your radio is drastically increased. There are new sounds... dial tones, ring tones, CW ID and the sound of voices you never expected to hear on your mobile or HT radio! What a convenience!

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To Learn more about PRIVATE PATCH III and the advantages of the VOX concept, call or write for our four page brochure today!

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- TOL RESTRICT (Digit counting and programmable first digit lockout)
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- AUTOMATIC BUSy SIGNAL DISCONNECT
- CONTROL INTERRUPT TIMER
- CW ID When you connect again c disconnect. Free ID chip
- SELECTABLE TONE OR PULSE DIALING
- MOVE LlGHTENING PROTECTORS
- THREE DIGIT ACCESS CODE (e.g. 911)
- RINGOUT (Reverse ring) Ringout inhibit if channel bus
- RESETTEx THREE MINUTE TIMER
- SPARE RELAY POSITION
- 115VAC SUPPLY

Options:
- FCC approved coupler
- 12 VDC or 230 VAC power
- VOX... the right choice!

VOX based phone patches offer many performance and operational advantages over the sampling method. These include operation through repeaters, compatibility with an radio, no lost words or syllables, greater range smooth audio free of continual noise bursts etc., etc.

Most amateurs are not aware that the competition's top of the line patch is VOX based. (You know... they $1000 model they enthusiastically call "our favorite commercial simplex patch on page 3 of their SP brochure.)

PRIVATE PATCH III offers about the same capability, performance and features as the top model but is priced closer to their bottom of the line (SP) model!

So why settle for SP when top of the line cost little more?

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When it comes to getting maximum HF performance for your dollar, the choice is clear. Yaesu's FT757GX.

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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.

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TR-751A
Compact 2-m all mode transceiver

It's the "New Sound" on the 2 meter band—Kenwood's TR-751A! Automatic mode selection, versatile scanning functions, illuminated multifunction LCD and status lights all contribute to the rig's ease-of-operation. All this and more in a compact package for VHF stations on-the-go!
- Automatic mode selection, plus LSB 144.0 144.1 144.5 145.0 146.0 148.0 MHz

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

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

- Dual digital VFOs
- Semi break-in CW with side tone
- MC-48 16-key DTMF hand microphone included
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- PS-430, PS-30 DC power supplies
- SW-100A/B SWR/power meter
- SW-200A/B SWR/power meter
- SWT-1 2-m antenna tuner
- TU-7 38-tone CTCSS encoder
- MU-1 modem unit for DCL system
- VS-1 voice synthesizer
- MB-10 extra mobile mount
- SP-40, SP-50 mobile speakers
- PG-2K extra DC cable
- PG-3A DC line noise filter
- MC-60A, MC-80, MC-85 deluxe base station mics.
- MC-42S UP/DOWN mic.
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Actual size front panel