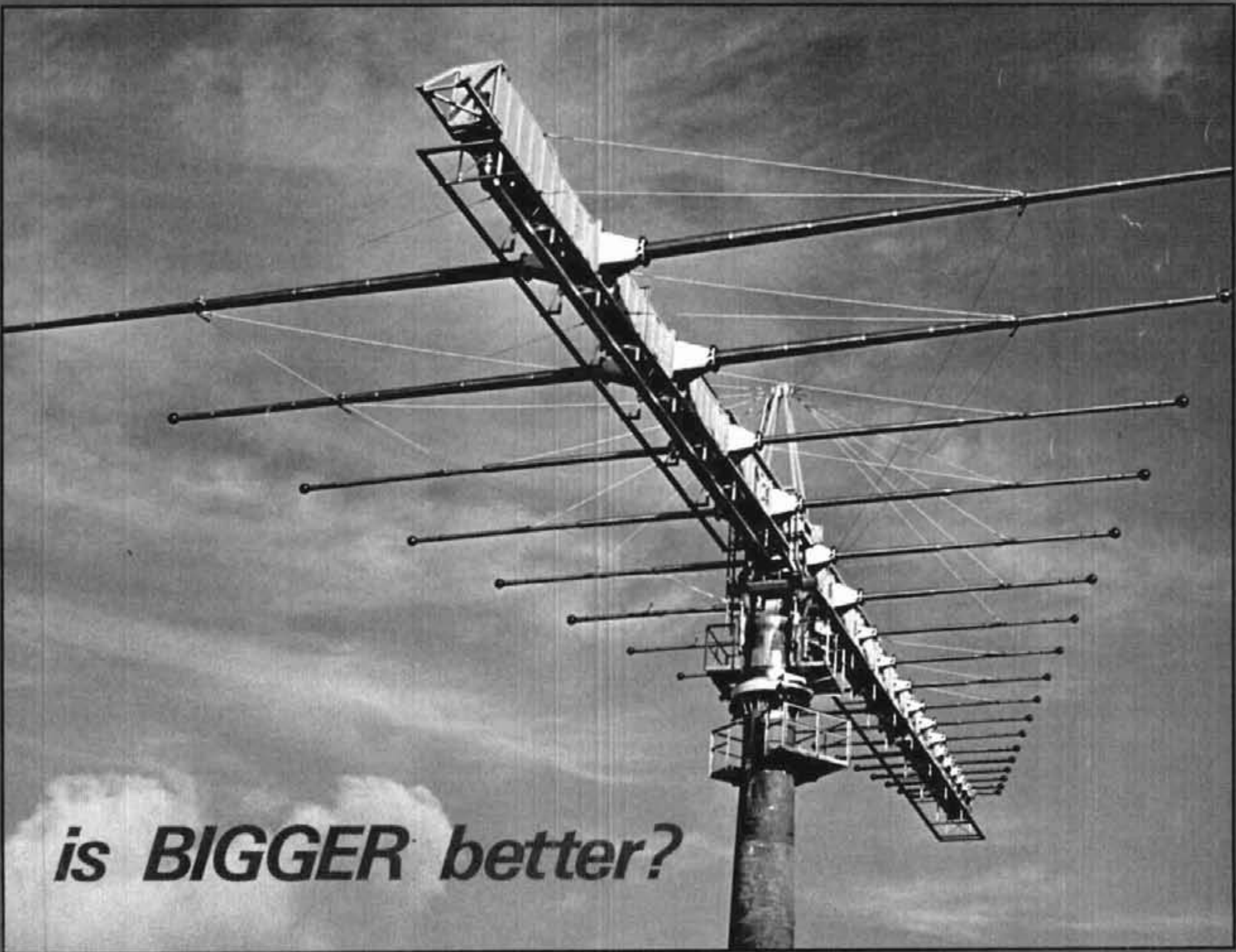
MAY 1985 / $2.50

ANNUAL ANTENNA ISSUE

ham radio magazine



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focus on communications technology

in this issue: stacking Yagis properly • 0.5-30 MHz active antenna • vary your take-off angle • switchable vertical wire array • alternative method of feeding phased arrays • multiband sloping vee beam • 160-meter transmission line antenna • RF transmission cable for microwave applications • baluns • convert your fixed tower to a tilt-over • plus W1JR, W6SAI, K0RYW, and the Guerri report

What To Look For In A Phone Patch

The best way to decide what patch is right for you is to first decide what a patch should do. A patch should:

- Give complete control to the mobile, allowing full break in operation.
- Not interfere with the normal operation of your base station. It should not require you to connect and disconnect cables (or flip switches!) every time you wish to use your radio as a normal base station.
- Not depend on volume or squelch settings of your radio. It should work the same regardless of what you do with these controls.
- You should be able to hear your base station speaker with the patch installed. Remember, you have a base station because there are mobiles. ONE OF THEM MIGHT NEED HELP.
- The patch should have standard features at no extra cost. These should include programmable toll restrict (dip switches), tone or rotary dialing, programmable patch and activity timers, and front panel indicators of channel and patch status.

ONLY SMART PATCH HAS ALL OF THE ABOVE.

Now Mobile Operators Can Enjoy An Affordable Personal Phone Patch. . .

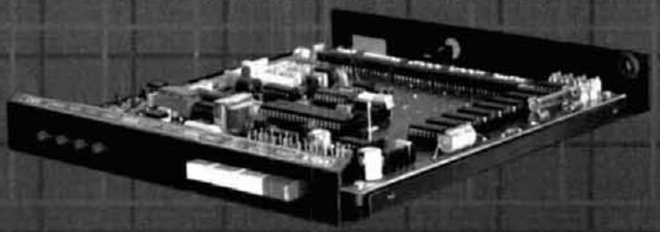
- Without an expensive repeater.
- Using any FM tranceiver as a base station.
- The secret is a SIMPLEX autopatch, The *SMART PATCH.*

SMART PATCH Is Easy To Install

To install *SMART PATCH,* connect the multicolored computer style ribbon cable to mic audio, receiver discriminator, PTT, and power. A modular phone cord is provided for connection to your phone system. Sound simple? . . . IT IS!

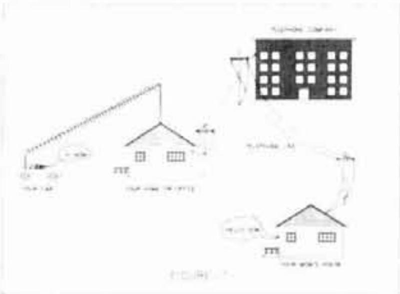
With SMART PATCH You are in CONTROL

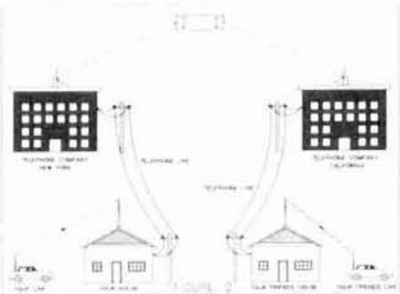
With CES 510SA Simplex Autopatch, there's no waiting for VOX circuits to drop. Simply key your transmitter to take control.



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

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





How To Use *SMART PATCH*

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

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

Use *SMART PATCH* for:

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

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Optional accessories:

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- **DC-21** DC-DC converter for mobile use
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- **EB-2** external C manganese/alkaline battery case
- **SC-8** soft case for TH-21A/31A/41A
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- **TU-6** programmable sub-tone unit
- **AJ-3** thread-loc to BNC female adapter
- **Service manual**

More information on the TH-series HTs is available from authorized Kenwood dealers.

- **Easy-to-operate, functional design.** Three digit thumbwheel frequency selection and handy top-mounted controls increase operating ease.

Note: Specifications guaranteed for the 144.000-148.000 MHz Amateur band only. TH-21AT shown. Standard versions TH-21A/31A/41A without DTMF pad also available. Specifications and prices are subject to change without notice or obligation.

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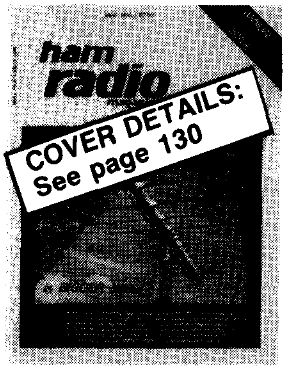

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contents

REFLECTIONS

the readers speak . . .

We asked — and you answered our call for solutions to the problems facing our hobby today (see "Reflections," February, 1985, page 5. Each and every one of your letters was read, and we're proud to act as a clearinghouse for your many ideas and suggestions.

Foremost you recognized that Amateur Radio has changed, and that hams have to accept that fact before any effective improvements can be made.

Here are some of your comments on the problems, followed by some suggested solutions:

"The challenge is gone. Want to hear China? Just turn on the TV."

"Equipment is just too expensive and complex for us to do our own repairs."

"Our kids are into computers, not radio."

"Hams are boring and don't know how to communicate any more."

"Consumer electronics and RFI — what a nightmare!"

"Enforcement, what a joke — the FCC's a paper tiger."

Can we expect the general public to help? I doubt it. Many of them see us as "the ham down the block with the ugly tower and wires all over." Don't expect too much sympathy from the neighbors — especially if their brand-new VCR is carrying our conversations as well as their programming. So what do we do?

SCHOOLS. Talk to your local school board. Could some space and time — say an hour a week — be set aside for a Novice course taught by local hams? What about high school science teachers? Would they be interested in having guest speakers address classes on Amateur Radio subjects? Radio clubs, how about sponsoring radio-related science fairs, with prizes or scholarships awarded for the best projects? How about donating software — morse code tutors and technical Q&A's, for example — to school libraries? Besides the school environment, summer camps and community centers would also be logical places for reaching and teaching prospective hams.

PUBLICITY. We need more of it — the good kind, that is. Make a personal effort to contact and provide details of Amateur Radio events to your local newspaper and radio or TV stations. Every little bit helps. There's a move afoot to produce and distribute a brochure describing the "fun" aspects of our hobby. When it becomes available, get some and hand them out to the neighborhood kids. Do any of you work in the media or public relations? How about using your skills to help improve our image?

PARTICIPATION. This means all of us. No contribution is too small. Participate by helping out at the club, helping newcomers to the hobby even *after* they're licensed. (This in itself might help reverse the "dropout" rate.) How about being an Elmer and forming a "ground wave net" to bring together new hams in a local net designed to help them overcome their initial shyness? I'm sure we can all remember how we felt during those first few weeks on the air.

Dear Senior Citizens, you have the time, the knowledge, and the political clout. Your active leadership and participation are essential.

What would happen if, for the good of Amateur Radio, we set aside our individual concerns and pooled our talents in a single "umbrella" organization dedicated solely to protecting and preserving our hobby? Perhaps then it would be more difficult for commercial interests to nibble away at our spectrum. We have to lobby from a position of unity and strength.

PERSONAL GROWTH. Hams used to be interesting people to talk to. We could converse on diversified subjects at length. Now too many of us appear to be overly involved in contesting and card-collecting — i.e., doing the same old thing all the time, when we should be advancing our knowledge, experimenting with different modes, and searching for new frontiers.

Perhaps we can act on some of the advice offered by our readers and help improve the hobby.

Rich Rosen, K2RR
Editor-in-Chief

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Low cost VHF SWR/Wattmeter! Read SWR (14 to 170 MHz) and forward/reflected power at 2 meters. Has 30 and 300 watts scales. Also read relative field strength. 4x2x3 in.

1 KW DUMMY LOAD

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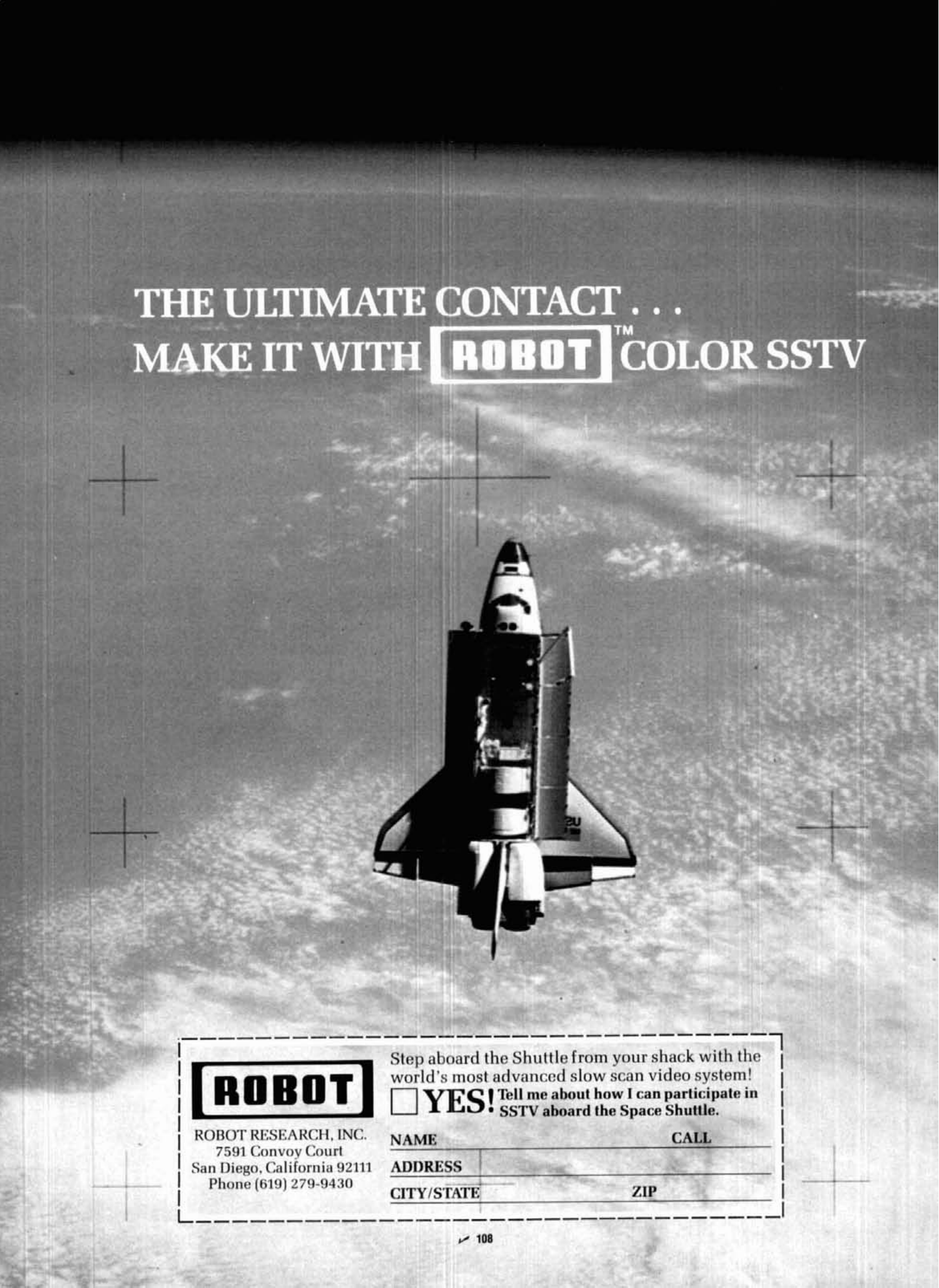
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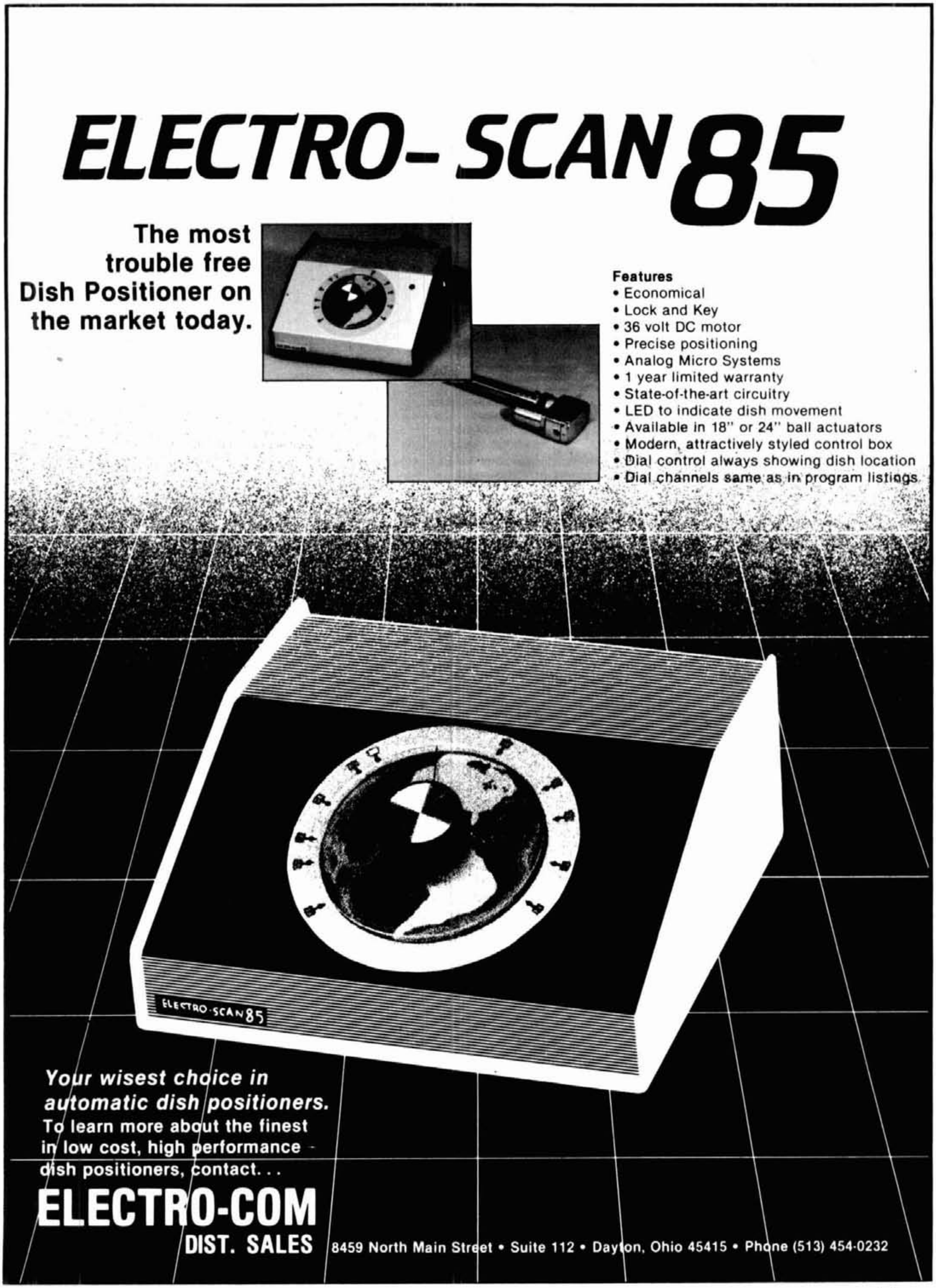
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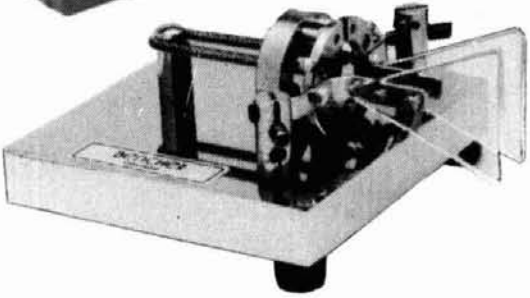

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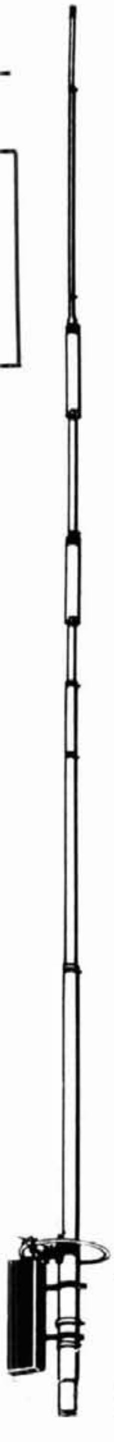

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THE 2-METER CHANNEL SPACING ISSUE MAY RESULT IN A CONFRONTATION that could leave Amateur Radio with some bad long-term wounds. Repeater operators from the mid-Atlantic and New England states met March 2 to strongly endorse 15 kHz spacing not only for 146-148 MHz, but even possibly for 144.5-145.5 MHz as well, thus picking up another six channels. In a similar action southern California's 2-Meter Area Spectrum Management Association met March 23 to also endorse 15 kHz spacing across the whole band, despite serious interest in northern California in shifting to 20 kHz as their neighbors in Oregon and Washington have done. By their action the southern California group's decision puts them in direct conflict with Mexican Amateurs, whose government has mandated 20 kHz on the 2-meter band. It's believed that Mexican representatives who attended that meeting may even ask their government to lodge a formal objection with the U.S. State Department.

20 kHz Proponents Seem Equally Determined In Their Choice, with Texas the latest in a number of western states to endorse the change. Michigan was the first state east of the Mississippi to adopt 20 kHz, and it's under heavy pressure to reconsider. Alabama is reported to have voted to implement 20 kHz by July 1, but Missouri opted to stay at 15 kHz at a February meeting. Midwestern repeater representatives plan to meet at Dayton for further discussions.

Despite The FCC's Strong Desire For A National Coordinator, formalized in PR Docket 85-22, the escalating 15 vs 20 kHz conflict seems to offer little hope for simple or early resolution of the increasing number of repeater conflicts that led to that NPRM. Indeed, the FCC may even be asked to endorse 15 kHz through a Petition for Rule Making. Such a move was considered by the East Coast group at its recent meeting in support of 15 kHz. However, it is hard to see how such a petition would find any support at all within the Commission, which is trying very hard to get away from regulating details of Amateur operations. Furthermore, in this case such an FCC mandate would put it in direct conflict with the Mexican government and thus risk diplomatic repercussions.

AMATEUR RADIO PROBABLY WON'T FLY ON THIS SUMMER'S SPACE SHUTTLE, according to late word from NASA. The official reason is problems of integrating the exotic Amateur equipment that Tony England, WØORE, was to use on Flight 51F with shuttle equipment. Though strong last-ditch efforts are being made to salvage the Amateur operation, at presstime it looks very much like there won't be an Amateur operating from space this year.

AMATEUR RADIO VS CABLE TV IS YET ANOTHER CONFRONTATION that seems to be escalating. In late February the FCC proposed in Mass Media Docket 85-38 that cable TV radiation limits be relaxed by another 8 dB, to 50 microvolts per meter, and that various other restrictions including the requirement for annual system inspections be dropped. In view of the number of Amateurs who've had problems with cable leakage interfering with their 144 or 220 MHz operations, this proposal presents a real threat to Amateur Radio. Comments were due in late March. Amateurs have a strong ally against the proposal in the broadcast industry.

Amateurs Have Been Shut Down Due To Cable Interference in two recent unrelated cases. In the first, WB2OTK/4 was ordered off the air by the Engineer-In-Charge of the FCC Atlanta Field Office for interference with the Greenville, S.C., cable system. FCC Amateur rule 97.73(d) on interference to other stations was cited, despite checks that showed the cable system was so badly maintained that a 150 mW hand-held's signal caused problems for viewers. The FCC inspected WB2OTK's station but did not even contact the cable operator in an apparent violation of the FCC's own rules requiring a cable system to take responsibility for resolving interference problems. In the other case, WB4NMA was shut down, again by the Atlanta Field Office, for interfering with cable viewers in Gainesville, Georgia.

2-Meter Privileges Were Restored To Both Operators following the intervention of the ARRL through its General Counsel Chris Imlay, N3AKD. However, the Commission's proposed cable rules relaxation combined with the kind of FCC Field Office attitude that led to these two cases could spell serious trouble for future Amateur Radio VHF/UHF operation.

BASH EDUCATIONAL SERVICES IS OUT OF BUSINESS. Writing to subscribers to his FCC Rules Part 97 update service, Dick Bash, KL7IHP, stated that his FCC exam study materials business had subsidized the rules updating service but, under the volunteer exam program, there was no longer a unique niche in training for him to fill. Bash was very controversial for his publishing of word-for-word correct answers to all FCC-administered Amateur exams.

A SUGGESTION THAT ARRL ASSUME CALLSIGN ASSIGNMENT RESPONSIBILITY is receiving some interest in Washington, as the FCC looks at tighter budgets. It's likely, however, that callsign responsibility would be delegated only as part of a total program that would include the entire licensing function now done by FCC's Gettysburg facility.

THE ANTENNAS VS LOCAL RESTRICTIONS ISSUE seems to be heading toward an FCC Notice of Proposed Rule Making, which will probably consider it from the private satellite dish viewpoint. Just what this means for PRB-1 and Amateur Radio remains to be seen.

NEW WARC BAND AVAILABILITY HAS BEEN DELAYED by at least three months. An extension of the Reply Comment period, requested by the Personal Radio Steering Group, bumped expected action on the 10, 24, and 902 MHz bands off the FCC's first quarter agenda. The PRSG is believed to be pushing for allocation of part of 902-928 MHz to a Personal Radio Service.

A NATIONAL VEC NET IS OPERATING on 20 meters Sundays, starting at 1700Z. The 40-meter midwestern VEC net has moved to 1800Z, still on 7280 kHz. DeVry is now officially a national VEC.

Nothing matches the MACC in voltage surge protection and component-by-component on-off control

- compact, attractive desk-top console
- eight clean AC power outlets
- individual and master on-off control
- superior three-stage auto-restore circuit with manual reset circuit breaker
- individually lighted rocker switches

Lightning striking miles away, electric motors running on the same power line, fluorescent lighting and even wind-driven snow static buildup can cause problems with delicate circuits and miniature electronic chips. But the MACC, within nanoseconds, can recognize the current disturbance, then clip it off and dissipate it, while maintaining clean current flow to your system's equipment. The MACC protects all semi-conductor, solid-state circuitry.

The MACC is designed with three 2000-amp surge discharge protection circuits — one between each of the AC input's hot, neutral and ground lines. Other surge devices may use a single 100-amp surge protector between the hot and neutral lines only. Its resettable circuit breaker adds further protection.

MACC gives you control convenience, too. It provides 8 plug-in "U" ground outlets for your components — including one "hot" outlet for a continuously powered application such as your clock. Seven "on/off" rocker switches let you control individual components. And you can turn your entire system on or off with a single master rocker switch.

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The MACC is tested to IEEE pulse standards and rated at 15A, 125V-AC, 60 Hz, 1875 watts continuous duty total for the console. A label on the unit describes the surge protection limitations.

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Size MACC-4	5-1/2" x 2-3/4" x 2-3/4"
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Alpha Delta Model MACC Systems are designed to reduce the hazards of lightning-induced surges. These devices, however, will not prevent *fire or damage caused by a direct* stroke to an AC line or a structure. Specifications, availability and price are subject to change without *notice.*

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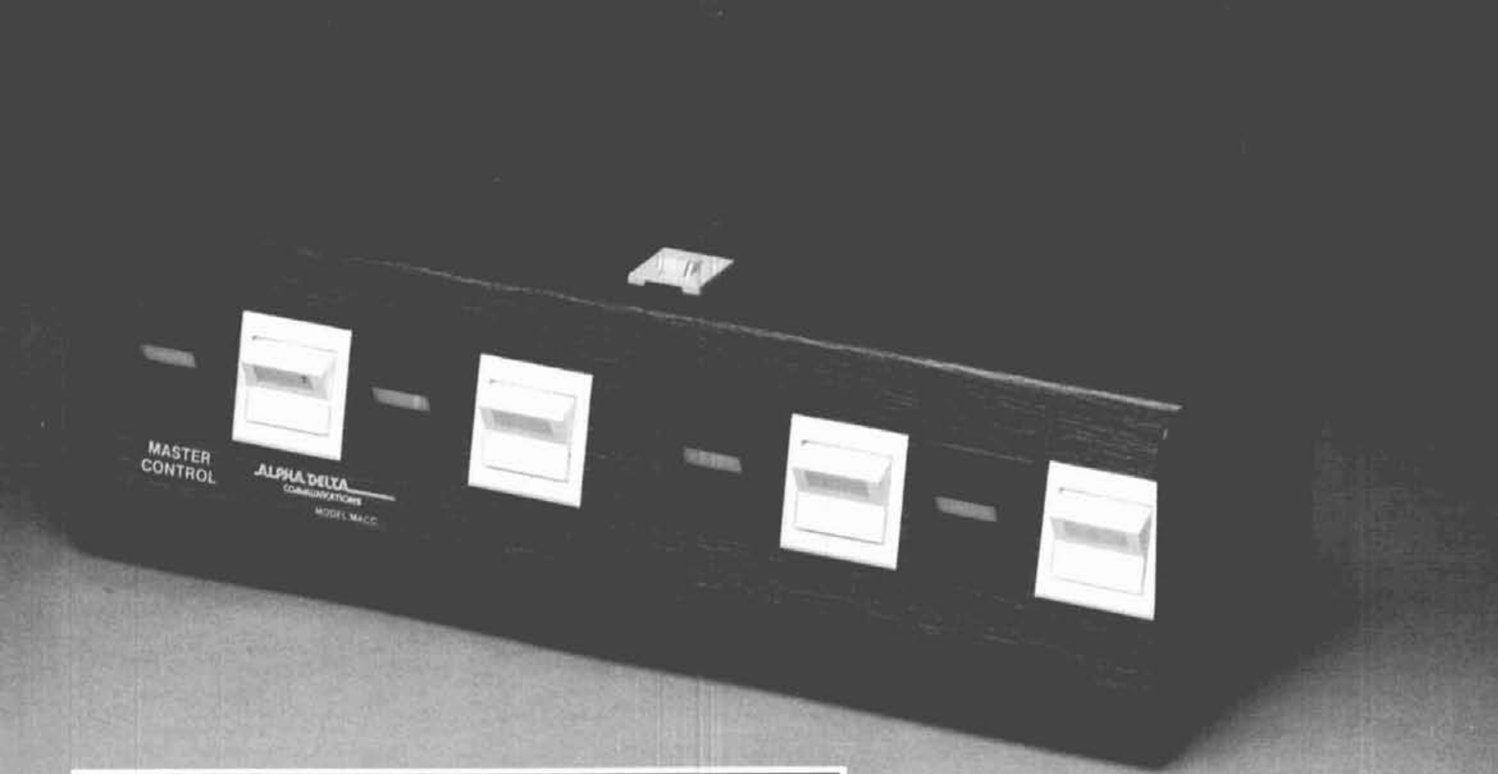

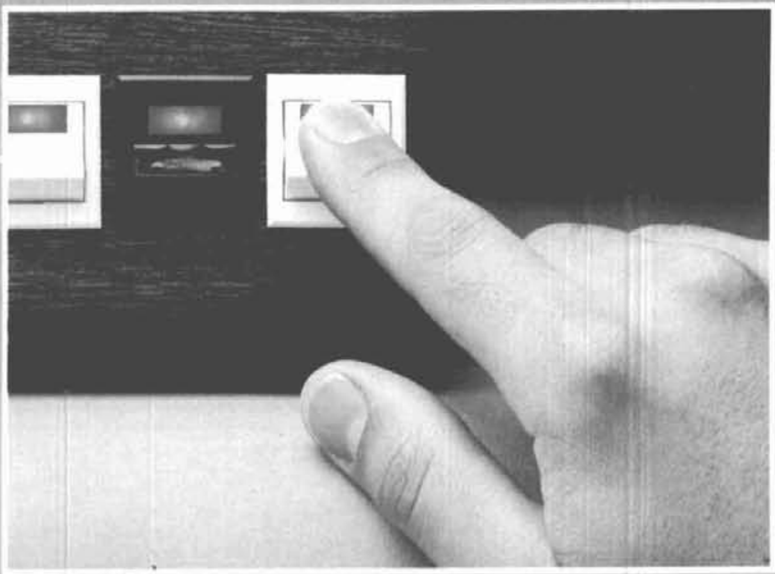

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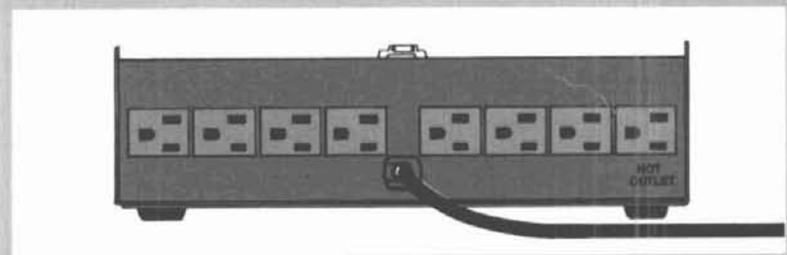

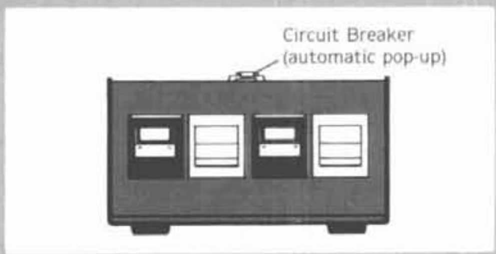

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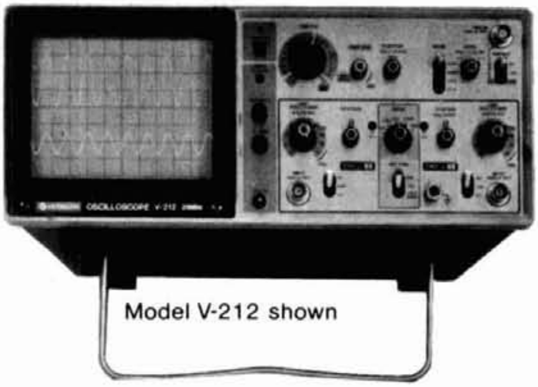
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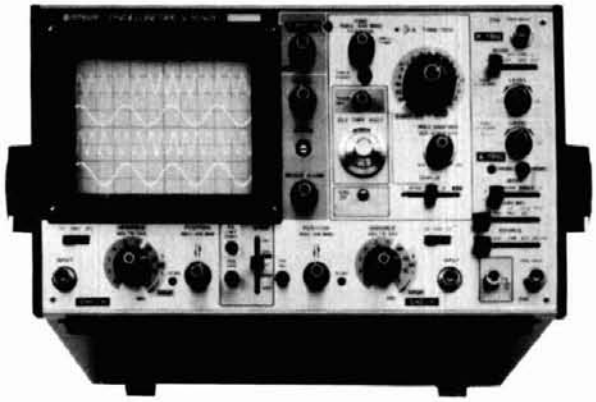
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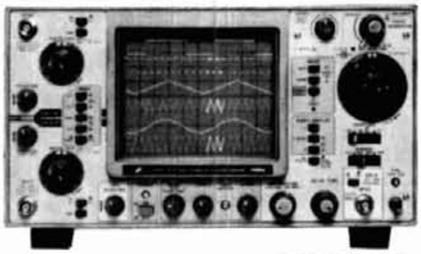

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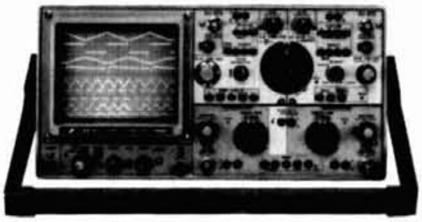

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stacking Yagis
is a science

Determining E/H plane patterns results in optimized performance

Several years ago I began a project designed to develop a means of determining gain of a particular 144 MHz Yagi. Knowing that number, I would be able to calculate the aperture. Once the aperture was known, I would know the correct stacking distance and would then be able to build the perfect 144-MHz array.

As one might expect, things didn't quite work out as planned. But eleven years and seven EME arrays later, I believe I have found an improved method of determining the optimum stacking distances for multiple Yagi VHF and UHF arrays.

what is optimum stacking?

"Best array performance" is a matter of opinion, and depends on how the antenna is used; an array can be optimally stacked, for example, to deliver maximum gain, or for a controlled *azimuthal* pattern that produces a deep null in the direction of interference. This article primarily addresses Yagi stacking for use in EME (Earth Moon Earth or moonbounce) communications. However, this technique is also appropriate for other space communications applications such as satellite communications and radio astronomy. It could also be used for land-based communication requiring high gain such as tropospheric scatter.

For EME and other weak-signal VHF/UHF work, *optimum stacking distance can be defined as* that distance which yields the greatest array gain versus lowest array temperature. Used by professional space communications engineers, this definition refers to maximizing the G/T ratio. With Yagis, the best G/T usually never occurs at the distance which yields maximum stacking gain. It normally occurs at significantly closer spacing. In simpler terms, optimum stacking distance is that stacking distance which yields the greatest array gain increase while simultaneously keeping all sidelobes at an acceptable level.

table 1. Typical temperatures of "objects" at 144 MHz and 432 MHz.

object	144 MHz degrees K	432 MHz degrees K
cold sky	175	10
hot sky	3,200	190
earth	290	290
arcing power line	100,000	6,000

the effect of antenna temperature

Several good sources of information are available for those unfamiliar with the concept of antenna temperature.[1,2] To review, antenna temperature is the temperature of the object at which the main lobe of the antenna is pointed — i.e. the Earth, Moon, Sun, hot sky, or cold sky. However, if the array has sidelobes of significant area and amplitude, unwanted noise can be picked up from noise sources in the direction in which the sidelobes are pointed. This unwanted noise reception will increase the net antenna temperature. (**Table 1** lists typical temperatures of several "objects" at 144 MHz and 432 MHz.) A 432-MHz array with large sidelobes pointed at the Earth will suffer a significant receive signal-to-noise loss because of the reception of Earth noise; likewise, a 144-MHz array with sidelobes directed toward a hot sky or a leaky power line will experience a similar degradation in receive performance.

By Steve Powlishen, K1FO, 816 Summer Hill Road, Madison, Connecticut 06443

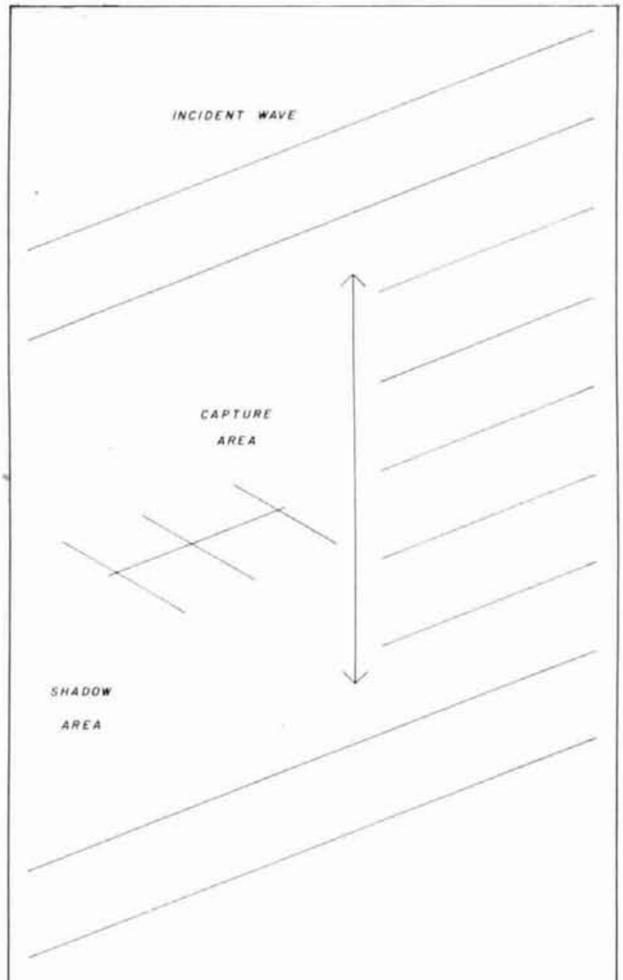


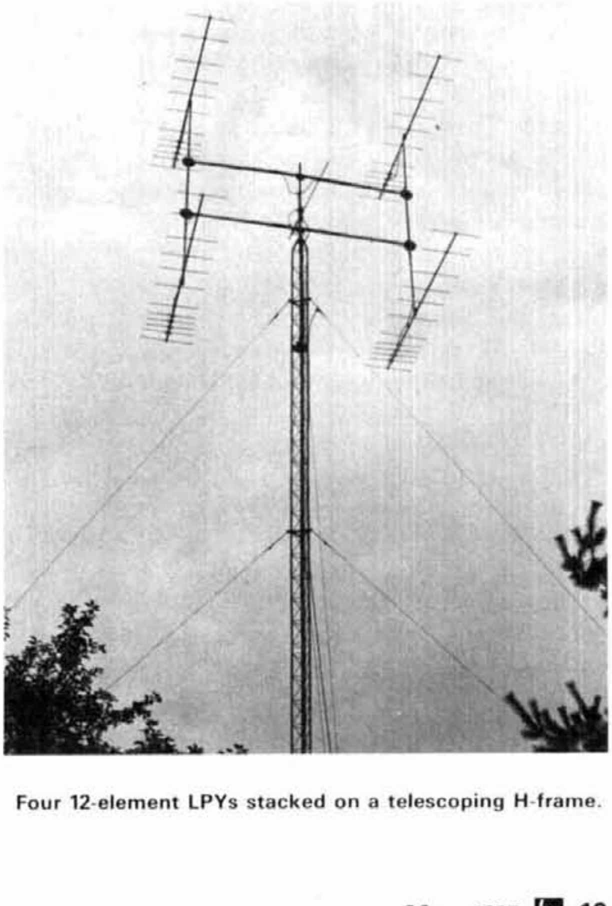
fig. 1. Antenna aperture and shadowing effect.

As a point of reference, commercial satellite Earth station antennas that use parabolic dish antennas with Cassegrain or Gregorian subreflector systems have antenna temperatures as low as 18 degrees K. In comparison, an Amateur dish using a simple dipole or horn feed at 432 or 1296 MHz has a typical antenna temperature of 65 degrees K, while a 16-Yagi 432-MHz array with the Yagis spaced for maximum gain may have an array temperature over 170 degrees K (or even worse if low-loss phasing lines are not used). Conversely, stacked 432-MHz EME Yagi arrays incorporating optimized stacking distances have been built to provide array temperatures lower than 85 degrees K — including phasing line losses. These antenna temperatures were measured by pointing the antenna at the Earth and then at the cold sky and comparing the noise ratios. The noise contribution due to the receiver can then be factored out if the receiver system noise temperature is accurately known. The significance of the lower array temperature cannot be overstated. If we assume a high performance receiver with a 0.45 dB system noise figure, lowering a 432 MHz array temperature from 170 degrees K to 85 degrees K results in a receive signal-to-noise improvement of about 2.3 dB or almost the equivalent of doubling the array size! These results have been obtained using standard Yagi designs such as the NBS Yagis and the K2RIW 19-element Yagi. I expect further improvements can be obtained when Yagis designed with best G/T in mind are available to Amateurs.

methods of determining optimum stacking distances

There are three methods of determining optimum stacking distances. The first method to be examined briefly, is based on classic antenna theory. The second, which will be emphasized, is experimental. Computer analysis, currently used by the professional community is the third, and will not be discussed here. With programs for Yagi analysis now readily available to the Amateur, it is hoped that the more mathematically inclined and computer-knowledgeable Amateurs will carry on where this article leaves off and extend computer modeling to include optimum stacking.

The concept of antenna directivity, (**fig. 1**), put forth by Kraus[3] and introduced to Amateurs by Orr and Johnson,[4] holds that all antennas have an effective capture area, or area around the antenna that "captures" or extracts the electromagnetic energy from space. The higher the gain of the antenna, the



Four 12-element LPYs stacked on a telescoping H-frame.

larger the area from which energy will be extracted. Behind the antenna there will be a shadow area, or space where the field strength of the incident wave is reduced in magnitude. (This concept is analogous to putting an object in front of a light source and creating a shadow behind it.) In mathematical terms the capture area is directly proportional to gain and is defined in **eq. 1**.

$$A_{em} = 0.13 \cdot 10^{dBd/10} \qquad (1)$$

Where A_{em} is the effective capture area in wavelengths squared and dBd is the gain of the antenna in decibels over a half wave dipole. For antennas such as Yagis, which have an elliptically shaped aperture, the size of the effective aperture will be slightly different between the E and H planes. The aperture dimensions in wavelengths squared can be calculated by using **eqs. 2** and **3**.

$$A_H = 2\sqrt{\frac{A_{em} \cdot \theta_E}{\pi \cdot \theta_H}} \qquad (2)$$

$$A_E = 2\sqrt{\frac{A_{em} \cdot \theta_H}{\pi \cdot \theta_E}} \qquad (3)$$

Where A_E is the E-plane aperture dimension, A_H is the H-plane aperture dimension, θ_E if the E-plane half power beamwidth, and θ_H is the H-plane half power beamwidth.

There are two problems with using these formulas to calculate stacking distances. First, an antenna's aperture is not an ellipse with a clearly defined boundary, with radio waves being extracted on one side of the boundary and nothing happening on the other side. Instead, an antenna progressively extracts less and less energy from space continuously. In addition, the half power beamwidths of an antenna are merely a point on the field strength gradient of the antenna. Therefore, proper stacking distance becomes a question of determining where two *unclearly* defined volumes separate. It is not a solid boundary like a brick wall.

The second problem, largely self-inflicted by Amateurs eager to believe they could defy the laws of physics and discover something that antenna engineers could not, is that of believing inflated gain figures produced by both Amateurs and some manufacturers of Amateur antennas. (In defense of Amateur equipment manufacturers, their claims are restrained in comparison to their CB and home TV counterparts). Using these optimistic gain claims, which in some cases are typically 3-dB high, leads to arrays which have grossly oversized stacking dimensions. The gain figures shown in the recommended stacking distance

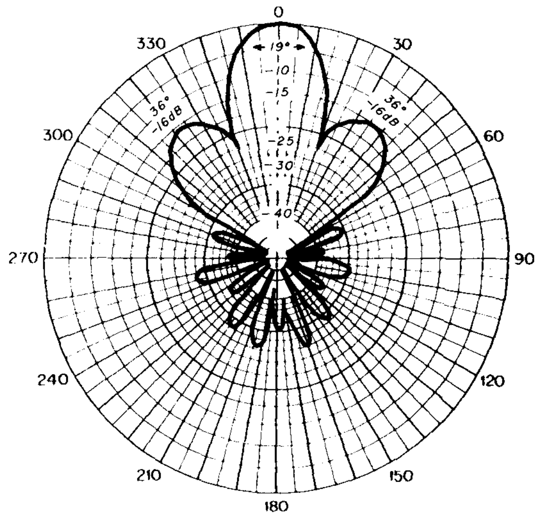


fig. 2. Four stacked 12-element Swan 2-wavelength LPY array E-plane pattern with 10-foot (1.5 wavelength) E and H-plane spacing.

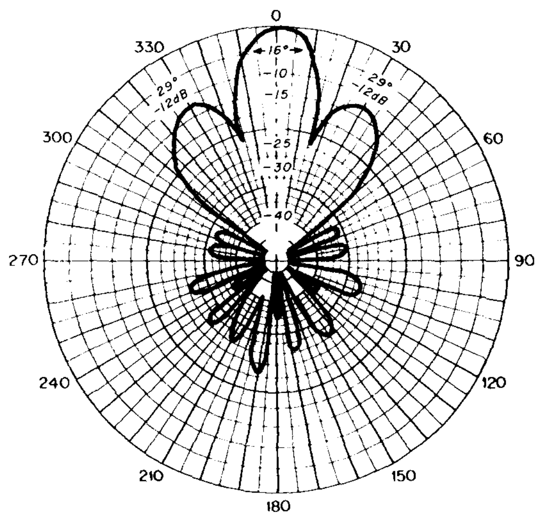


fig. 3. Four stacked 12-element Swan 2-wavelength LPY array E-plane pattern with 12 foot 0 inch (1.76 wavelength) E-plane and 11 foot 4 inch (1.66 wavelength) H-plane spacing.

table (**table 2**) represent hundreds of hours of antenna measurements I have performed, the compilation of data from ten years of antenna gain contests, and finally, computer analysis of almost all the antennas listed in the table. The result is a listing of gain figures closer to reality, I believe, than anything previously available. (For further discussion of how much gain can be expected from a given boomlength Yagi, reading DL6WU's article is suggested.)[5]

measuring antenna gain

As part of my experiments to measure antenna gain and determine proper stacking distances, a telescoping H frame was constructed on my 60-foot (18.3 meters) tower to measure the 144-MHz antenna. This arrangement allowed for rapid placement of Yagis along with a simple method of adjusting the spacing to any separation of up to 16 feet (4.9 meters). A smaller frame (6 feet/1.9 meters) was used to measure the 432-MHz Yagis.

The next step was to figure out a relatively accurate means of making pattern measurements. Over the years I tried a variety of measurement techniques, including use of strip chart recorders, spectrum analyzers, and RF voltmeters. Out of all this came a relatively simple and reasonably accurate method that is within the reach of most serious VHF/UHF experimenters.

The basic requirements for pattern measurement are:

- an accurate direction indicator;
- a receiver with a calibrated signal strength indicator; and
- a signal source located so as to minimize reflection problems.

Satisfying each requirement was surprisingly simple. The direction indicator I used was a selsyn readout* with close to 1 degree accuracy. Alternatively, the digital readout system using 10 turn pots and popularized by many EMErs[6] could be used. The availability of signal generators such as the Hewlett-Packard 608 series (or their military counterparts, the TS-510 series)* solves the receiver calibration problem. My method of measurement consisted of connecting a digital voltmeter (DVM) to the AGC (automatic gain control line) of the station receiver (an R-4C and TR-7). Care must be taken to keep signal strengths high enough above the noise (floor) to eliminate signal-to-noise plus noise ratio correction problems. The signal level must not be so high that it causes gain compression problems. The quick way to get a pattern was to run the antenna through 360 degrees while recording the AGC voltage readings on the DVM. The antenna was then replaced with the signal generator and the AGC readings were converted to a dB scale. (A 10 dB attenuator was placed between the converter and antenna or signal generator to eliminate impedance problems.) This "calibration" of the receiver was done after every measurement to eliminate receiver gain drift errors.

The signal source presented the trickiest problem, but again a simple solution was found. A number of signal sources were tried including locating signal sources in my back yard, in the woods about 1000 feet (305 meters) away, and at a local ham's QTH about 2 miles (1.3 km) away. All of these solutions gave marginally repeatable results. That is, an antenna would look different from day to day and from source to source. Because I believed the problem to be reflections from various objects, I decided to try a signal source located above the clutter. My location at that time was 105 feet (32 meters) above sea level. The antennas were located at 65 feet (20 meters), well above the nearby trees. My location was surrounded by hills up to 1200 feet (366 meters) high, 10 to 12 miles (16 to 19.2 km) away. The ground between my location and the hills dropped in elevation, which made the tops of the hills a completely clear shot at about a 0.5 degree elevation angle. A fellow ham located on one of the hills was called upon; by using high gain source antennas (stacked 3.2 wavelength NBS Yagis on 144 MHz and RIW19s on 432 MHz), repeatable pattern measurements became a reality. After performing many measurements I was able to "calibrate" my range such that I could see how different antennas gave the same false lobes or left to right unbalance. The patterns shown in this article have been cleaned up to eliminate known range errors. Various NBS antennas were constructed and their patterns measured. My measured patterns correlated very well with the NBS published patterns and offered proof of the method's validity.

It was also found that accurate relative gain measurements were possible. Gain measurement calibration was made by putting two identical antennas on the frame and measuring the relative signal level between them. The antennas were then switched in position and the measurement repeated. In this manner any differences in signal strength could be factored out before a test antenna was measured. Results were found to be repeatable to within 0.2 dB over the two-year period the gain tests were made. A similar method was used to measure the gain increases to be had from stacking antennas.

the effects of antenna spacing

To get an indication of what happens when the spacing of Yagi arrays is changed, an array of four 12-element LPY (log periodic Yagis, as introduced by Oliver Swan and later produced by KLM) was set up on the telescoping H-frame. Pattern measurements were made at one foot (0.3 meter) spacing increments from 10 feet (3.0 meters) up to 16 feet (4.9 meters) (1.4 to 2.3 wavelengths). The resultant patterns are

*Available from Fair Radio Sales, P.O. Box 1105, Lima, Ohio 45802 typical of all two-wide Yagi arrays. As the spacing between Yagis is increased, the main lobe beamwidth narrows, the sidelobes increase in amplitude and the nulls get much deeper. The E-plane pattern at 10 feet (3.0 meters), 12 feet (3.7 meters) and 14 feet 4 inches (4.4 meters) spacings is illustrated in **figs. 2, 3,** and **4**. Looking at the sample patterns, it can be seen that the beamwidth of the first sidelobes is close to that of the main lobe for each spacing and that its amplitude increases rapidly at larger separations. Other minor lobes start to have significant amplitudes at the greater separations.

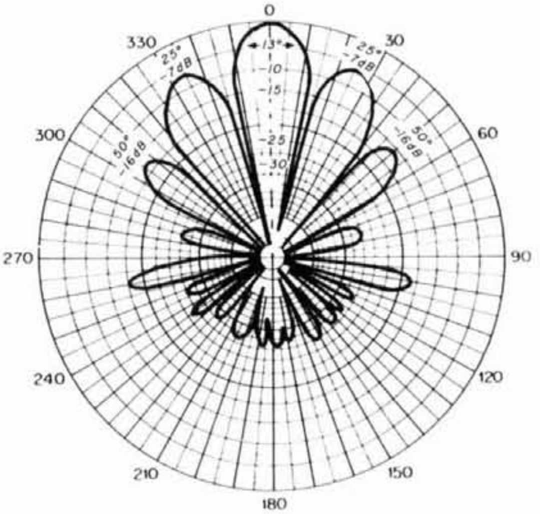


fig. 4. Four stacked 12-element Swan 2 wavelength, 144-MHz LPY array E-plane pattern with 14 foot 4 inch (2.1 wavelength) E and H-plane spacing.

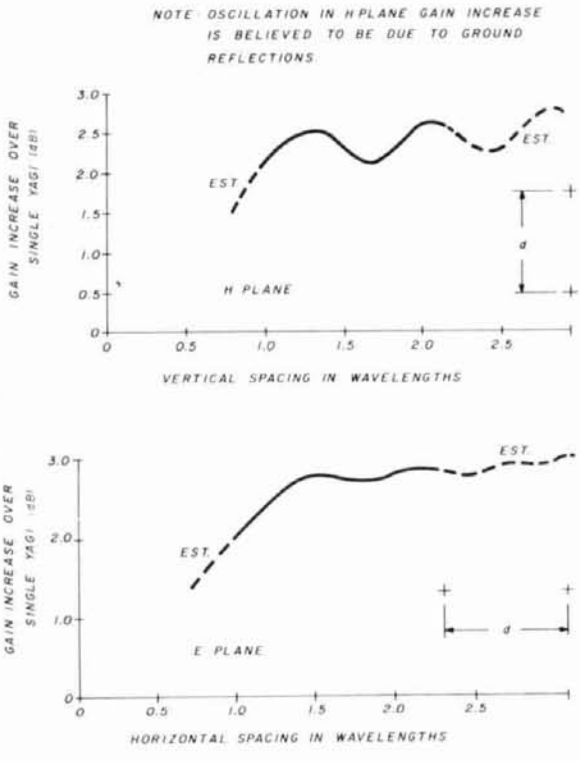
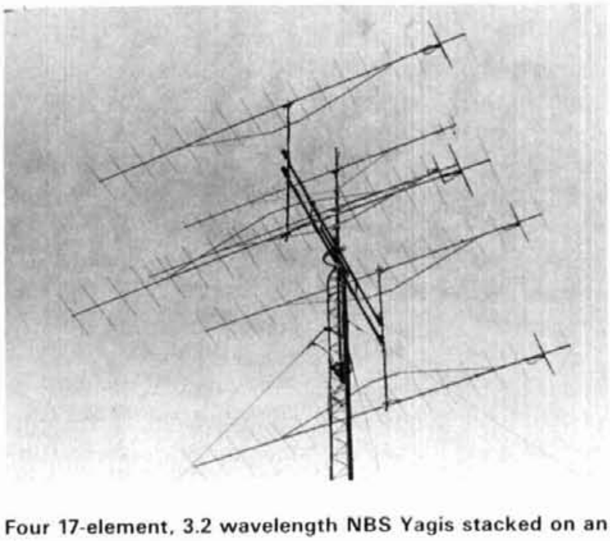


fig. 5. Array gain versus spacing using Swan 12-element, 2 wavelength 144-MHz LPYs.

The question of which distance is the proper one still remained to be answered. Gain and individual pattern measurements on the 12-element LPY indicated an actual gain of about 11.2 dB over a half-wave dipole (dBd). By using **eq. 1, 2,** and **3** (single antenna pattern of 36 degrees E-plane by 40 degrees H-plane), stacking distances of 10 feet 8 inches E-plane (3.3 meters) 9 feet 7 inches (2.9 meters) H-plane were calculated. The 10 foot 8 inch (3.3 meter) E-plane spacing gave a pattern similar to **fig. 2**, but with first sidelobes down 14 dB. Next relative gain measurements were attempted between one and two antennas. Resultant gain curves showing stacking gain versus spacing are shown in **fig. 5.** The general shape of the curves are similar to those given in the now-famous NBS Technical Note 688,[7] (**fig. 6**) except I did not see any gain decrease as the spacing was increased to large distances, only a flattening of the gain curve. I also saw an apparent larger gain increase in the E rather than the H-plane. This is again indicated in NBS Note 688. As illustrated in **fig. 5**, the knee in the gain increase occurs at about 2.7 to 2.8 dB in the E-plane and at 2.5 to 2.6 dB in the H-plane. (When phasing line losses are factored out.)

Next, I attempted to relate first sidelobe levels to position on the gain increase curve and found that the gain increase started to flatten out when the first sidelobes were − 12 to − 13 dB down. It should be pointed out that at the time these measurements were made,



Four 17-element, 3.2 wavelength NBS Yagis stacked on an H-frame.

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SUMMARY

	CONTROL WAITS	TIME WAITED
Private Patch II	1	15 seconds
Sampling	180	6 minutes

If the sampling patch has a circuit that ***"slows the sample rate when telephone audio is present,"*** the speed of acquisition is made even slower. The wait time increases, and the phone party can say perhaps 25 or more words before they can be cut off.

WHY LAND MOBILE PROFESSIONALS **AVOID** SAMPLING PATCHES . . .

The majority of radios on the market (especially synthesized and relay switched types) **do not T/R quickly enough to give acceptable results.** Often engineering level modifications are required to improve T/R response time.

The slower the T/R response time, the longer the sample must last. And of course no telephone audio is heard during the sample. ***Just noise.*** The result is ***lost words and syllables*** which are proportional to T/R response.

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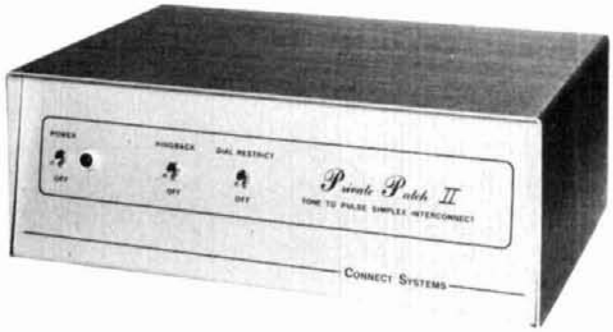

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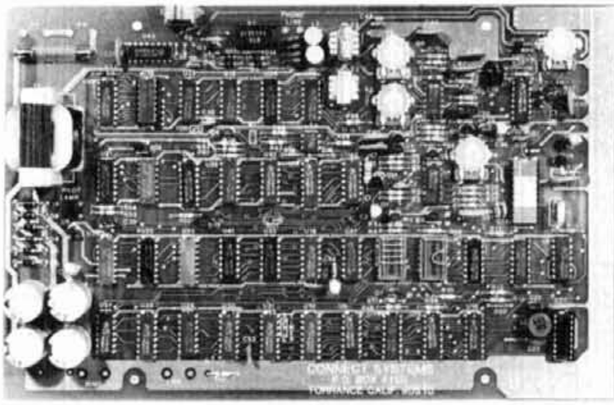

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very wide spacing was very popular and many Amateurs, including myself, thought the NBS report with its relatively close spacings was in error. The correlation between my measurements to the NBS curves was truly amazing, especially considering that I was intent on proving NBS *wrong*.

The additional rule of thumb used by Amateurs was to stack Yagis so that the first sidelobes were 13 dB down. This seemed to correspond to where the gain increase curves flattened out; however, when the sidelobes were −13 dB, the main lobe was less than one half that of a single antenna. When I attempted to find out where the −13 dB rule of thumb came from, the only explanation I could find was that two sidelobes at −13 dB were, in total, −10 dB from the main lobe and anything 10 dB down (or 1/10 amplitude) was insignificant. This seemed plausible except that the H-plane should have a pattern similar to the E-plane — and if it also had two sidelobes 13 dB down (with similar beamwidth to the main lobe), the sum of just those four lobes would be −7 dB relative to the main lobe or 20 percent of the amplitude of the main lobe. Thus if all four sidelobes were looking at noise sources 10 times stronger (in reality, it is not very likely all the sidelobes would be facing similar noise sources) than the background noise the main lobe was looking at, the array would suffer a 6 dB signal-to-noise loss on receive.

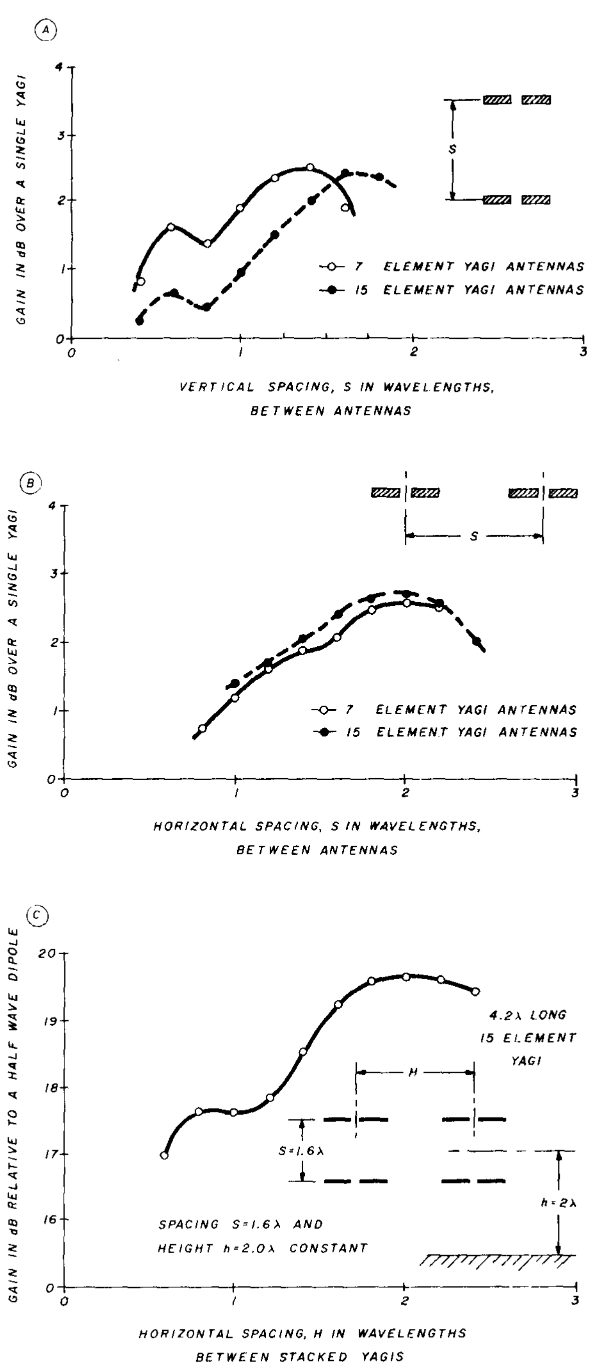


fig. 6. Array gain versus spacing per NBS Technical Note No. 688. (A) Vertical stacking improvement for either a 7 or 15-element Yagi, (B) horizontal stacking improvement for either a 7 or 15-element Yagi, and (C) horizontal stacking improvement for two sets of stacked Yagis spaced vertically 1.6 wavelength apart.

improving a 144-MHz EME array

With this information in mind, I began to look at the 144-MHz EME array I was using at that time. It consisted of 4 Cushcraft A32-19, 19-element 3.2-wavelength 22 foot (6.7 meter) long Yagis patterned after the NBS 17-element Yagi, with a tri-reflector added. The gain of a single A32-19 is about 13.2 dBd with −3 dB beamwidths in the E and H-plane of approximately 28 by 33 degrees. By using the previously defined aperture calculation method, spacings of 2.1 by 1.75 wavelength or 14 feet (4.3 meters) E-plane by 12 feet (3.7 meters) H-plane were calculated. The manufacturer of the antenna was recommending the same spacings, so it seemed reasonable to use them when constructing the array.

The performance of the array seemed acceptable. I usually received good signal reports, but on receive, signals always were poorer than expected. I easily dismissed the lack of hearing on a noisy urban environment. Looking at the NBS stacking curves, NBS was recommending 2.0 by 1.6 wavelength spacing for the 15-element 4.2 wavelength Yagi, an antenna with about 0.8 dB more gain than the A32-19. I then made some sidelobe measurements and found that the first E-plane sidelobes were down about 12 dB and the H-plane sidelobes were down only 10 dB. A quick decision was made to move the antenna spacing in to 1.9 by 1.6 wavelenghts or 13 by 11 feet (4.0 by 3.4 meters) E by H-plane, respectively. The results were startling. During the first two months of operation at the closer spacing, about 20 new stations were worked on EME,

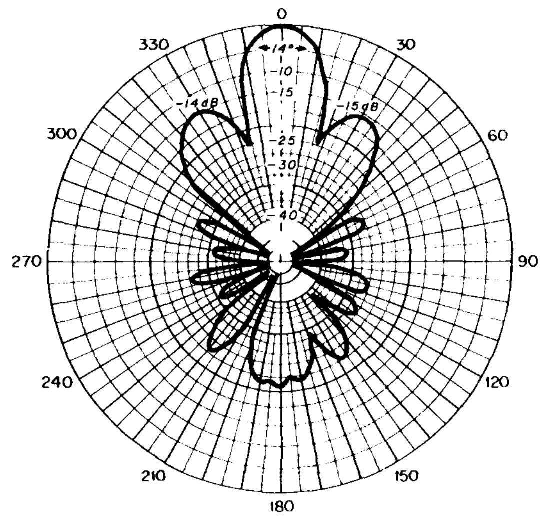


fig. 7. Four stacked NBS 17-element, 3.2 wavelength Yagi E-plane pattern with 13 foot 0 inch (1.9 wavelength) E-plane and 11 foot 0 inch (1.61 wavelength) H-plane spacing.

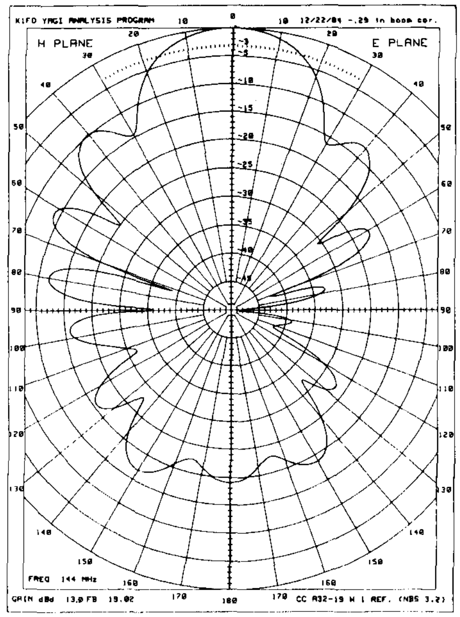


fig. 8. NBS 17-element, 3.2 wavelength Yagi computer generated E and H-plane patterns.

many of them stations I had tried to work in the past without success.

After that I obtained four more A32-19 Yagis. I modified them to standard NBS dimensions and removed the tri-reflectors. I then set them up on the telescoping H-frame and set out to find what was going on. The E-plane pattern of the 17-element 3.2λ NBS array spaced at 13 feet (4.0 meters) E-plane is shown in **fig. 7**. The pattern looks very good, with first sidelobes down 14 to 15 dB and all other lobes down 25 to 30 dB. H-plane patterns are usually more difficult to measure. Reflections from objects such as trees and utility poles, which are essentially vertically polarized, complicate the problem. Tilting the array back causes changes in ground reflections, which can induce errors if that method is used. Because of that I did not make a complete H-plane pattern measurement, but I did check the first H-plane sidelobes and found them to be only 12 dB down at the 11 foot (3.4 meter) spacing. The aperture calculations indicated that the spacing was already too close — however, NBS had indicated that 1.6-wavelength or 11-foot (3.4 meter) spacing was correct for the higher gain 15-element Yagi. To explain this wide discrepancy between calculated spacings and measured patterns, the patterns of the individual Yagis were examined. **Figure 8** is a computer-generated plot of the E and H-plane patterns of the 3.2 wavelength NBS Yagi. The H-plane pattern is noticeably less directive than the E-plane with larger sidelobes over the entire pattern. The array pattern of a number of Yagis is the resulting interference pattern of the individual Yagi patterns interacting with each other. It follows that the resulting array pattern of multiple Yagis will have larger sidelobes in the H-plane.

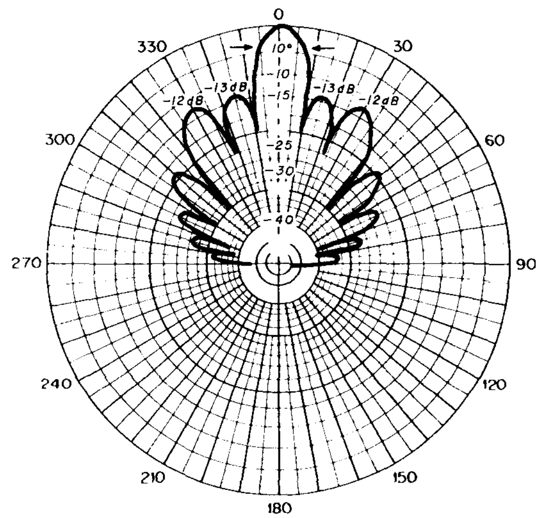


fig. 9. Six stacked NBS 17-element, 3.2 wavelength Yagi half H-plane pattern with 13 foot 0 inch (1.90 wavelength) (2 wide) E-plane and 11 foot 0 inch (1.61 wavelength), (3 wide) H-plane spacing.

While measuring the four 3.2-wavelength NBS Yagi array, it was decided to attempt to relate array main lobe beamwidth to sidelobe level and array gain increase. The 3.2 wavelength NBS Yagis reacted similarly to the 12-element LPY antennas previously meas-

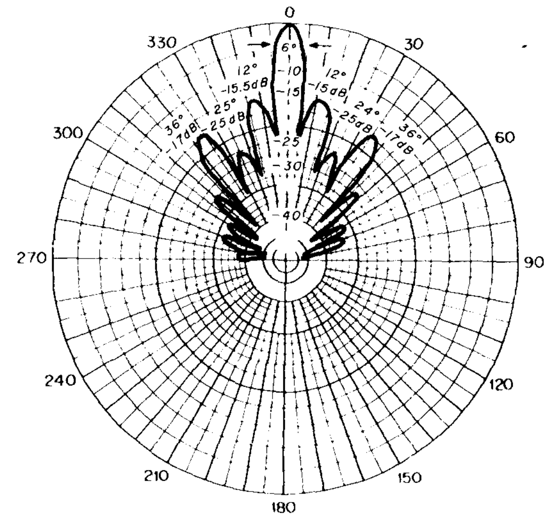


fig. 10. Sixteen stacked Cushcraft 424B Yagi E-plane pattern with 60 inch (2.2 wavelength) E-plane and 58 inch (2.1 wavelength) H-plane spacing.

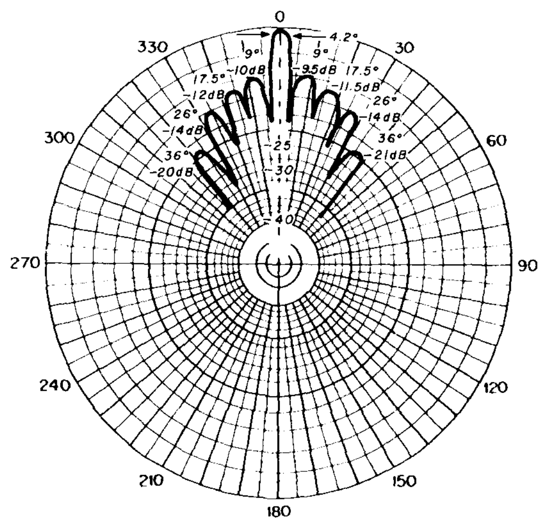


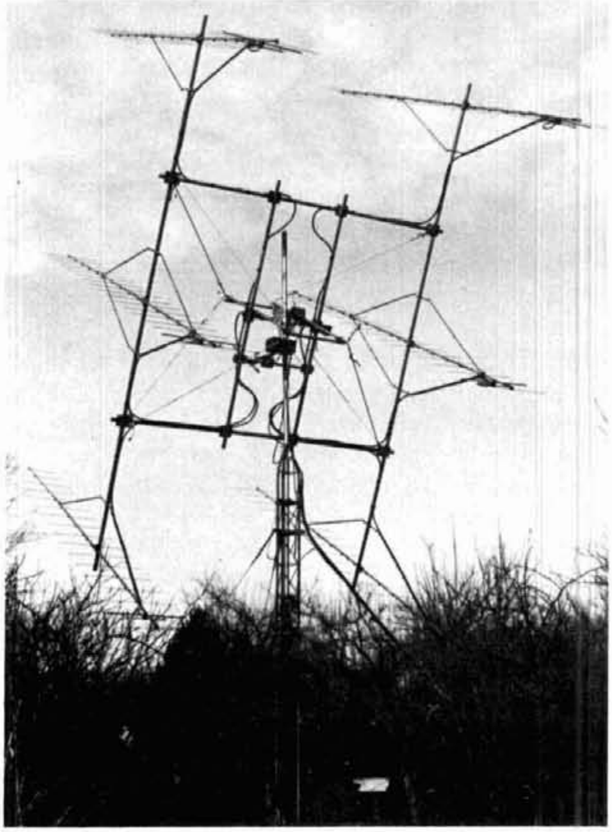
fig. 11. Sixteen stacked Cushcraft 424B Yagi H-plane pattern with 60 inch (2.2 wavelength) E-plane and 58 inch (2.1 wavelength) H-plane spacing.

ured. When the first sidelobes were −13 dB, the main lobe was narrower than one half that of a single Yagi. Likewise, the main lobe was approximately one half the beamwidth of a single Yagi when the first sidelobes were −14 to −15 dB. *This relationship of first sidelobes at −14 to −15 dB when the main lobe beamwidth is half that of a single Yagi has held up in all subsequent arrays I have measured.* This also includes arrays that are three and four Yagis wide where the array −3 dB beamwidth is approximately equal to the beamwidth of a single Yagi divided by the number of Yagis in that plane. As an example, my 144-MHz array was expanded to six 3.2 wavelength Yagis. The vertical spacing was kept at 11 feet (3.4 meters). The array's H-plane pattern is shown in **fig. 9**. The number of major sidelobes in an array is equal to the number of elements in a plane minus 1. Thus the six-Yagi array will have two major H-plane sidelobes. In this case, the first sidelobe is −13 dB down and the second is −12 dB down. As expected, the main lobe is narrower than one third that of a single Yagi at 10 degrees. Note that as the number of elements in an array are increased (and consequently the number of major sidelobes increase) it becomes much more important to keep the sidelobe amplitudes under control. A look at a 16 Yagi 432-MHz EME array will expand on this point.

more dramatic results at 432 MHz

Frank Potts, WA1RWU, had erected a 432 MHz EME array consisting of 16 Cushcraft 424B 24-element 7.6 wavelength Yagis. The instruction sheet for the 424B recommended 66-inch E-plane by 60-inch H-plane spacing. This was considerably closer than the spacings determined from calculating the aperture. Based on actual antenna gain of 15.8 dBd and a pattern of 20 degrees by 22 degrees (E by H), the spacings were calculated to be 72 inches (1.8 meters) by 65 inches (1.7 meters) E-plane by H-plane. When Dave Olean, K1WHS, of Cushcraft was contacted, he recommended the use of even closer spacings for an EME array — as close as 60 inches (1.5 meters) by 54 inches (1.4 meters). Because of mechanical considerations, the array was assembled using 60-inch (1.7 meter) horizontal (E-plane) by 58-inch (1.5 meter) vertical (H-plane) spacing. Phasing lines consisted of 1/2-inch and 7/8-inch hardline and were cut on a return loss bridge known to be accurate. The performance of the array had a familiar ring to it; Frank would receive excellent signal reports, but on receive, signals were far poorer than expected. Checking into the 432-MHz EME activity, Frank found that there had been a considerable number of other hams who had erected 16-Yagi EME arrays for 432 MHz that never worked well, and as a result, their stations had disappeared from the EME ranks.

At this point I began helping Frank to improve the array. The first priority, I decided, was to obtain a pattern measurement. The height of the array, 20 feet (6.1 meters) above ground, made the likelihood of taking accurate measurements remote. However, with the amount of array gain available (close to 26 dBd) I decided it should be possible to make adequate measurements by using Sun noise.[8,9] The E-plane pattern looked excellent, with the three major sidelobes down over 15, 25, and 17 dB, respectively



Six stacked NBS 17-element, 3.2 wavelength Yagi 144-MHz EME array.

(**fig. 10**). The main lobe beamwidth was close to 6 degrees or greater than one quarter that of a single antenna. The H-plane was a shock with the −3 dB beamwidth of 4 degrees or much narrower than the expected 5.5 degrees. The major sidelobes were very large, at only 9.5, 11.5, and 14 dB below the main lobe (**fig. 11**). No EME signals had ever been copied when the array elevation was below 18 degrees. The fact that this angle was the same as the second sidelobe direction was no coincidence.

Some tests with a pair of K2RIW 19-element Yagis were run to measure changes in H-plane sidelobe levels. It was found that the first sidelobes changed at about 1 dB for every 2 inches of spacing change. Since the gain of the RIW19 (15.1 dBd) is close to the 424B it was felt that the results would be similar with the 424B. The vertical spacing was moved in by 6 inches (15 cm) to 52 inches (1.3 meters). The first sidelobes were expected to drop down to −12.5 dB. The results of that spacing change were amazing. The major sidelobes were now −12.3, −20.7, and −14.4 dB (**fig. 12**). Sun noise was up over 2 dB.* The on-the-air performance improvement was even more spectacular, with 41 QSOs made with 34 different stations during the first ten days of operation at the new spacing. Fewer than 20 QSOs were made in over two months of operation at the wider spacing. Most of the contacts were on random operation (as opposed to pre-arranged schedules) and included several 8 Yagi and one 4 Yagi stations. EME signals, including echoes, were now consistently copied down to 2 degrees elevation (the elevation angle where the main lobe would be clearing the earth). The main lobe beamwidth was still narrower than one quarter that of a single 424B at 5 degrees. This again supports previous measurements which indicated that a 1/4 beamwidth (5.5 degrees) would not occur until the first sidelobes are down 14 to 15 dB. The pattern indicates that the array has not yet been optimized. It is estimated that the best performance would occur at 62

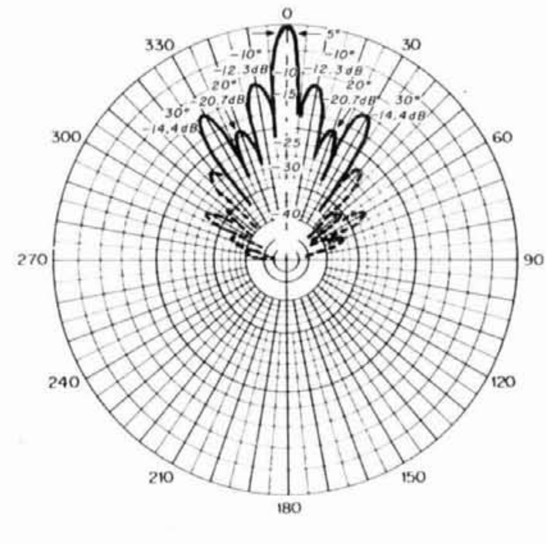


fig. 12. Sixteen stacked Cushcraft 424B Yagi H-plane pattern with 60 inch (2.2 wavelength) E-plane and 52 inch (1.9 wavelength) H-plane spacing.

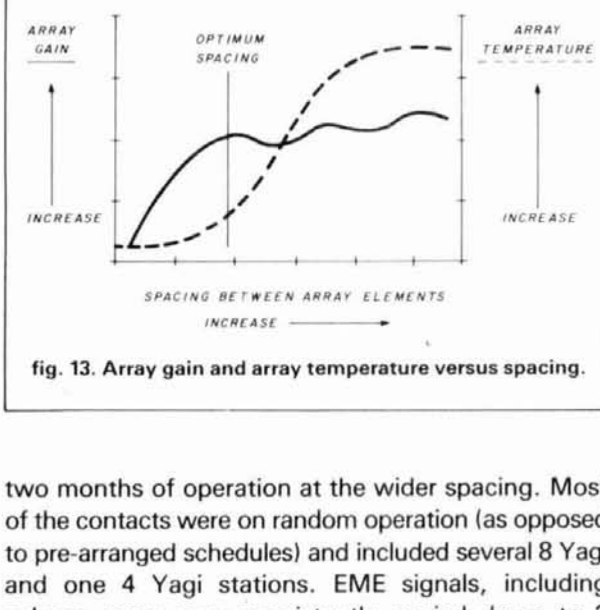


fig. 13. Array gain and array temperature versus spacing.

*Sun noise is measured by pointing the array at cold sky, noting the noise level, and then pointing the array at the sun and measuring the noise increase. Sun noise is a combination measurement of overall receiver temperature and array gain.

inches (1.6 meters) E-plane by 50 inches (1.27 meters) H-plane spacing.

The reason for this dramatic improvement can be explained by looking at the approximate Earth noise pickup from the major sidelobes when the array was operated at low elevation angles. The main lobe at 432 MHz may typically see a sky temperature less than 20 degrees K. The sum of the first three sidelobes at −9.5, −11.5, and −14 dB would be equivalent to a single lobe 6.5 dB below the main lobe. Pointed at Earth (290 degrees K), those lobes would contribute about 65 degrees K of noise or cause a 5.1 dB degradation in signal-to-noise ratio. With the reduced sidelobes at the closer spacing, the sum of the three major sidelobes is about −9.8 dB and would cause about a 1.8 dB signal-to-noise degradation. This represents a *3.3 dB receive improvement*, which is quite significant on EME. The actual array noise is much more complicated; to calculate it would require summing all the sidelobes and accounting for the strength of the noise sources toward which they pointed. The over-2 dB Sun noise improvement nonetheless confirms the performance improvement.

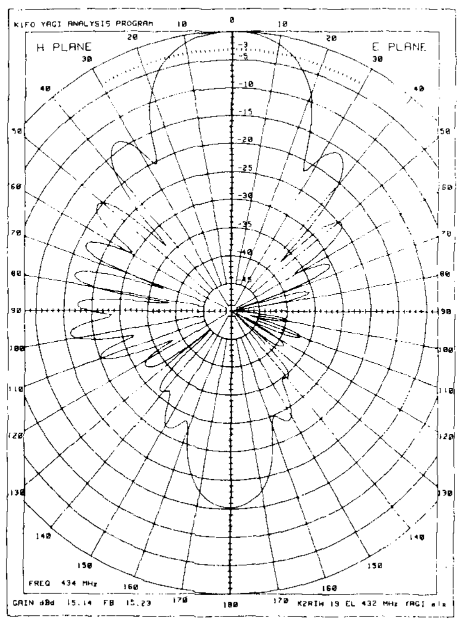


fig. 14. RIW 19-element Yagi computer generated E and H-plane patterns.

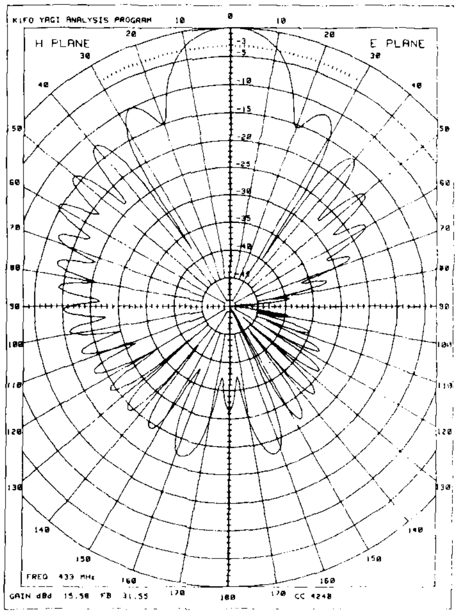


fig. 15. Cushcraft 424B Yagi computer generated E and H-plane patterns.

An alternative method for checking system temperature without taking array gain into account is to measure Earth noise. This is done by pointing the array at cold sky and then at the Earth and then comparing the noise levels. A well-performing 432-MHz EME system should see over a 4 dB ratio. Since this measurement does not take array gain into account it should not be used for array optimization because doing so could result in significant gain loss. **Figure 13** is a graph of typical array temperature versus stacking gain increase. The temperatures are not "real world" because they are quite different for the various Amateur frequencies.

easier method for measuring array beamwidths

Measuring the −3 dB beamwidths on high gain arrays with very sharp beamwidths can be a difficult task. WA1RWU's 16-Yagi 432-MHz array uses a prop-pitch motor for an azimuth rotator and has a 360-degree rotation time of over 3 minutes. The elevation leadscrew drive takes over 2 minutes to run 90 degrees. Even with such a rotating system, attempting to measure a 5 degree beamwidth can be a taxing experience. With a conventional commercial rotator it appears to be impossible to get an accurate measurement. It was discovered very early on that the half-power beamwidth was always equal to slightly less than 1/2 the spacing of the first nulls on either side of the main lobe. Interestingly, DL6WU has said that the beamwidth of a single Yagi is equal to 0.485 times the first null spacing. The measurement of the first nulls provides a much easier and most likely more accurate means of determining antenna half-power beamwidths.

The H-plane pattern measurements on the RIW19 Yagi provided yet another surprise. A pair of RIW19s had first H-plane sidelobes down 13 dB at a spacing of 54 inches (1.37 meters). The 424Bs had first H-plane

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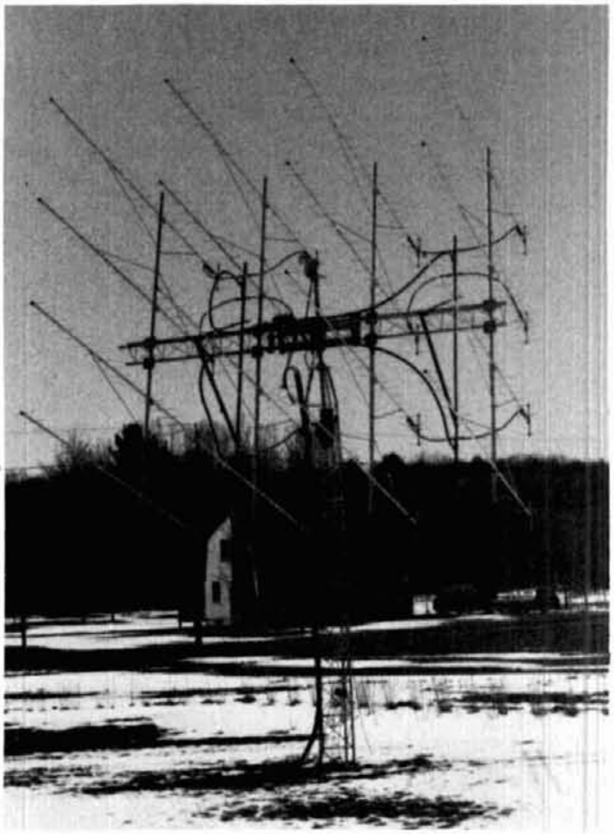

Sixteen stacked Cushcraft 424B Yagis in a 432-MHz EME array.

sidelobes down 12.3 dB at a spacing of 52 inches (1.32 meters). Considering that the 424B has an appreciably narrower H-plane beamwidth (22 inches versus 26 inches) and that it has more gain (15.8 dBd versus 15.1 dBd), just the opposite might be expected. The explanation again lies in the patterns of the individual antennas. **Figures 14** and **15** are computer-generated patterns for the RIW19 and the 424B. The RIW19 has, in general, sidelobes significantly lower than the 424B which would explain the different spacings for best array sidelobe levels. This effect has been noted in other Yagis also, and unfortunately makes most of the methods of calculating stacking distances (such as the aperture equations, or any of the various beamwidth formulas) of little use when array temperature is of concern. I spent a considerable amount of time trying to come up with a clever little formula for calculating stacking distances, but every one I tried had more Yagis disobey its numbers than ones that would.

This causes the optimum stacking distances to be different for different Yagis *even if they have the same gain*. Likewise a Yagi with a very clean pattern may have an optimum stacking distance greater than another with more gain but a poorer pattern. Keep in mind that "optimum" has, in this case, been defined as the highest G/T ratio.

mounting different frequency antennas on the same tower

The effect of having antennas for different bands located in close proximity has not received much attention. The interaction between antennas can be understood by looking again at **fig. 1**. If another antenna is located in the shadow of the first, it will not be able to extract as much energy as the first simply because the field strength is reduced behind the first antenna. To quantify the effect of having different antennas located nearby can be complicated. To evaluate the effect of a 144-MHz antenna on a nearby 432-MHz antenna, the aperture of the 144-MHz antenna at 432 MHz would have to be calculated in order to see how much of the capture areas overlapped. Next it would have to be determined who had "first dibs" on the signal or which antenna was in the other's shadow.

The only conclusive measurement I have been able to make has been to measure the Sun noise of a given array by itself and then add the other antennas and again measure Sun noise. I have found a consistent degradation in Sun noise by having arrays interlaced. Surprisingly, in most cases it is the lower frequency array that suffers. A side effect also appears to be the occurrence of stray sidelobes. The explanation of that phenomenon is that the unused antenna is re-radiating signals it had captured. Although not conclusive, terminating the unused antennas in a 50-ohm load appears to minimize the effect.

To be on the safe side, antennas should be located such that their apertures do not overlap. This can sometimes lead to very large spacings. As a practical matter the casual VHF/UHF operator may never see the performance degradation. The EME operator or enthusiastic weak signal worker who is looking for the last bit of performance is advised to either not mix arrays or to maintain sufficient spacing between them.

alternate stacking arrangements

This article has addressed only arrays with the Yagis arranged in uniform rows and columns. It may be possible to obtain additional stacking gain while controlling sidelobes by using other arrangements such as circle or diamond configurations. This would be due to the lower amount of aperture overlap required for sidelobe level control. I have not examined these alternative arrangements because of the difficulty in adapting them to an array with elevation control.

conclusions

Since most readers are likely to be more interested in a guide to how far apart to stack various antennas than in duplicating my work, **table 2** is provided. It covers a number of popular 144 MHz and 432 MHz antennas and their recommended stacking distances.

table 2. Measured performance of 144 and 432 MHz antennas.

144 MHz ANTENNAS

ANTENNA TYPE	GAIN dBd		PATTERN E x H	BOOMLENGTH	feet	SIDELOBES E x H -dB		STACKING feet E x H
6 el NBS	10.2	a	40 x 42	1.2	8.2	17	9	9.6 x 7.5
9 el F9FT	10.6		38 x 46	1.6	10.8	18	14	9.9 x 7.0
11 el Swan/KLM	10.8		40 x 44	1.8	12.3	13	10	9.6 x 7.5
11 el Cushcraft	10.8	b	40 x 46	1.7	11.8	19	13	10.0 x 7.5
12 el Swan/KLM	11.2		36 x 40	2.0	14.1	14	10	10.6 x 8.6
14 el Swan/KLM	11.8		34 x 37	2.5	17.4	15	10	11.0 x 9.5
20 el CC Colin	11.9		45 x 26	-.-	--.-	--	--	9.8 x 13.2
14 el Hy-Gain	11.9		35 x 35	2.3	15.5	--	--	11.0 x 9.9
12 el NBS	12.0	a	34 x 36	2.2	15.0	15	11	11.2 x 9.6
14 el Cushcraft	12.1		34 x 36	2.2	15.0	15	12	11.2 x 9.6
16 el KLM	12.2		29 x 31	3.0	20.7	12	9	11.4 x 9.6
11 el KLM 11X	12.2	u	34 x 38	2.3	15.3	19	14	11.5 x 9.9
16 el F9FT	12.5		32 x 34	3.0	20.8	17	13	12.2 x 10.2
11 el LUNAR	12.6	c,g	32 x 35	2.6	17.4	16	12	12.4 x 10.2
13 el KLM LBA	13.0		31 x 32	3.1	21.5	14	10	12.7 x 10.6
15 el Cue Dee	13.1		30 x 32	3.1	21.3	--	--	12.8 x 10.7
17 el NBS	13.1		28 x 33	3.2	22.0	13	10	13.0 x 10.4
19 el Cushcraft	13.2		28 x 33	3.2	22.0	14	11	13.0 x 10.5
13 el W2NLY	13.4	d	27 x 29	3.5	23.5	12	9	13.3 x 11.2
15 el Telrex	13.5		26 x 28	4.1	27.8	12	9	13.3 x 11.3
14 el K1FO	13.7	g	29 x 31	3.6	24.3	15	13	13.7 x 11.2
15 el NBS	13.9	a	26 x 29	4.2	28.7	14	11	13.7 x 11.4
16 el KLM LBX	14.3	u	28 x 30	4.1	28.1	17	14	13.8 x 11.6
18 el Cushcraft	14.5		27 X 28	4.2	28.7	15	12	14.0 x 11.8

432 MHz ANTENNAS

TYPE	dBd		E x H		feet	E x H -dB		inches
11 el Tilton	11.8	f,g	34 x 36	2.6	6.0	17	13	46 x 40
13 el W6QKI	13.3		27 x 29	3.4	7.8	12	9	53 x 44
13 el K2RIW	13.5		27 x 29	3.4	7.8	13	10	54 x 45
15 el NBS	13.9	a	26 x 29	4.2	9.6	14	11	55 x 46
16 el KLM LB	14.4		24 x 25	5.3	12.0	11	9	56 x 48
19 el K2RIW	15.1		24 x 26	5.6	12.8	16	14	60 x 54
21 el F9FT	15.2	h	24 x 26	6.6	15.0	14	12	58 x 52
26 el DL9KR	15.5	u,i	24 x 25	6.1	13.8	17	15	62 x 58
24 el Cushcraft	15.8		20 x 21	7.5	17.1	12	10	62 x 50
22 el DL6WU	15.8	u,l	23 x 24	6.9	15.6	15	14	64 x 58
24 el K1FO	16.6	k	22 x 23	7.5	17.2	16	15	66 x 60
28 el W1JR/DL6WU	17.0	u	20 x 21	9.3	21.1	14	13	70 x 64
30 el KLM LBX	17.3	u	19 x 20	9.6	21.9	15	13	72 x 66
31 el W1JR/DL6WU	17.5	u	19 x 20	10.4	23.7	14	13	74 x 68

a These NBS yagis have gain peaks 2 percent high in frequency.
b Gain peak is 11.1 dBd at 146 MHz, 38 x 44 degree pattern.
c Has incorrect balun length. With stock balun gain is 12.4 dBd.
d Figures are for 0.125 inch taper version with 20 in. reflector spacing
f Is tuned to 440 MHz. Retuned to 432 MHz gain would be 12.6 dBd.
g Design based on Greenblum / Tilton information.
h Is designed for 435 MHz. Gain peak is 15.5 dBd at 436 MHz.
i Uses 8 element screen reflector.
k Is a modified 424B using a single reflector and 22 directors.
l Is designed for 435 MHz. Gain peak is 16.0 dBd at 436 MHz.
u Design based on DL6WU information.

Although a few tenths of a dB additional gain may be obtainable at larger spacings, the added size, weight, and windload would most likely not justify the wider spacing even if EME or satellite communications are not anticipated.

It should be emphasized that gain alone does not tell the whole story. A Yagi with a cleaner pattern may be a better choice for an EME array than one with higher gain and a "messy" pattern. The highest gain Yagi in the world is of little use if it splits into 5 pieces the first time a storm passes by.

Finally, the following summary should serve as a guideline in building multiple Yagi arrays:

• Optimum stacking distance is a compromise between gain increase and sidelobe level (G/T).

• Array -3 dB beamwidth will be equal to single element beamwidth divided by the number of elements in a plane when the first sidelobes are -14 to -15 dB. This usually represents optimum stacking or best G/T.

• The H-plane's inherently less directive pattern requires substantially closer spacing than the E-plane to achieve optimum sidelobe levels.

• Negating phasing line losses, doubling the number of elements in an array at optimum spacing will give approximately 2.7 to 2.8 dB gain increase in the E-plane and 2.5 to 2.6 dB in the H-plane.

• The greater the number of elements in an array, the more critical it is to have that array optimally spaced.

• The higher the frequency of operation, the more critical it is to have an array with small sidelobes (i.e. optimally stacked).

• The cleaner the pattern of an individual Yagi, the greater the optimum stacking distance will be — hence the greater the array gain.

• Although spacings closer than the maximum gain distance can cause the loss of a few tenths of a dB in array gain, the closer spacing can result in several dB of signal-to-noise ratio improvement on receive.

• If you are going to make a mistake, put your antennas "too close together" rather than "too far apart."

• Placing different band antennas in close proximity can degrade performance.

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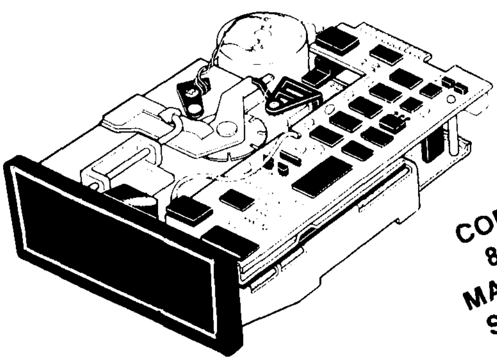

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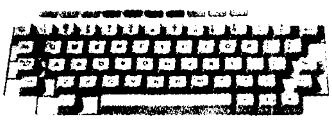

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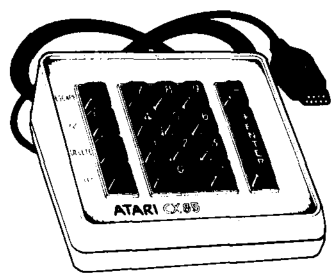

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active antenna covers 0.5-30 MHz

Double duty allows 2-meter operation as well

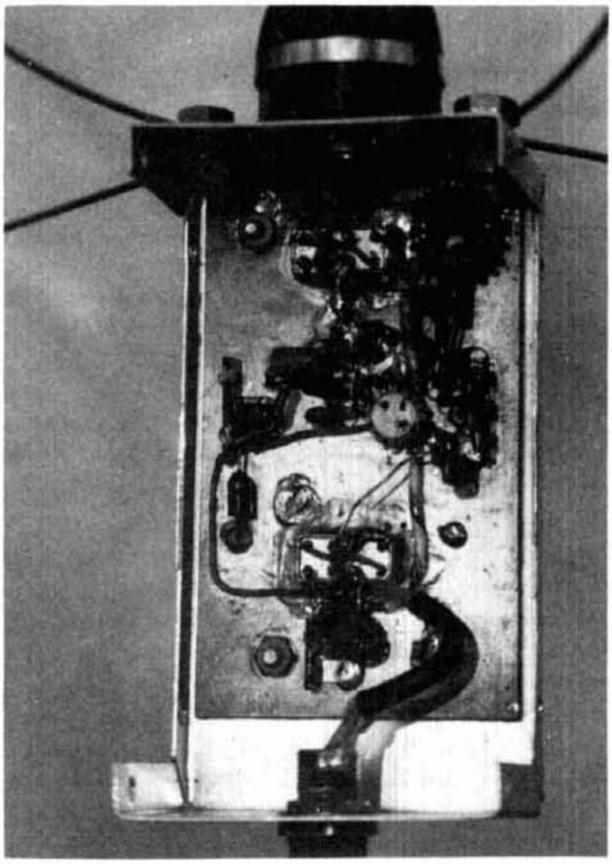
Active antennas have been available commercially for several years, but relatively little practical information about them has appeared in the Amateur journals.[1,2] This article illustrates how to build a simple one covering from 500 kHz to at least 30 MHz using commonly available components. As an added bonus, the antenna works as an omnidirectional 2-meter antenna when not in use for HF reception. It will also meet the needs of SWL's for casual monitoring on the HF bands.

First, some clarification is in order. True active antennas (sometimes referred to as voltage probe antennas) use circuitry somewhat more sophisticated than what is presented here.[3] Antenna probe lengths of 2 inches have been used in some commercial models intended for military markets. Their circuitry does not match impedances in the usual sense, as does the simple approach used here.[3,4] Instead, their reactive components are made small in comparison to the extremely high source-follower FET input impedance, effectively swamping out the reactive component. A short probe antenna, at the lower HF frequencies, may have a capacitive reactance in the millions of ohms, while its effective radiation resistance is only a very small fraction of an ohm.[2] Despite its lack of eloquence the antenna presented here works well, and can be built in a weekend for very little cost.

general coverage antenna needed

Amateur Radio manufacturers have caught on to the market for general-coverage reception — today many transceivers will receive from the lower LF ranges continuously up to 30 MHz and beyond. While the benefits of general-coverage receivers are obvious, some problems await those seeking a single antenna capable of spanning several octaves.

The simple link-coupled LC preselector circuits used in vintage tube-type receivers were capable of matching to a wide variety of loads, and an "antenna" tuning control served in tweaking the most out of any antenna. But the situation is somewhat different today. Modern receivers are carefully designed for proper gain distribution. The tracking preselectors and high-gain front ends are gone; in their place are mod-



Internal view of unit shows the construction details of the active antenna. The ASP-677 commercial antenna was used. Because of the softness of the minibox aluminum, the 3/8-inch snap-mount washer was removed and installed on the inside wall of the minibox. This washer is part of the ASP snap-mount assembly.

By Peter J. Bertini, K1ZJH, 20 Patsun Road, Somers, Connecticut 06071

item	description
ANT-1	antenna probe, 20-50 inch length. Stainless steel antenna whip, aluminum tubing, or collapsible whip. Radio Shack No. 15-232 (38 inches) or No. 270-1401, 270-1402, 270-1403, or 270-1405.
F1	1 amp, fast-blow fuse
J1	RF connector, SO-239
RFC-1	20 turns No. 26 wire on Amidon FT50-61 core material (see text)
RL1	reed relay, SPST, 12 VDC coil.
S1	SPST switch, 125 VAC rating. Radio Shack 275-612 or equivalent
T1	9 bifilar turns, No. 26 wire on Amidon T68-8 core material. Wire 4-6 twists per inch (see text)
T2	power transformer, 117 VAC to 12.6 VAC at 100 mA minimum. Radio Shack No. 273-1385 or equivalent

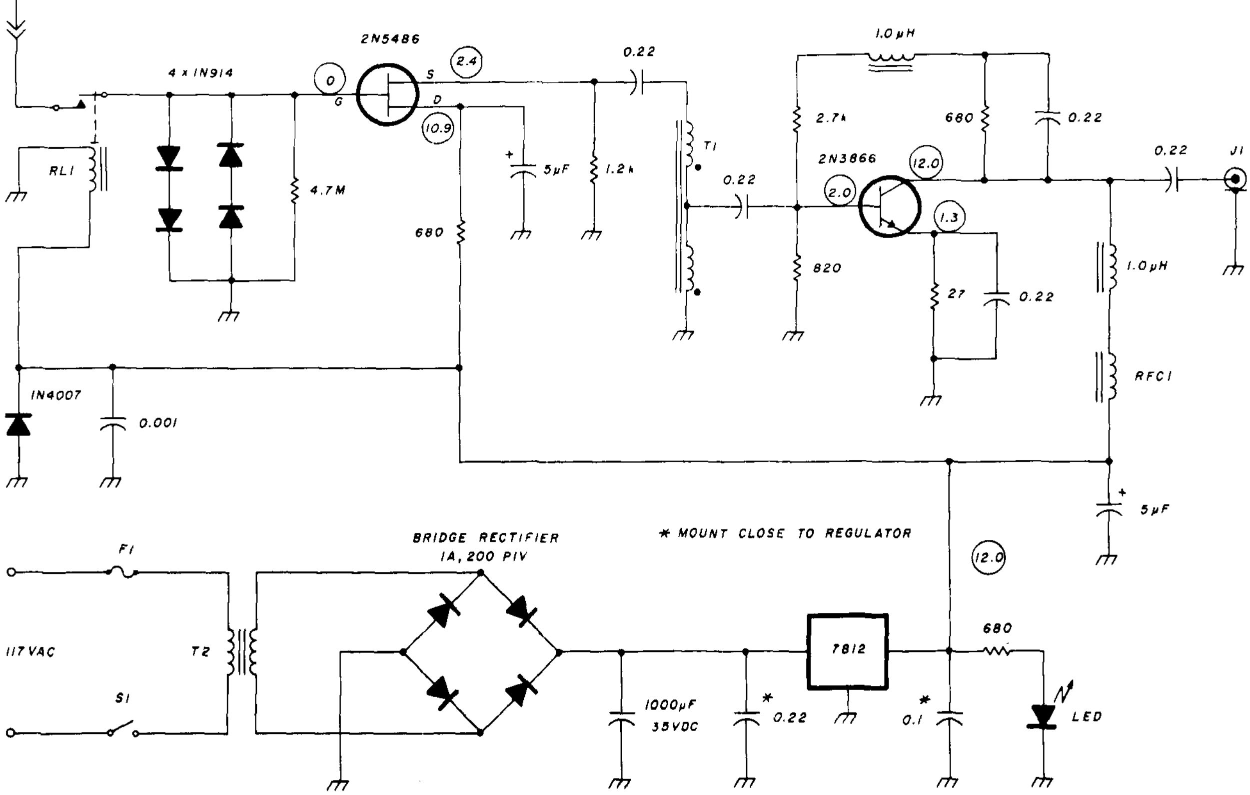


fig. 1. The schematic for the *indoor* antenna. This version has no provisions for 2-meter operation. DC voltage measurements are provided to assist in troubleshooting. *Voltages are indicated by circled values.*

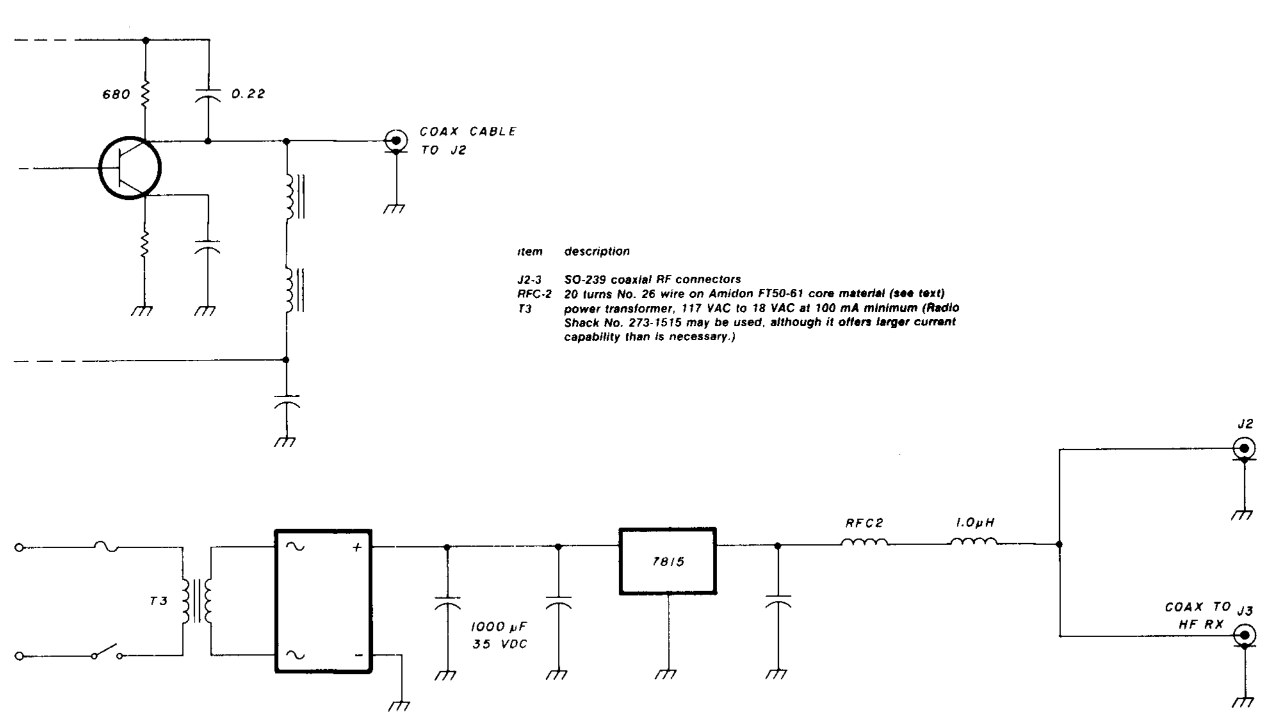
ern electronically-switched broadband filters. But these filters are not tolerant. If the load is not 50 ohms, their performance is no longer predictable and losses can become excessive. Consider the use of an 80-meter antenna for shortwave reception in the 40-meter region. An 80-meter dipole at 40 meters is virtually unusable because as the feedpoint impedance soars to a very high value the shunt capacity of the coax greatly attenuates incoming signals.

impedance transformation needed

Did you ever wonder how an automobile's AM antenna could work effectively on FM and yet be so short? The answer lies in the special high-impedance coax and special front-end design used in these receivers. (If you've ever tried to replace this coax with a length of RG-58 you've quickly learned a lesson in capacitive losses.)

If a short antenna will work at 550 kHz, it will work elsewhere as well. All that's needed is an impedance transformation network to change the extremely high termination impedance of our short "probe" antenna into a usable 50-ohm impedance for our receiver, across a range of several octaves. The size of an antenna has little bearing on its performance — full-size antennas do offer 50-ohm feedpoint impedances and low enough resistance losses to allow efficient RF radiation.[5] For receiving applications, many Amateurs have found that antennas such as the Beverage, ferrite-loop, and active antenna often out-perform full-size transmitting antenna arrays because of their lower susceptibility to noise pickup — and in some cases, their excellent directivity in the lower HF regions.

A JFET source-follower stage provides the desired high-to-low impedance transformation. (While a 2N5486 was used here, an MPF102 will also work.)



item	description
J2-3	SO-239 coaxial RF connectors
RFC-2	20 turns No. 26 wire on Amidon FT50-61 core material (see text)
T3	power transformer, 117 VAC to 18 VAC at 100 mA minimum (Radio Shack No. 273-1515 may be used, although it offers larger current capability than is necessary.)

fig. 2. The schematic for the outdoor antenna. Only circuit changes from *fig. 1* are shown. Note the elimination of the 0.22 µF coupling capacitor, allowing DC feed on the coaxial cable. Power supply components have been changed for 15-volt output, compensating for possible resistive cable losses. Component values not shown are the same as in *fig. 1*.

The antenna is a length of wire, about 48 inches (1.22 meters) long. A length of stainless-steel wire salvaged from an old VHF whip or automobile antenna or even a section of aluminum tubing may be used for the antenna probe.

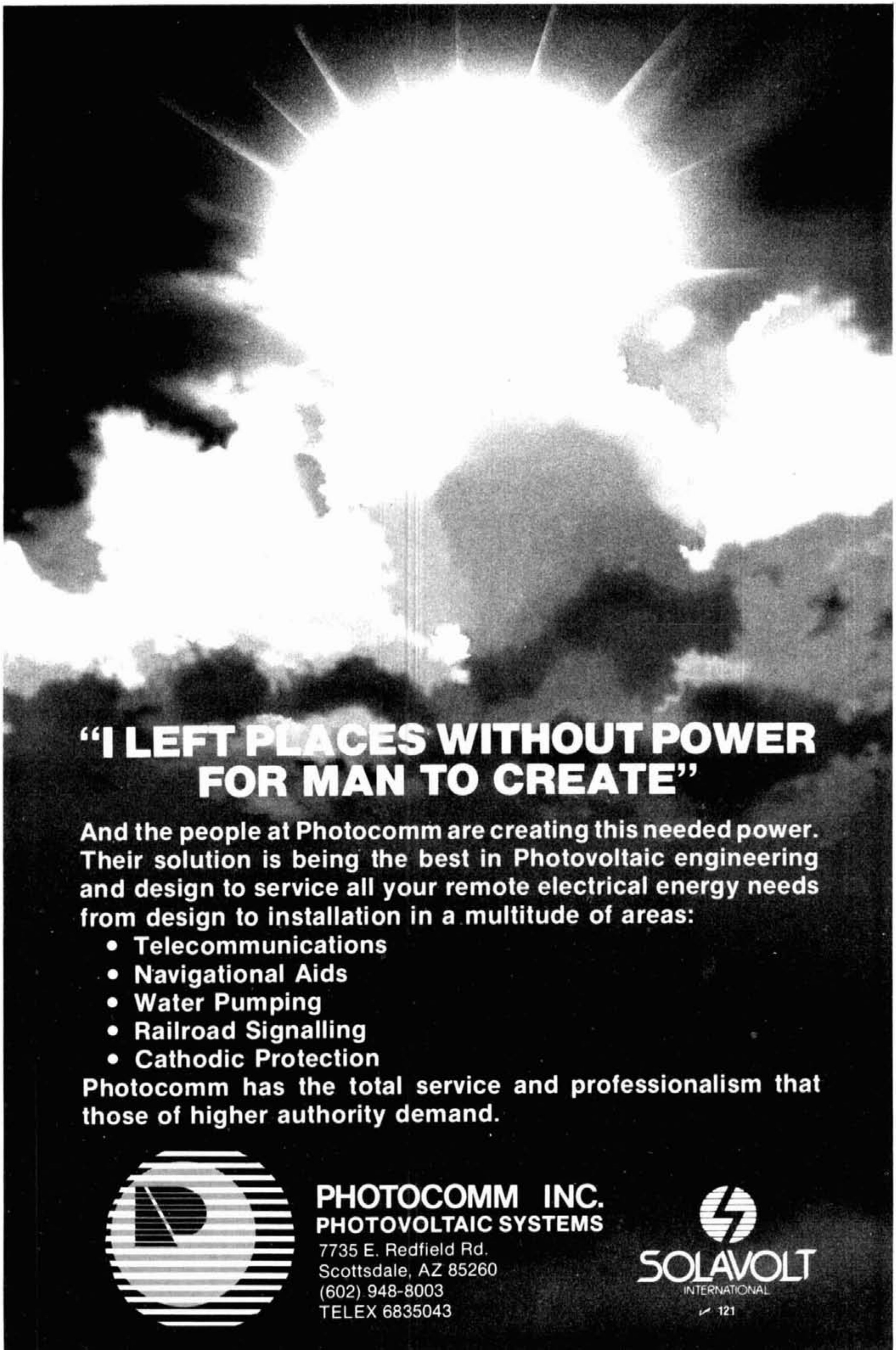
Two versions of this antenna were built and tested; one was designed for indoor use and the other for outdoor mounting. The indoor unit was built in a small enclosure. The exact dimensions are not critical, providing all components can be comfortably mounted inside. The only difference between the indoor and outdoor models is in the packaging — the outdoor model uses a remote weather-proof housing for the preamp and antenna probe. Everything is self-contained in the indoor version.

Referring to **fig. 1**, for the schematic for the indoor model, note the back-to-back diode protection from the JFET gate to ground. I found that the static discharge generated from shuffling across the shack floor was responsible for the untimely demise of several 2N5486 devices before I realized what was going on. These diodes do not guarantee total protection — the best safeguard is to avoid touching the antenna probe. To prevent generation of an insidious form of TVI in the outdoor antenna caused by diode rectification of RF radiated from nearby HF or VHF transmitters, a small reed relay is used to disconnect the antenna probe from the preamp stages when the antenna is not in use. This also offers some protection to the JFET during electrical storms, when static charges might build up on the antenna. The reed relay should be used in the indoor model as well for protection against static discharges. The reed relay is used only in the HF model — for 2-meter operation a more involved switching scheme using DPDT relays is needed. (This will be addressed in greater detail below).

The schematic shown in **fig. 2** serves as the basis for the outdoor HF active antenna. The only difference is in the power feed arrangement. In the outdoor model, power for the preamp head is fed through the coax from the indoor power supply.

additional gain needed

Following the JFET device, which does not provide voltage gain, is a class-A bipolar stage using a 2N3866 transistor. (A 2N5109 could be used here instead.) "Hotter" transistors such as the TRW LT1001 might offer some improvement, especially at higher frequencies, but they might also require some circuit revisions to prevent self-oscillation. This stage does provide gain, building up the very small signals captured by the short antenna. The transistor must be heatsunk; the stage draws about 25 mA resulting in considerable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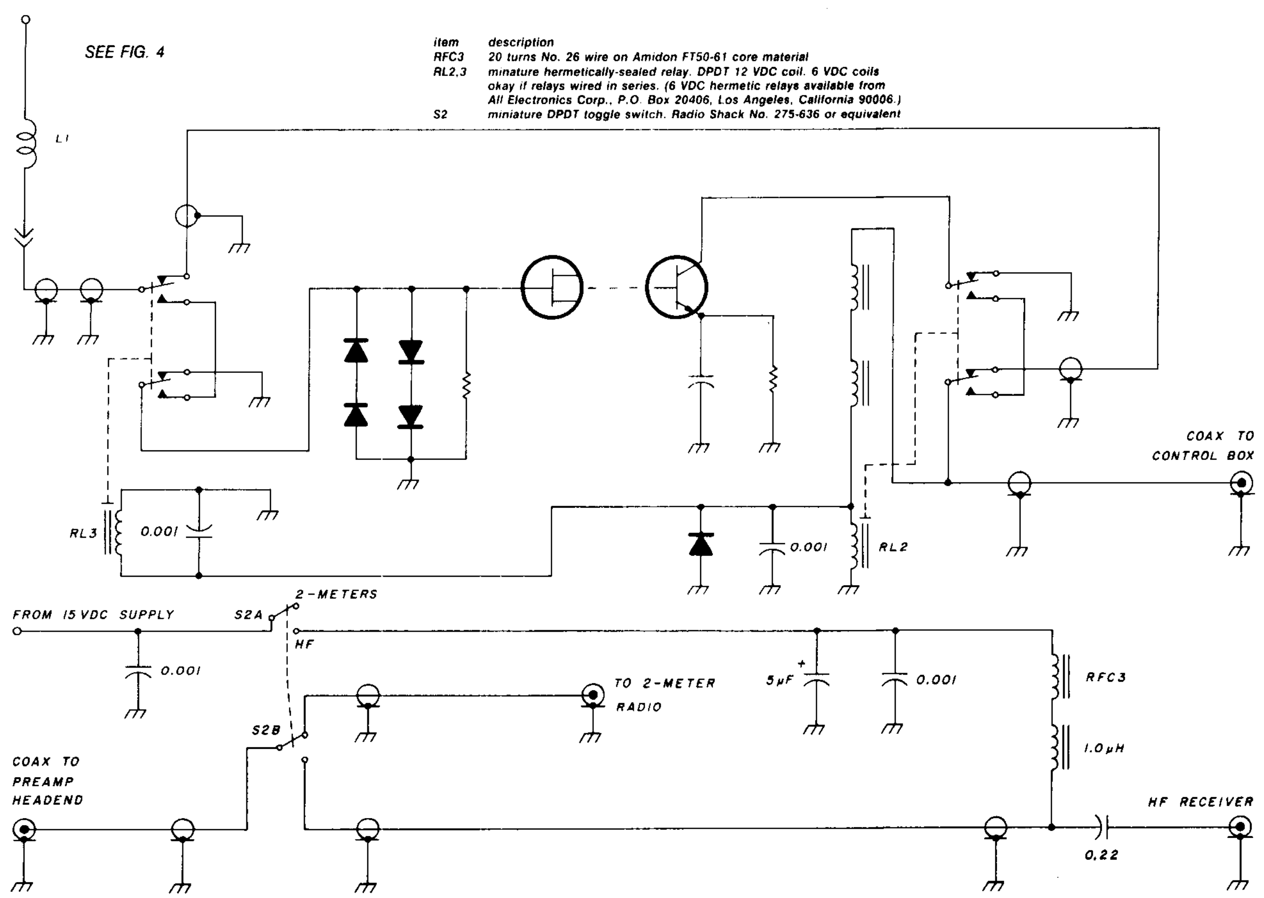


fig. 3. The changes allowing 2-meter operation for the active antenna while not in use on HF. The 15-VDC power source is the one shown in *fig. 2.* Two DPDT relays bypass the active antenna preamp stages for straight-through operation on 2 meters. Six-volt relays will work, providing the coils are wired in series. Component values are not shown if unchanged from previous diagrams.

device dissipation. Shunt feedback sets the stage gain and insures stable operation. A series choke in the feedback network allows greater gain at higher frequencies, this is necessary because the f_T (the gain-bandwidth product, or the frequency at which the current gain reduces to unity) of the 2N3866 is only 500 MHz. A broadband interstage matching transformer is used between the source follower and bipolar amplifier. Using 20 bifilar turns allows enough inductive reactance for operation through the AM broadcast band. If AM broadcast band coverage is not desired, the windings may be reduced to nine bifilar turns. This will cause gain to start rolling off below 1800 kHz, while yielding a slight improvement above 30 MHz.

All models were constructed and tested using point-to-point wiring techniques on double-sided PC board material. Phenolic soldering strips provide the mechanical support needed for components and wiring. While the results are not overly photogenic, the circuit works as intended. Etched printed-circuit construction is not needed here.

The outdoor model works best.[1] Mounted high and in the clear, it is not subjected to the man-made noises carried and radiated on the home's wiring. Many common home appliances will generate copious amounts of broadband hash across the HF spectrum: vacuum cleaners, television horizontal-sweep circuits, fluorescent lights, light dimmers, computers, and numerous other devices will cause grief for the serious HF operator. While the antenna can be side-mounted to an existing tower leg, it is best to mount it away from nearby metal objects. If at all possible the antenna should be top-mounted on the tower masting. Lead-in coax can be either RG-59 or RG-58 type cable. RG-8 coaxial cable can be used with the outdoor combination 2-meter/HF model to limit the VHF losses.

use for 2 meters as well

Since the antenna probe is 48 inches long, we have the basic foundation for a 5/8-wavelength vertically polarized antenna for 2 meters. All that's required is a matching transformer (**fig. 4**) to match the

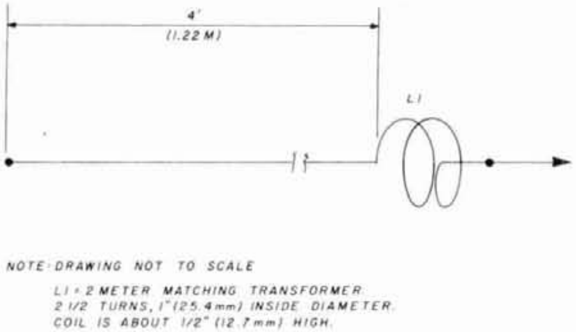


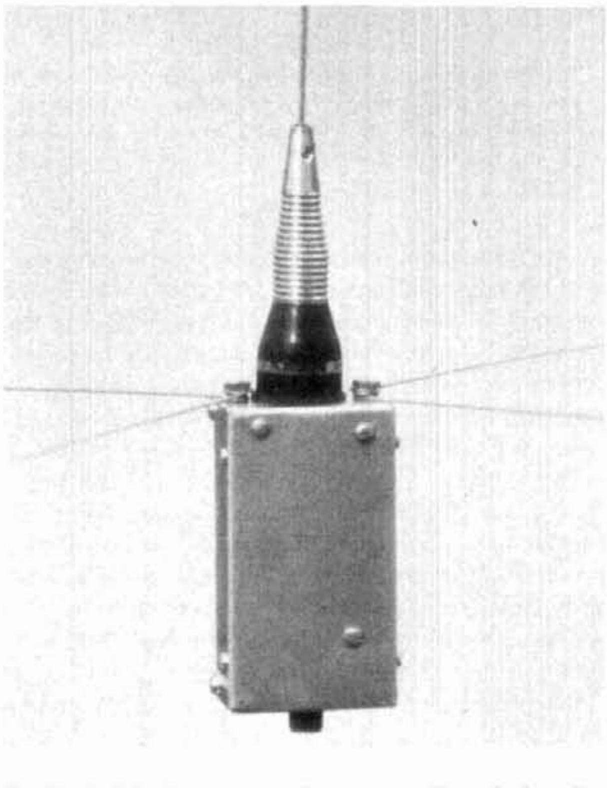
fig. 4. Construction details for the 5/8λ two-meter radiator and matching transformer. The transformer may be formed by winding the antenna rod around a suitable form. These dimensions were taken from the ASP-677 matching transformer assembly.

5/8-wavelength radiator to 50 ohms. Given a length of stainless steel antenna rod, it is possible to make the coil and whip one continuous piece. A commercial 5/8-wavelength antenna, such as the Antenna Specialists model ASP-677, could serve here as well, and was my choice for my outdoor HF/VHF combination antenna. Note that the ASP whip is cut for about 46 inches (1.17 meters); this is because of the added length introduced by the spring assembly. *Half-wave or 5/8-wavelength antenna designs using grounded, tapped matching transformers will not work.* The extremely small inductances will short circuit HF signals.

Three or four ground radials are needed for the 2-meter/HF combination active antenna. These should be a little longer than a quarter-wavelength, 20-inch lengths of stainless steel antenna whip wire or aluminum tubing will serve here. SWR is adjusted by trimming the radiator length; 48 inches will be about optimum for the upper 2 MHz of the band. If trimming the antenna does not yield an SWR under 1.5 to 1, compressing or expanding the transformer coil should provide a good match. The radials must make good electrical contact to the metal enclosure housing the antenna. A Radio Shack catalog No. 270-238 mini-box houses my unit. Its 5-1/4 × 3 × 2-1/8 inch (13.34 × 7.62 × 5.52 cm) size is roomy enough to comfortably mount the preamp components. The PC board used for mounting the active antenna components must also make a good low-impedance RF ground connection to the enclosure. This provides the needed RF ground path for the 2-meter antenna. If the ASP antenna is used, a short length of RG-58 coax should be used between the 3/8-inch snap-mount and preamp changeover relay. Use short coax lead connections to the relay and ground.

Figure 3 outlines the electrical details for the dual-purpose antenna. Two miniature hermetically sealed relays are used to bypass the preamp stages, allowing straight-through operation for 2 meters when the power is removed from the antenna. Metal-can 6 VDC hermetic relays can be used, providing the coils are connected in series. Six-volt relays are often more easily available, and cheaper, than their 12-volt counterparts. A 1N4007 silicon power diode protects the amplifier from reversed supply voltages; and from the counter-EMF generated by the relay coils as power is removed. Depending on the length of coax used, the power supply voltage may have to be increased to compensate for voltage drops in the coax cable. The 2-meter version draws over 100 mA; at least 12 volts should be available at the antenna preamp.

Short leads are mandatory for good VHF operation. The straight-through 2-meter operation uses a short piece of coax cable between the relays. RG-174 is okay for this, but extremely short ground and center wire connections must be made at the relays. The shack-mounted power supply unit should be as carefully constructed, to keep the losses at a minimum. Note the use of the DPDT switch; it does "double-duty" in switching the power to the antenna preamp and also changing the feedline between the HF receiver and



The finished dual-purpose active antenna. Note the installation of the 1/4-wave 2-meter radials. (See W6SAI's November, 1984, column in *ham radio* for a timely discussion on improving radial performance for 5/8-wave 2-meter antennas used in this fashion.)

2-meter FM rig. Very short leads are used for the coax connections at the switch terminals, avoiding severe impedance bumps at 146 MHz. Use care in soldering; overheating the center insulation may result in a short to the coax braid. The outdoor antenna enclosure should be weatherproofed. (Silicone bathroom caulk will do well for this purpose.) Be sure to allow for condensation; a small drain hole on the bottom of the enclosure is needed. Also spray the PC board and components with clear acrylic spray to prevent corrosion. Anti-moisture and fungicidal varnish, carried by some electronic suppliers, is what I used, and it is also ideal for sealing the coax connections after they have been taped.

what to expect

Although performance of either model is adequate for casual monitoring, it is difficult to evaluate these antennas unless an antenna test range equipped with full-size antennas for all of the frequencies involved is available. S-meter comparisons alone can be deceptive. A higher S-meter reading may be obtained with an active antenna with excessive internal gain, while the signal-to-noise ratio may be best on the comparison antenna. This lesson was demonstrated some years ago when I tried using an old RME preselector ahead of a 51J3 Collins receiver. Above 15 MHz the S-meter was very "busy". Switching off the preselector often dropped S-9 signals to an S-1 or less, even though the readability increased dramatically.

With the active antenna connected to your HF receiver and turned on, a slight increase in receiver noise should be heard. Disconnecting the whip antenna from the preamp should cause a noticeable reduction in receiver noise. This is a good indication that everything is working as it should. The gain of this active antenna is not as great as some commercial units I've used in the past. Do not expect signals to produce the same S-meter readings as a full-size antenna.

Some variations of the design are possible. SWL's with a need for coverage in the LF ranges below 550 kHz might consider eliminating the interstage matching transformer. However, without the matching transformer, 60-cycle cross-modulation from strong nearby AC powerline fields will be an annoying problem. This can be especially troublesome in the indoor model where the probe and preamplifier stages are near to the power transformer. The limiting factor for LF performance is the choke values used to isolate the DC supply voltages. They will have to be increased to allow operation below 500 kHz. There is no magic in the antenna probe length — antennas as short as 20 inches might prove adequate. The 48-inch length was selected to allow 5/8-wave 2-meter operation. An 18-inch (45.7 mm) probe could serve as a 1/4-wave 2-meter radiator and eliminate the need for the 2-meter matching transformer.

A few words of caution: the 2-meter antenna will handle about 25 watts. More than this invites damage to the 1-μH chokes. When using the antenna on an HF transceiver, never transmit into the antenna. Always disconnect the mike and key and set the drive and mike controls at minimum *before* connecting to the active antenna!

There you have it, all in one package: an all-band HF antenna for SWL'ing on your transceiver and a 2-meter antenna for your FM rig. Considering the obstacles facing many Amateurs — lot size, restrictive zoning regulations, and unsympathetic landlords — this antenna will offer a lot of performance in a small, inexpensive and inconspicuous design.

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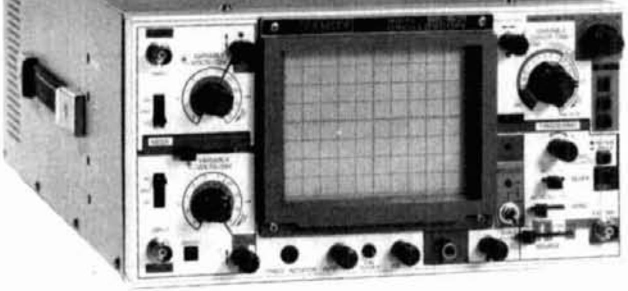

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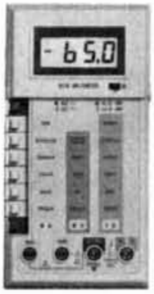

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control your take-off angle: the JR vari-lobe antenna

Dial in your skip distance and maximize your signals

The *ham radio* staff was saddened to learn of the recent death of Dick Schellenbach, W1JF.

In memory of this exemplary Radio Amateur we are proud to present the following two articles.

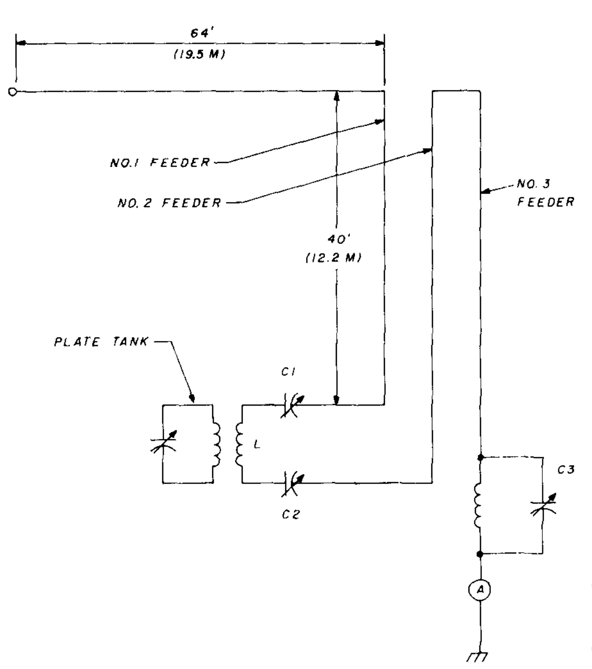

fig. 1. The original Reinartz antenna system. A current-fed Hertz (on 80 meters) with one quarter wave section horizontal and unconventional three-wire tuned feeders.

Most Radio Amateurs, I'm sure, are quite familiar with the directional properties of simple halfwave antennas. In these antennas, the majority of radiation is broadside to the radiating element, in the case of a horizontal type antenna. Some Amateurs may be familiar with, or may have experienced, the effect of raising or lowering an antenna and have seen how its launch angle, as well as its impedance, was significantly affected by the change in height. In this respect, a lower angle of vertical radiation usually produces a stronger signal further out in distance than one that has an extremely high angle of radiation when the communication path is governed by sky waves. This path distance versus launch angle phenomenon is very noticeable on the lower frequency Amateur bands of 160, 80, and 40 meters, where both high and low angles of radiation are useful in radio communications.

Given the fact that a half-wave antenna generally radiates most of its signal broadside to the antenna, what would you think of a simple modification that would permit controlled selection of its radiation angle? This would allow the Amateur station to take advantage of the prevailing ionospheric conditions, night or day, and therefore enhance signals to and from a particular distant location. Such an antenna system *is* feasible.

The basic idea for the variable lobe system was developed fifty years ago by the legendary John L. Reinartz, W1QP.[1]

In developing this new concept and publishing the results of his experiments Reinartz discovered he truly had a multiband antenna system as well as one providing versatile radiation angle control allowing him to maximize signal strengths at different locations. Reinartz also found out he could compensate for time-varying propagation conditions, especially when the

By R.R. Schellenbach, W1JF, 12 Whitehall Lane, Reading, Massachusetts 01867

reflective layer was in the process of changing heights, thereby requiring a different radiation angle while he was communicating.

The ability to alter an antenna's vertical lobe characteristics is one solution to the thought-provoking question, why does it often seem that signal reports appear to differ drastically between individual stations, even when the stations are located only a few miles apart in the same general direction?

The causes for inconsistencies between signal reports include a myriad of possibilities such as polarization differences, vagaries of the ionospheric reflective layers, multi-hop propagation, launch radiation, and receiving station antenna angle differences, to name a few. Because of the large number of variables affecting sky-wave propagation, the solutions to these problems are complex. However, if a radio station possesses the capability to adjust to any potential condition, the inconsistencies are not at all important — only the corrective measure capability matters.

Reinartz recognized the same perplexing propagation differences between the station he worked and proposed that if he were to vary the vertical angle pattern of his antenna, he should maintain a maximum signal strength at both ends of the communication path. In his model, Reinartz developed an antenna system which is basically a simple current-fed Hertz type antenna with one quarter-wave horizontal section and another sixth-wave feeder section, the latter consisting of two normal operating feeders and a third, vertical wire carried into his ham shack for tuning and compensation control. The original Reinartz version of the controlled radiation angle antenna is shown in **fig. 1**. The model as shown, operating on the 80-meter band, proved to be capable of operating under vertical angle of radiation control at twice or even four times its fundamental design frequency.

In spite of the antenna's multiband capability, it was used primarily on the 80-meter band, where daily and seasonal propagation effects were more pronounced and allowed Reinartz to do a lot of experimentation during variable band conditions.

how it works

Referring again to **fig. 1**, illustrating the original Reinartz antenna system, it should be mentioned that the variable capacitor C2 was found to be unnecessary in the 80-meter application and that all vertical angle lobe changing was affected by varying C1 while maintaining resonance of the parallel L/C network against ground for each particular operating frequency. Reinartz used an RF current reading ammeter to determine resonance in the third (vertical) feeder wire, but the meter is deemed unnecessary, as other means are available to determine proper resonance of the vertical wire section.

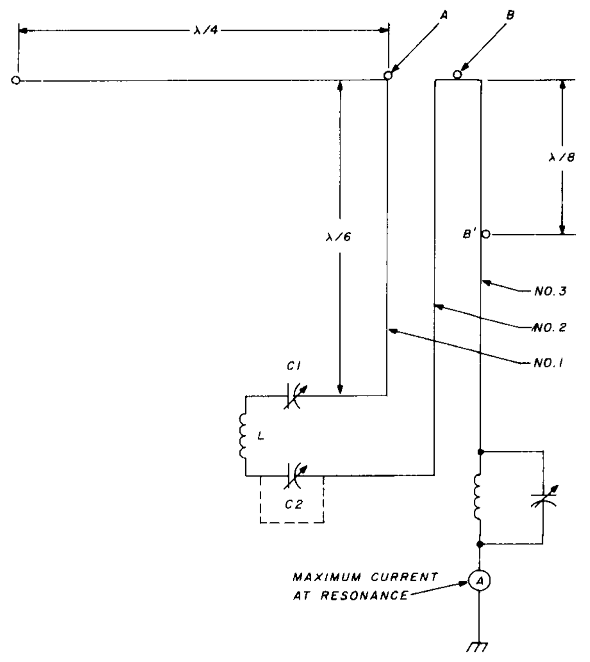

fig. 2A. Mechanism for changing current point *B* up or down by adjustment of series capacitor C1.

More details of the mechanism for changing the antenna's vertical field pattern is shown in **figs. 2A** and **2B**, where on the 80-meter band these figures indicate the voltage and current distributions on the model and the method employed to change the radiating current points on the system. The horizontal wire section of the antenna in **fig. 2A** is only one-sixth wavelength above the ground and hence, most of its radiation is directed upward — a real "cloud burner." During nighttime conditions, for example, this pattern would produce strong local signals because of the high angle and short distance skip zone; if we were to move the current point from the top of feeder number 3 downward, however, then the radiation characteristic would be reversed and the antenna's radiation would become predominately low angle — good for DX.

The change in vertical radiation pattern with relationship to the RF current maximum point on the third (vertical) wire section is illustrated in **fig. 3**. As one may surmise, the third vertical wire section of the antenna functions to provide the vertically polarized and low angle lobe control for the system. By controlling the current distribution by altering capacitor C1 in the series tuning circuit of **fig. 2**, the Vari-Lobe antenna changes from a high vertical angle radiator to a low vertical angle radiator quite simply. When capacitor C1 is slowly tuned, the antenna's vertical pattern may be finely adjusted anywhere between the two extremes dipicted in **fig. 3**. This tuning control

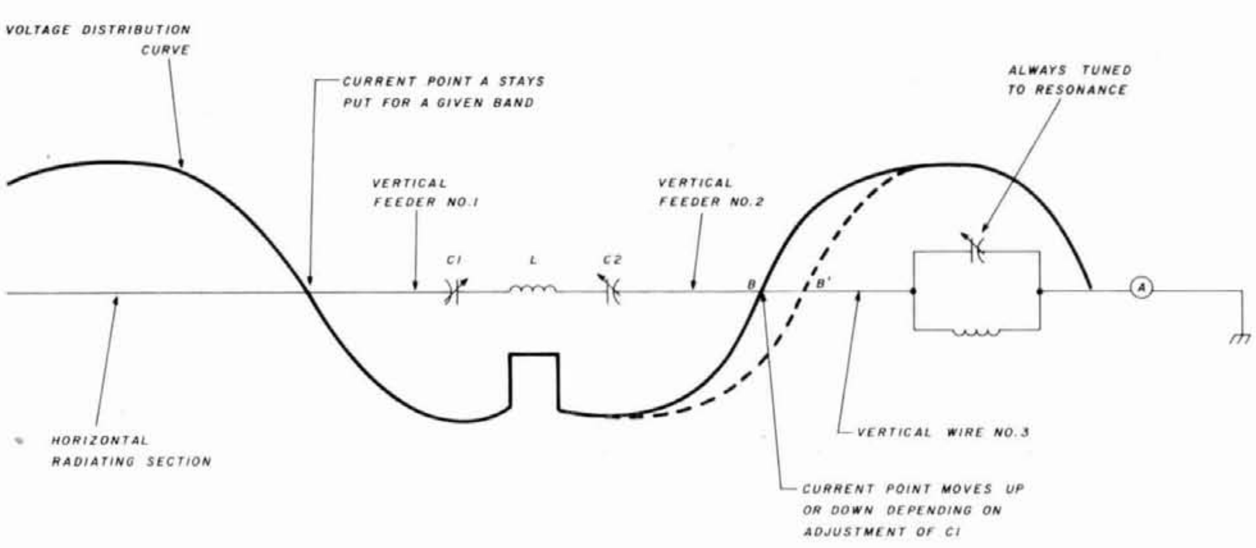

fig. 2B. The antenna system shown stretched out to illustrate the standing wave (voltage and current) distribution (80-meter example).

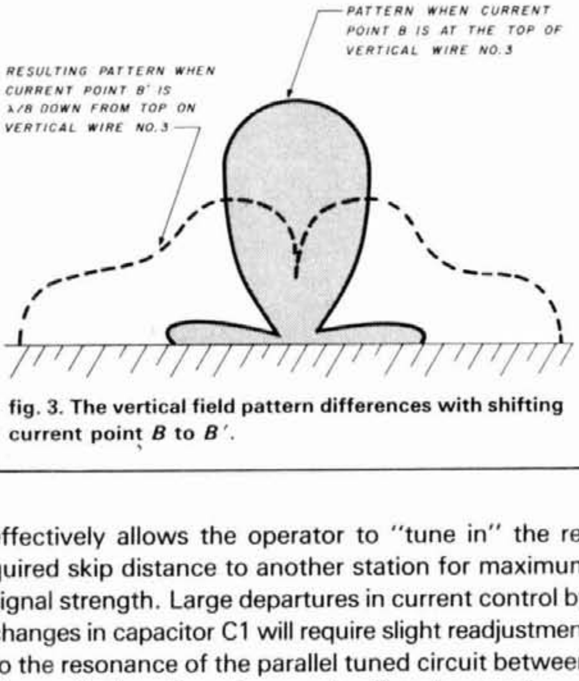

fig. 3. The vertical field pattern differences with shifting current point *B* to *B'*.

effectively allows the operator to "tune in" the required skip distance to another station for maximum signal strength. Large departures in current control by changes in capacitor C1 will require slight readjustment to the resonance of the parallel tuned circuit between the vertical section wire number 3 and ground.

According to tests by Reinartz in which he instrumented the vertical wire from top to bottom with small pilot lamps to indicate antenna current distributions, the further downward the current maximum was toward the one-eighth wavelength point, the greater the low angle effect and the further out the skip became.

It is interesting to note that Reinartz performed many of his early experiments and collected data on the shifting field strength patterns on the 10-meter band. Later, actual on-the-air tests using a full-scale 3.5 MHz (80 meter) model was used to communicate with a number of Amateurs up and down the east coast of the United States.

Concluding remarks by Reinartz indicate that his repeated tests showed that compensation for the advance of time from early evening to past midnight must be made by a change in the location of the maximum current point on the vertical section in order to maintain maximum signal strength at the receiving station. During daytime operation, he noticed that although there was one generally satisfactory setting of C1, slight changes could be made in the lobe adjustment to provide a maximum signal at some particular receiving station. He noticed too, that some stations were always consistent in the antenna's lobe setting for obtaining a maximum signal strength.

a modern version of the JR antenna

By carrying Reinartz's ideas further and adding modern improvements, the JR Vari-Lobe antenna came into being. The new system offers more operating frequencies with ease of controlled radiation from either the ham shack or by remote control. The modern version is shown in **fig. 4** and its control section in **fig. 5**. I prefer the remote tuning method because it keeps the necessary radiating elements away from the surrounding objects such as houses, trees, telephone and power lines, etc. The JR Vari-Lobe antenna's performance could be adversely influenced by such local obstructions because the antenna is a relatively low height system and it utilizes low angle vertical polarization.

As an additional feature of modernization, I incorporated a 15-meter "high gain" capability by using the "JF Array"[2] principally on the horizontal section. When used, the JF Array mode is automatically invoked when the system is tuned up on the 15-meter band. On this frequency, the antenna acts as a two-element, wide-spaced collinear array producing a good 3-dB gain broadside to the horizontal sections. Vertical angle selectivity is not used on this higher frequency band because the system is operated in its "Zepp" mode, in which feeders A and B are used and B and C are tied together as shown in **figs. 4** and **5**.

The reader will notice that there are small differences between the original Reinartz antenna and the modern version. Most of the recent changes were brought about by the addition of the JF Array feature and a more compatible feeder length to handle multiband applications. In a departure from the original antenna system, we have taken advantage of using a multiband tuning network to implement the third wire to ground resonance of the system. This expedient is in keeping with modernization of the compensation tuning, since in practice, only one adjustment needs be made for each operating band segment, and one that holds for a bandwidth of 40 to 60 kHz on the 80-meter band and greater than 60 kHz on the 40-meter band.

The coaxial transmission line to the radio station equipment may be provided by either a 50 or 75-ohm coaxial cable through a 1:1 balun transformer connected across a few turns at mid-point on inductor L of **fig. 5**. As discussed previously, capacitor C1 of **fig. 5** is the vertical lobe angle control, where decreasing its effective capacity corresponds to raising the current maximum point on the vertical wire number 3 corresponding to a high lobe angle for the antenna. Conversely, an increase in capacitance by C1 results in lowering the current maximum point on the vertical wire number 3 corresponding to a low angle of radiation for the antenna. Each extreme capacitance change of C1 must be followed by an adjustment of the parallel tuned resonance circuit, especially if the operating frequency has also been changed beyond the bandwidth restrictions previously mentioned.

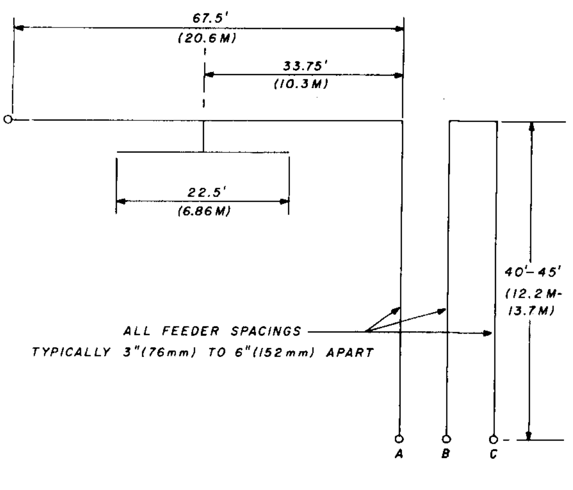

fig. 4. The modernized JR vari-lobe antenna system.

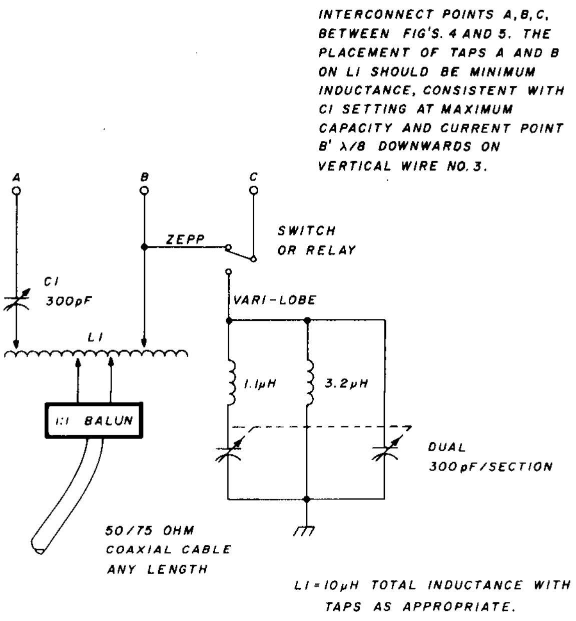

fig. 5. The tuning section for all bands and modes.

performance

Because the JR Vari-Lobe antenna system is intended to be used primarily on the 80 and 40-meter bands with infrequent excursions to 15 meters, it is important to have a good ground in order for the system to work well. Ground radials should be employed beneath the horizontal section of the antenna and extend outward in a fan shape from the third (vertical) wire section. A good ground system will not only enhance the lobe selectivity feature, but will also significantly diminish ground losses surrounding the radiating system, especially on the lower frequency bands.

On-the-air tests were conducted on the 80, 40, and 15-meter bands over a period of three months. Based on these tests, it may be stated that the JR Vari-Lobe radiation characteristics on the 80 and 40-meter bands successfully proved to correspond to Reinartz's theory. The variable angle selectivity feature has enabled maximum signal strength adjustment over different path distances both during night and daytime conditions. While operation on the 15-meter band does not include variable angle control, it has proven to be an effective radiating system of modest size and relative simplicity. Although tests were not performed on the 10 and 20-meter bands, Reinartz has shown the antenna system will operate as a conventional Zepp on all bands and if desired, with variable angle control as well. Conventional Zepp configurations do not require the parallel tuning network to ground for the third (vertical) wire. Thus, the simple expedient of tying together feeders B and C of **fig. 5** changes the antenna into a Zepp configuration. The Zepp mode may be used on all bands higher than 80 meters, providing a flexible multiband antenna system if you don't mind the coupling adjustments and tuning of two feeder wires. The system is a natural for the Amateur who has limited antenna space but would like something different and more versatile than other systems.

resonance tuning features

The original Reinartz antenna system used an RF ammeter in series with the ground connection to determine resonance of the antenna when excursions were made in lobe angle and frequency. A diode detector probe positioned near the top of the parallel tuning network will work as well and could be remoted quite easily if desired. However, it is also posssible to tune the system "by ear." When the parallel tuned circuit is tuned to the correct resonant point, a noticeable increase in received signal strength or background noise is apparent, thereby dispensing with the requirement for remote meter reading.

The multiband tuner operates satisfactorily over all of the harmonically related Amateur Radio bands to maintain resonance of the system. Obviously, if only limited operation is contemplated on 80 or 40 meters, then the multiband tuning function may be eliminated and a single-band network would serve as well. In my installation, using remote controlled tuning proved to make the operation of the Vari-Lobe a joy to use. Small 24-VAC furnace valve control motors were coupled to the shafts of both tuning capacitors to provide remote tuning control from the shack. These small, economical motors rotate slow enough to allow sufficient tuning resolution and accuracy even though they are turning only in one direction. An alternative to these AC-type control motors are surplus stepping motors featuring bi-directional incremental DC pulse control with 3.65 degree/step resolution. These devices are available from a number of sources for a nominal price. Some even include additional gearing for slower response.

references

1. J.L. Reinartz, "A New Antenna System For Operating Control of Radiation," *QST*, February, 1935, page 9.
2. R.R. Schellenbach, W1JF, "The JF Array," *QST*, November, 1982, page 26.

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The 30- and 40-meter bands were selected because of the increased activity on those bands — especially for DX — resulting from the diminishing MUF caused by declining solar activity. The selectable directivity and low radiation angle of this system should offer significant performance advantages as interference and competition on these bands increase. While the gain of this phased array is modest, the system will effectively double the RF radiated power of a single vertical in the preferred direction. The array also provides deep nulls spaced 90 degrees apart on each side of the main beam pattern, thus improving rejection of unwanted signals.

theory of operation

The 2 x 2 phased array is a pair of two parallel-element end-fire vertically polarized matched arrays, each of which is similar to W8JK's single section beam, with elements fed 180 degrees out of phase and spaced 1/8 wavelength apart. A composite simplified view of the array is shown in **fig. 1**. By folding the top and bottom 1/16-wavelength end sections of each element, a useful height reduction results without significantly effecting similar normal full-size array characteristics caused by element folding. Because each connecting wire at the base and the elevated end sections are only 1/16 wavelength long and carry very little current, little radiation and pattern distortion result from these folded sections

construction and implementation

Figure 2 depicts the 2 x 2 phased array configuration; **table 1** provides the element lengths and spacing as well as mast height requirements. **Figure 3** illustrates the matching 1/4-wavelength stub and

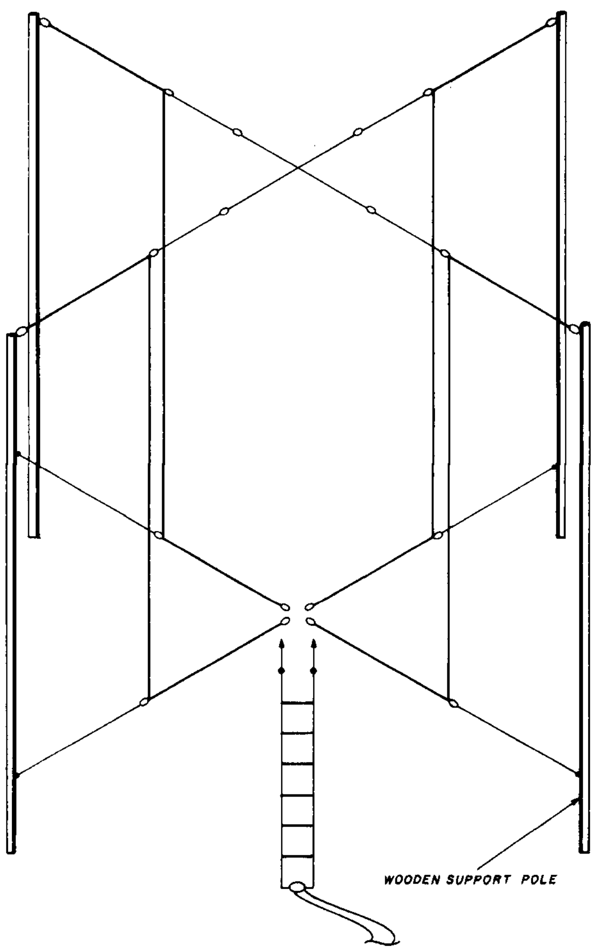

fig. 1. Composite — simplified view of 2 × 2 phased array.

By R.R. Schellenbach, W1JF, 12 Whitehall Lane, Reading, Massachusetts 01867

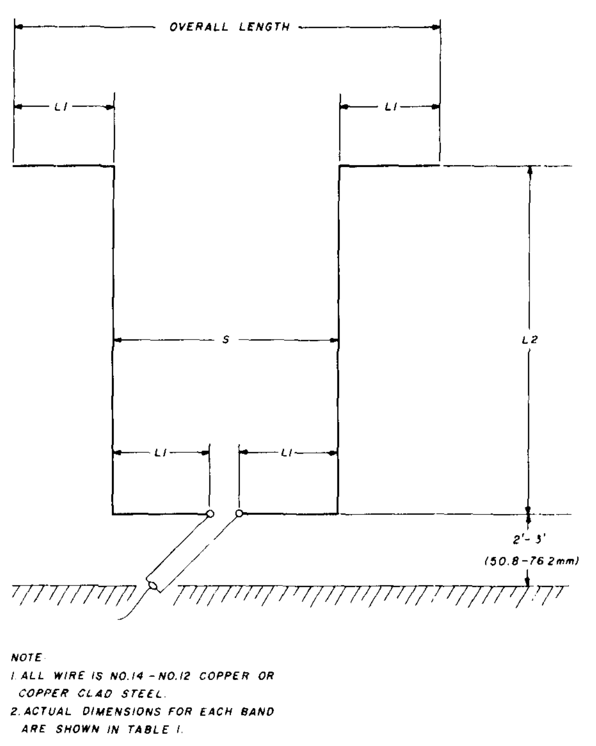

fig. 2. 2 × 2 phased array configuration; single element shown.

remote relay switching scheme including a balun for mating with coaxial cable. The length and physical positioning of the coaxial cable into the station are not critical.

Because the 2 x 2 phased array consists of two identical two-element arrays crossing at right angles to each other, a simple DPDT relay controls the selection of the array to be connected to the common 1/4-wavelength stub and hence through the balun transformer and coaxial cable into the station.

Once the 1:1 balun transformer tap position has been adjusted for a low VSWR at the desired operating frequency, no tuning or matching are required between the station and the system. The actual tap position depends on the stub line impedance and interwiring characteristics of the relay switching.

In order to reduce difficulties in array matching as much as possible, each element on an array — as well as the overall symmetry of the arrays — should be made as identical as possible to preserve balance and uniformity when changing directivity. Because a common 1/4-wavelength stub is used for matching into the antenna system, it is important that all wire connections to the DPDT relay be made equal in length. In placing the tap point for the balun transformer, you will find that with 75-ohm coaxial cable, the tap location will be a few inches higher toward the relay end than that of 50-ohm coaxial cable. More detail on proper matching is provided later, but the process is simple and provides wide bandwidth on either band of operation.

table 1. Physical dimensions for the 2 × 2 phased array on 40 or 30 meters.

	40-meter operation	30-meter operation
L1	8.75 feet	5.80 feet
L2	43.00 feet	29.00 feet
L3 (stub)	34.00 feet*	23.25 feet*
S	17.50 feet	11.60 feet
overall length	35.00 feet	23.25 feet
pole height (min.)	45.00 feet	31.00 feet

*May be laid horizontal as required.

site and space requirements

Four poles, preferably wooden, are required to sup-

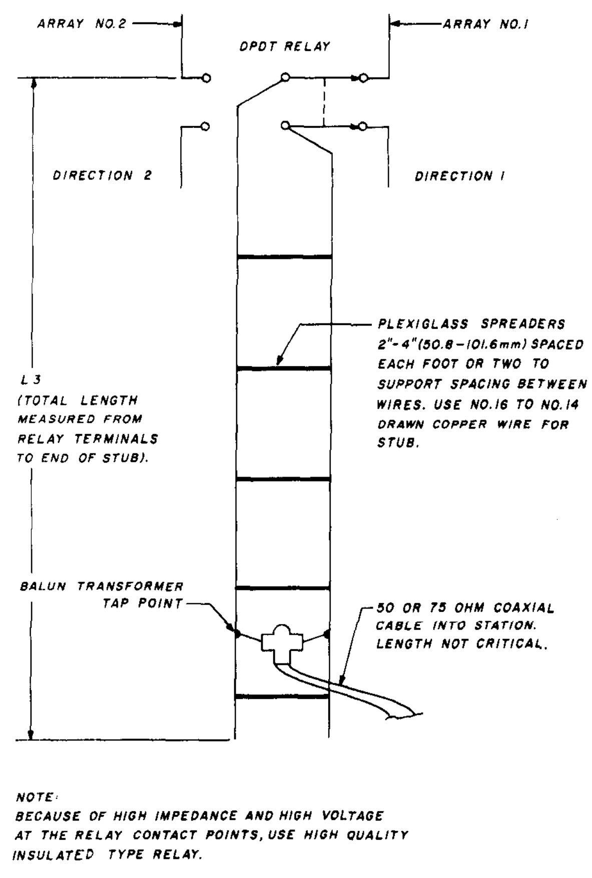

fig. 3. Matching quarter-wave stub, relay and balun transformer installation.

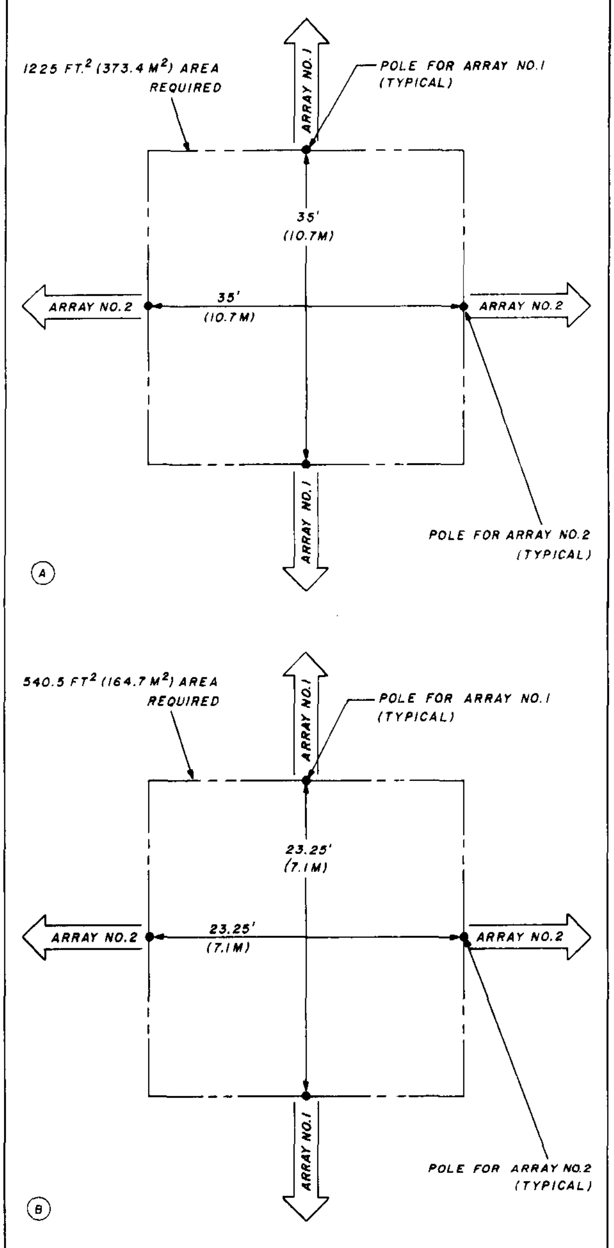

fig. 4. Site and space requirements of 2 × 2 array: (A) 40-meter version and (B) 30-meter version.

port the array. While they are oriented as shown in **fig. 4**, the distance between them can be increased to meet individual requirements. **Figure 4** also indicates the principal beam directions with respect to the DPDT relay position that is controlled from the station end. Using this directivity characteristic of the array, the individual beam patterns may be oriented in the most favorable compass directions.

To assure maximum low angle radiation and deep null beam pointing performance — and to eliminate effects of pattern distortion and RF absorption — the array should be located in an area free of structures or power lines for at least 250 feet from its center on 40 meters and 190 feet on 30 meters.

technical performance

The 2 x 2 phased array provides approximately 4 dB gain over conventional 1/2-wavelength dipoles and 6 dB gain over 1/4-wavelength ground mounted single verticals. The azimuthal bi-directional beam pattern, although relatively broad, (approximately 80-degree half-power beamwidth) has quite deep nulls, better than 20 dB down from the main lobe maximum. The nulls are also bi-directional in either case and are located at right angles (90 degrees) to the two major beam lobes produced by each active array.

In operation, these nulls may be used to advantage to eliminate strong interference coming from an undesired direction. The major radiating point on each active element occurs at a point 42 percent up from the bottom end of each vertical. The distance between the bottom horizontal 1/16-wavelength interconnecting wires and earth ground should be no more than 2 to 3 feet for proper performance.

remote switching and balun tap alignment

The simple arrangement of a common 1/4-wavelength stub switching to activate either array provides controlled directivity for both transmitting and receiving. The length of the 1/4-wavelength stub for either band is given in **table 1** as a starting point for the balun tap position.

The tap should be made progressively upward from this overall dimension. Each time the tap location is changed a few inches at a time, the operator should observe an in-line measurement of SWR. The proper tap point will result in the lowest VSWR reading when matching into appropriate coaxial cable using a 1:1 ratio type balun transformer. The use of a balun in this array application is highly recommended to maintain a complete balance of the array system and to minimize beam pattern distortions as well as deterioration of noise pick-up immunity so characteristic of poorly matched or unbalanced feed systems.

The coaxial cable, whose length is not critical, may be buried and its outer shield grounded for further immunity from noise pick-up in severe cases.

Because of weather considerations for rain or snow, the DPDT relay should be mounted inside a waterproof enclosure. This may be combined with supporting the four bottom horizontal 1/16 wavelength wires if the enclosure is elevated by a post at the recommended 2 to 3 feet above the ground level.

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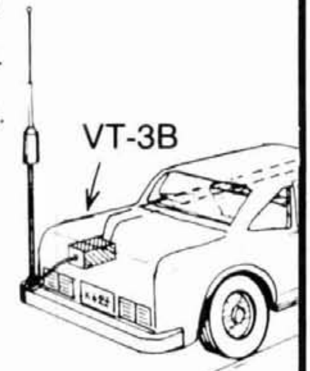

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feeding phased arrays:
an alternative method

Carefully chosen feeder lengths provide good match

This article describes a method of feeding a two-element phased-array antenna without using impedance-matching or phase-delay networks at each element. The method requires determining the length of the feedline from each antenna to the "common point" (the point at which the feedlines are combined) and installing a matchbox or antenna tuner at this location (or in the shack) in order to transform the paralleled impedance to 50 ohms.

network method of matching

As was clearly pointed out by Forrest Gehrke, K2BT, in his extensive series of articles on phased arrays, the insertion of a 90-degree delay line into a feeder will, in most cases, *not* guarantee a 90-degree phase shift in the feeder current.[1] If the actual driving-point impedance of each element is known (for a specified current amplitude and phase), then the voltage amplitude and phase at any point on that feeder can be calculated. The technique given by K2BT allows one to choose any convenient length for the antenna feeders and then design suitable networks to alter the feeder voltages so that they are all transformed to the same value of voltage amplitude and phase. These terminals can then be safely and correctly joined together (at the "common point") since they are all at the same voltage. The impedance-matching and phase-delay networks are used to force all the voltages to be the same. Any convenient length of 50-ohm transmission line (the main feeder) can then be utilized to span the distance from the common point to the shack. The main feedline will be "flat" (the SWR will be low) because the networks at the ends of the antenna feeders are designed to present a combined impedance of $50+j0$ ohms (pure resistance) when "looking" into the common point toward the antennas (see **fig. 1A**).

The method shown in this article calculates the voltages that must exist at various points along the antenna feeders. When a point is found on one antenna feeder where the voltage (both amplitude and phase) is identical to the voltage at some point on another antenna feeder, then those two points can be connected together without altering the relationship of the currents at the driving points of the two antennas. Rarely will the impedance seen looking toward the antennas from this common point be 50 ohms.* Thus, the main feedline running from this point into the shack will not be flat (the SWR will be high) and a matchbox or tuner will be needed at the operating position to present a well-matched load to the transmitter, (see **fig. 1B**). Note: the matchbox could be

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placed into this circuit at the common point if desired. Then the main feeder into the shack would be "flat" as in **fig. 1A**. Of course, the matchbox would then be "dedicated" to the array and could not be used for other purposes unless removed.

calculations are simple

Only one formula, used repeatedly, is needed to calculate the voltages at all points along the antenna feedlines. It's best to utilize a personal computer or programmable calculator to reduce the drudgery of this task.

$$\bar{E}_{IN} = \bar{I}_{OUT}\,(A\bar{Z}_L + B) \tag{1}$$

where $\bar{E}_{IN}$ = voltage at the input end of the antenna feeder

$\bar{I}_{OUT}$ = current at the output or load end of the antenna feeder
= current at the driving-point of the antenna

$\bar{Z}_L$ = impedance at the output or load end of the feeder
= driving-point impedance of the antenna

A = cos θ

B = $jZ_0 \sin \theta$

Z_0 = characteristic impedance of the antenna feeder

θ = electrical length of the antenna feeder, in degrees (*360 degrees* = λ)

Note that $\bar{E}_{IN}$, $\bar{I}_{OUT}$, and $\bar{Z}_L$ are all complex numbers; that is, they have both magnitude and phase. The equation therefore requires the use of complex, or vector, arithmetic. *A* and *B* are two of the "ABCD" parameters discussed by K2BT in Part 5 of his series.[2] (In addition, both "*A*" and "*B*" can be complex numbers as well. "*A*" is complex if the cable attenuation is taken into account.)

The goal is to find a place on the antenna No. 1 feeder where the voltage is identical to the voltage somewhere on the antenna No. 2 feeder. To do this, make a list for each antenna, labeling one column for "feeder length in degrees" and the other "voltage at end of feeder." Then calculate and record the voltage on each feeder at 10 degree intervals. After finding 10 or 15 values for each feeder, stop calculating and compare the lists. It is better to record the voltages in polar form (amplitude and phase angle) for easier comparison. Also, keep all the angles less than or equal to ±180 degrees. (For example, an angle of −230 degrees is equivalent to +130 degrees. Always use the smaller number.) When two amplitude values are found that are close to each other, check the angles to see if they are similar. If both amplitude and phase are "in the ballpark," redo the calculation at 1 degree or 1/2 degree increments until two lengths are found where the voltages are identical, or nearly so. If none of the recorded values on one list are comparable to those on the other list, continue the calculations and add more data points to the lists — in other words, make the antenna feeders longer. It should be possible to find the required line lengths within a reasonable amount of time.

*A 1:1 VSWR occurs only when the paralleled driving-point impedance of the elements equals the characteristic impedance of the line. **Editor.**

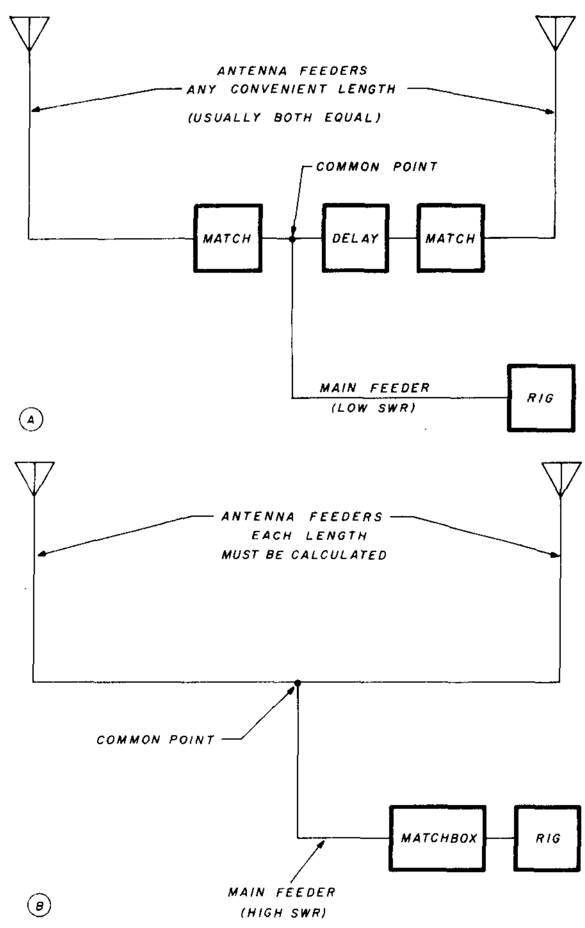

fig. 1. Diagram shows similarities and differences between KB8I's method and that of K2BT. (A) The effect of different feeder lengths are compensated for by the use of individual matching circuits. (B) By moving the matchbox to the common point arbitrary feeder lengths can no longer be used (see text).

cutting the coax

After the required length of each antenna feeder has

✓ 134

been calculated, it's time to actually cut the coax, remembering to take the velocity factor of that particular cable into account. It's a good idea to actually measure the velocity factor of the cable, rather than relying upon the manufacturer's data. Since the electromagnetic fields travel more slowly inside the cable than they do in free space, the physical length of the cable will be shorter than the electrical length:

$$L = 2.734\ (L_e)\ (V_F)/f \qquad \textbf{(2)}$$

where L = physical length of antenna feeder, in feet (1 meter = 3.281 feet)

L_e = electrical length of antenna feeder, in degrees

V_F = velocity factor of the cable, as a decimal (i.e., 0.66)

f = operating frequency, in Megahertz

switching directions

For a two-element array, the pattern may be reversed by interchanging the antenna feeder cables at the antenna terminals. One way to do this, shown in **fig. 2**, is to cut the longer of the two antenna feeders into two pieces, one of which is the same length as the shorter antenna feeder. These two equal-length cables are then connected directly to the antenna feedpoints and the remaining third piece of cable is switched back and forth from one antenna feeder to the other using a DPDT relay. For best results when building a switchable array, the lengths of the radiators and the ground systems under each antenna should be adjusted until both antennas have the same self-impedance.[3]

20-meter array

I became interested in phased arrays while accumulating the contacts necessary for WAS on 20 meters. A home-brew three-element wire beam suspended from trees at 18 feet (5.5 meters) seemed to be performing satisfactorily, and I was working new states at a good pace. However, a phone call revealed that I was also "quite strong" on my neighbor's (just to the west) color TV set. I wasn't too surprised because his portable TV — equipped only with rabbit ears for an antenna — was less than 50 feet (15.2 meters) from my wire beam, and I was running the legal limit. It became vitally important that I construct an antenna that would concentrate all the RF energy toward the east and place a big null right over my neighbor's living room — *he is, after all, not only my neighbor, but my landlord.*

My backyard was too small for a two-element array with 1/4 wavelength spacing, but the literature revealed that 75 degree spacing (0.208 wavelength) combined with 105-degree phasing would yield the desired cardioid end-fire pattern. Measurements showed that I could squeeze this array into the yard without the radials protruding onto the property of my neighbor to the east. Two tri-band trap verticals were

table 1. Voltages at various points along the antenna feeders.

west antenna (I = 1 /0 degrees)

θ (degrees)	E_{IN} (volts)
0	15.56 /−45 degrees
10	11.04 /−11.23 degrees
20	12.35 /33.2 degrees
30	18.17 /58.4 degrees
40	25.17 /70.4 degrees
50	32.02 /77.2 degrees
60	38.2 /81.7 degrees
70	43.4 /85 degrees
80	47.37 /87.7 degrees
90	50 /90 degrees
100	51.19 /92.1 degrees
110	50.89 /94.2 degrees
120	49.11 /96.4 degrees
130	45.92 /98.96 degrees
140	41.43 /101.7 degrees
150	35.82 /105.4 degrees
160	29.32 /110.6 degrees
170	22.32 /119 degrees
180	15.56 /135 degrees

east antenna (I = 1 /−105 degrees)

θ (degrees)	E_{IN} (volts)
0	49.68 /−64.9 degrees
10	54.92 /−57.95 degrees
20	59.16 /−52.13 degrees
30	62.14 /−46.98 degrees
40	63.69 /−42.2 degrees
50	63.74 /−37.53 degrees
60	62.27 /−32.77 degrees
70	59.37 /−27.65 degrees
80	55.19 /−21.87 degrees
90	50 /−15 degrees
100	44.18 /−6.41 degrees
110	38.31 /4.83 degrees
120	33.26 /19.84 degrees
130	30.18 /39.02 degrees
140	30.09 /60.32 degrees
150	33.02 /79.71 degrees
160	37.99 /94.96 degrees
170	43.84 /106.39 degrees
180	49.68 /115.10 degrees

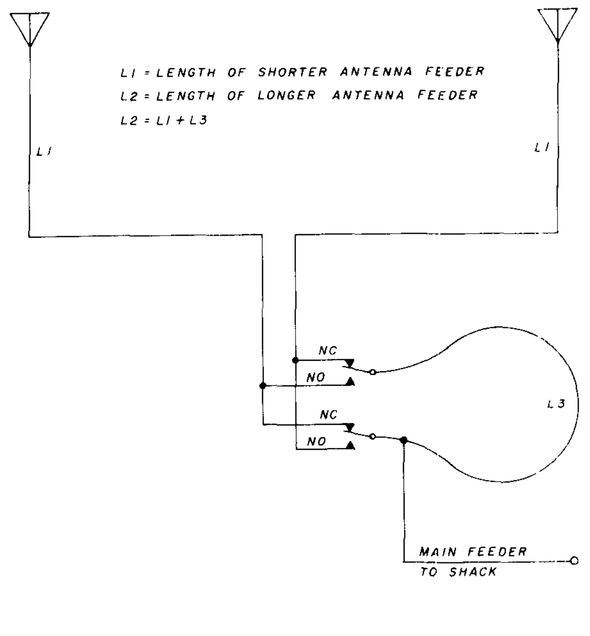

fig. 2. Wiring diagram for DPDT relay used to reverse directivity of array. Directivity is toward the right when connected as shown.

erected, each atop a 15-foot (4.6 meter) mast. They were spaced 75 degrees apart (14.4 feet or 4.4 meters at 14.25 MHz) on an east-west line, and each had twenty 1/4 wavelength radials. The feed system would be designed so that each antenna received the same current amplitude, but the east antenna would lag the west antenna by 105 degrees, placing the null directly on my landlord's living room.

After everything was built, I used an antenna noise bridge and calculator to analyze the system according to the procedure described by K2BT.[3] I measured the self-impedance and driving-point impedance of each vertical at the end of a known length of coax, and then "rotated" each of these values to the antenna feedpoint. This may be done on a Smith chart or through the use of the following formula:

$$Z_L = \frac{D\overline{Z}_{IN} - B}{A - C\overline{Z}_{IN}} \tag{3}$$

where

Z_L = load impedance at the output end of the transmission line

Z_{IN} = impedance measured at the input end of the transmission line

A = D = cos θ

B = $jZ_0 \sin\theta$

C = $j \sin\theta / Z_0$

Z_0 = characteristic impedance of the transmission line

θ = electrical length of the line, in degrees

While it's better to measure all the impedances right at the antenna feedpoint, I didn't enjoy the prospect of standing on tiptoe perched 10 feet (3 meters) above the ground. I opted for the easier way, and the data obtained enabled me to calculate the mutual impedance between the two verticals. I used this figure to determine the actual driving-point impedance of each element when fed by the currents I had specified for the array. The product of the driving-point impedance and current gives the actual voltage at the feedpoint of each antenna:

west antenna:

$$I_1 = 1\underline{/0 \text{ degrees}} \text{ amperes}$$

$$Z_1 = 11\text{-}j11 \text{ ohms}$$

$$= 15.56 \underline{/-45 \text{ degrees}} \text{ ohms}$$

$$E = I_1 Z_1 = 15.56 \underline{/-45 \text{ degrees}} \text{ volts}$$

east antenna:

$$I_2 = 1\underline{/-105 \text{ degrees}} \text{ amperes}$$

$$Z_2 = 38 + j32 \text{ ohms}$$

$$= 49.7 \underline{/40.1 \text{ degrees}} \text{ ohms}$$

$$E_2 = I_2 Z_2 = 49.7 \underline{/-64.9 \text{ degrees}} \text{ volts}$$

The antenna currents were assumed to have a magnitude of 1 ampere for ease of calculation. The actual current magnitudes will be determined by the amount of drive power. What *is* important is that the actual currents be equal in magnitude, and that the east antenna current lags the west antenna current by 105 degrees.

My lists of the voltages that will occur at various points along each antenna feedline are shown in **table 1**. Scanning the table, we can see that the voltage on the west antenna feeder at a point 50 degrees from the antenna is $32.02\underline{/77.2 \text{ degrees}}$ volts, while the voltage on the east antenna feeder at a point 150 degrees from the antenna is $33.02\underline{/79.71 \text{ degrees}}$ volts. These two values are close to each other, and we can now calculate more voltages, this time at 1 degree intervals centered around 50 degrees for the west feeder and 150 degrees for the east feeder. This information is shown in **table 2**. Comparing the voltages on the two feeders, we can see that the values are nearly identical for a 51-degree west feeder ($32.67\underline{/77.77 \text{ degrees}}$ volts) and a 149-degree east feeder ($32.61\underline{/77.95 \text{ degrees}}$ volts).

table 2. Voltages at 1 degree intervals along the antenna feeders.

west antenna (I = 1 /0 degrees)

θ (degrees)	E_{IN} (volts)
47	30.02 /75.53 degrees
48	30.69 /76.12 degrees
49	31.36 /76.7 degrees
50	32.02 /77.2 degrees
51	32.67 /77.77 degrees
52	33.32 /78.27 degrees

east antenna (I = 1 / −105 degrees)

θ (degrees)	E_{IN} (volts)
147	31.87 /74.29 degrees
148	32.23 /76.14 degrees
149	32.61 /77.95 degrees
150	33.02 /79.7 degrees
151	33.45 /81.43 degrees
152	33.89 /83.11 degrees

table 3. Theoretical front-to-back ratio of the 2-element phased vertical array.

elevation angle, θ (degrees)	front-to-back ratio (dB)
0	∞
10	39.72
20	27.68
30	20.61
40	15.56
50	11.59
60	8.26
70	5.31
80	2.60

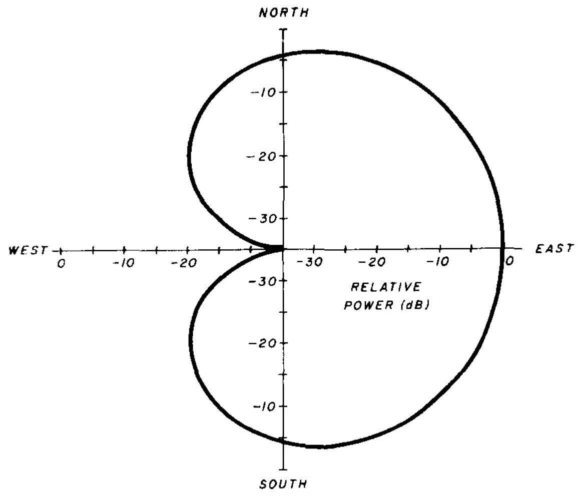

fig. 3. Azimuthal-plane power pattern for two 1/4 wavelength monopoles; spacing = 75 degrees, currents = 1 /0 degree, 1 / −105 degrees, perfect ground; 0 degree elevation angle.

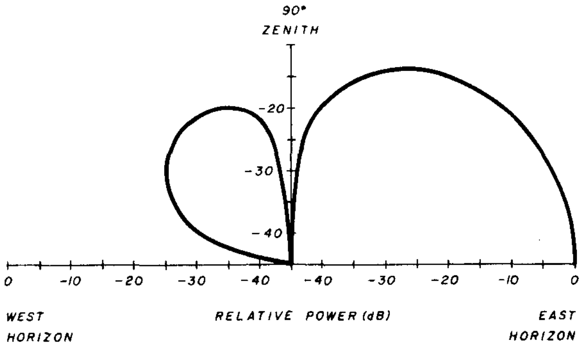

fig. 4. Elevation-plane power pattern for two 1/4 wavelength monopoles; spacing = 75 degrees, currents = 1 /0 degree, 1 / −105 degrees; perfect ground; east-west azimuth.

Notice that the driving-point currents are 105 degrees out of phase, yet the points on the feeders where the voltages are in phase are only (149 degrees − 51 degrees =) 98 degrees apart. Also notice that the east feeder, which has the lagging feed-point current, is longer than the west feeder, which one would expect.

Measurements on the RG8X cable used for the antenna feeders showed that its actual velocity factor was 0.725 rather than the advertised value of 0.81. Using **eq. 2**, the actual lengths of coax needed were 7.094 feet (2.162 meters) and 20.726 feet (6.317 meters). These two antenna feeders were cut to length and installed. A piece of RG-8 about 30 feet (9.1 meters) long extended from the Tee connector, where the antenna feeders were joined, to the matchbox in the shack.

The array performed as expected. State number 50 (Delaware) was worked shortly thereafter, along with contacts in Africa. There were almost no contacts to the west — but there also were no further TVI problems. The major azimuthal and elevation-plane radiation patterns are shown in **figs. 3** and **4**; the front-to-back ratio in the main elevation plane is provided in **table 3**. Notice that the front-to-back ratio is infinite only on the horizon (0 degree elevation angle) and deteriorates to just one or two S-units at high angles. There is actually a fairly large rear lobe whose maximum occurs at an elevation angle of about 60 degrees. Thus, there will be a fair amount of radiation and signal pickup off the back of the array if propagation favors this high angle.

conclusion

A technique has been demonstrated for feeding two-element phased arrays based upon the premise that the feeders from individual radiating elements may be directly connected together if the voltages at the point of connection are identical in magnitude and phase. A method was shown for determining the voltage at any point on an antenna feeder when the impedance and current at the driving-point of the antenna are given. Using these ideas, an actual 2-element array can be built and operated successfully on the air.

acknowledgements

The author would like to thank Forrest Gehrke, K2BT, for his encouragement, especially during the early stages of this project in 1983. Appreciation is also expressed to Margaret Shields in the Department of Electrical and Computer Engineering at Ohio University for typing the manuscript.

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ham radio

ham radio TECHNIQUES

Bill Orr W6SAI

the first Radio Amateur

The world in 1900 was a far different place than the world we know. No one had heard of credit cards or ball point pens; time sharing meant togetherness, not computers. There were no fluorescent lights, instant coffee, antibiotics, Frisbees or frozen foods. There was no television, no radio — and no Amateur Radio.

Into this late Victorian era there stepped a Giant. In 1896 a young Italian arrived in England with some mysterious scientific apparatus in his luggage. The Customs officials, who had seen nothing like it before, examined it so thoroughly that the delicate apparatus was completely wrecked. This was the inauspicious beginning of a venture destined to remold the pattern of 20th-century living.

Guglielmo Marconi, at 26, had come to England to seek aid in developing his latest invention, a means of signalling at a distance without wires. The hub of a great Empire, Britain possessed the world's greatest mercantile fleet and the mightiest Navy — and it was in shipping that Marconi could see his dream come true. For once a ship left the sight of land it was isolated from the world. When disaster struck — as it often did — some form of communication between ship and shore was sorely needed.

Marconi demonstrated his equipment to the War Office and the British Post Office. The War Office was interested, but the idea of an alternative means of communication seemed to be unpleasant to the Post Office; it was unenthusiastic.

By 1898 Marconi had successfully demonstrated overland and ship-to-shore communication and had formed the Wireless Telegraph and Signal Company Limited. From time to time, communication across distances of up to 100 miles could be established. Yet therein lay an enigma. Hertz's early experiments showed that the invisible "wireless" waves obeyed the laws of light and travelled in straight lines. How, then, could Marconi communicate beyond the visible horizon? The scientific community regarded Marconi's experiments with caution.

The Post Office monopoly on long distance telegraph communication and other restrictions made it impossible for Marconi to set up a revenue-earning inland wireless telegraph service. His company was rapidly going bankrupt. What to do?

the transatlantic gamble

Marconi had two ambitions: one, to prove his system offered dependable long-range capability and two, to compete directly with the Post Office, breaking its monopoly, and maintaining a profitable wireless telegraph service. He conceived a bold stunt to draw attention to his plan: he would send a wireless signal across the Atlantic! Marconi proposed a station of breathtaking power, size, cost, and complexity. It was like proposing to build a cathedral in a world which had seen nothing more grandiose than a log hut. The directors of his company objected to taking such a risk. His grand idea was met with scorn and disdain.

But Marconi convinced his colleagues to go along with his plan. The station, to be built in Poldhu, Wales, was staggering in concept; a 25 kilowatt power plant would drive a two-stage spark transmitter (**fig. 1**) connected to a 400-wire antenna supported by 20 masts, each 200 feet high.

By early 1901 the station began to take shape. Preliminary tests indicated a range of at least 225 miles. Despite a myriad of troubles, the station could be heard as far away as Ireland. It had already proven that wireless waves followed the curvature of the globe; Marconi was certain that his signal could be extended to North America.

In March, 1901, Marconi sailed for America and chose the site for a second station: South Wellfleet, a small town on the eastern shore of Cape Cod, Massachusetts. Leaving his chief engineer there, Marconi returned to England.

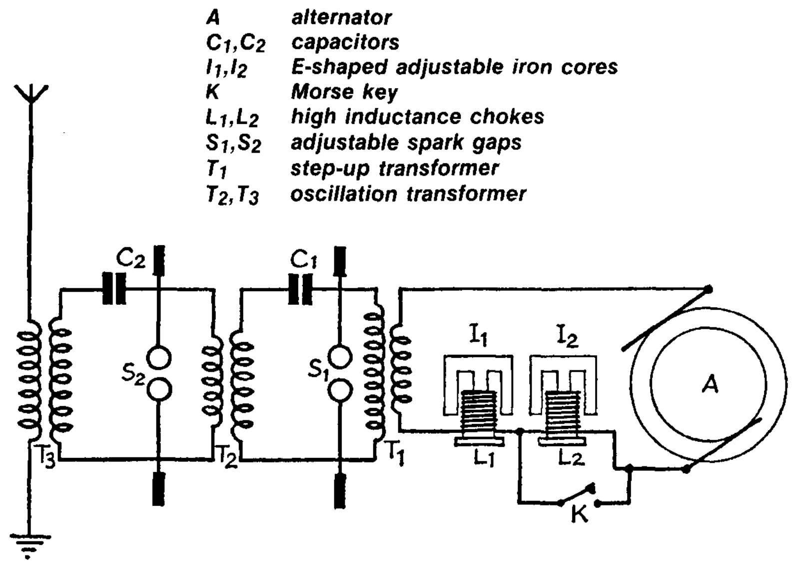

fig. 1. Marconi spark transmitter at Poldhu.

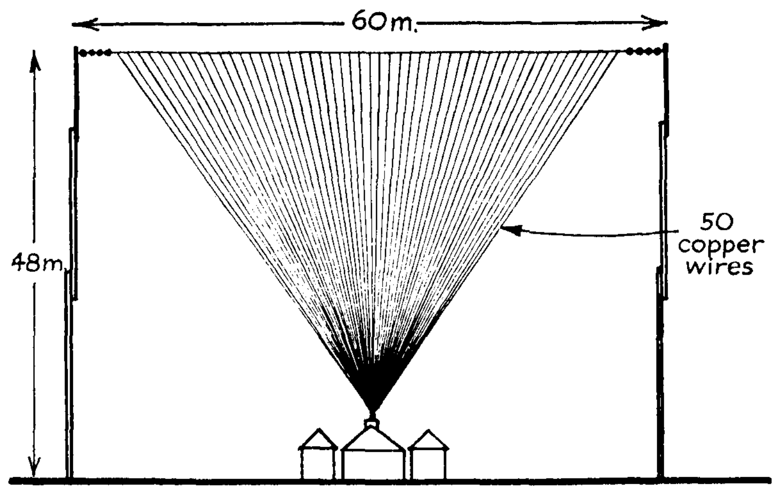

fig. 2. The temporary antenna used at Poldhu for the transatlantic tests.

Catastrophe struck in September when a vicious gale hit the coast of Wales, breaking one of the many guy wires. All 20 masts collapsed into a shambles of broken timber and tangled wire. Just a month later a second storm destroyed the antenna system at South Wellfleet.

The directors of the Marconi Company were appalled. Over a quarter million dollars had been spent with nothing to show for it but chaos. Marconi would not give up; he cleared away the wreckage, erected a temporary antenna (**fig. 2**) and had the station back on the air in 11 days.

Because of the diminished capacity of the makeshift station, Marconi decided to abandon the Wellfleet site and set up temporary receiving equipment in Newfoundland, the point of landfall nearest to Wales. In great secrecy he set sail for St. John, with a small stock of kites and balloons to keep a single wire aloft in the stormy weather.

A site was chosen on Signal Hill, and on December 9 the apparatus was assembled in an abandoned military hospital. The balloon was prepared for inflation and ground plates were buried. A cable was sent to Poldhu requesting that the Morse letter "S" be transmitted continuously from 3 to 7 PM. Marconi chose his message wisely. He knew the fragile state of his equipment, and that the transmission of dashes, rather than dots, would have imposed too great a strain on the keyer and the transformers.

On December 10th the weather was fair. A balloon-supported kite antenna was sent aloft. The transmissions started at a power level of about 10 kilowatts and on a wavelength of about 366 meters (820 kHz). Since there was no means of measuring frequency, the actual wavelength remained a matter of speculation.

As the wind picked up, the balloon bobbed and weaved about in the sky above Signal Hill. Marconi adjusted his new "syntonic receiver" — a glass tube within which a globule of mercury was held between two iron or carbon rods, forming a crude semiconductor. Nothing which could be identified as the letter "S" could be heard amid the static. The wind picked up and the antenna crashed to earth as the balloon was swept away.

December 12, 1901

On the 12th the wind increased in intensity. A kite was launched bearing a 510-foot wire. The wind carried it away. A second kite was launched with a 500-foot wire attached. Because he had observed that the buffeting of the antenna by the wind made it impossible to keep the newer receiver in tune, Marconi sat listening intently at an older, untuned receiver (**fig. 3**). Time slipped by. Suddenly, at 12:30 PM, Newfoundland time, he handed the earphone to George Kemp, his

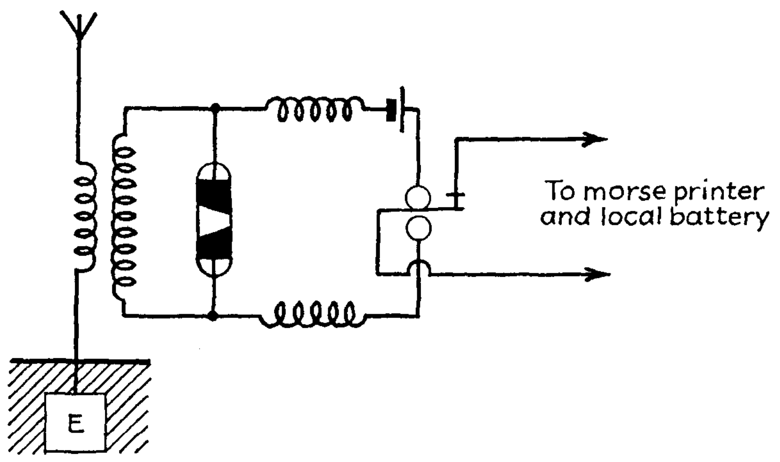

fig. 3. Marconi's untuned receiver.

assistant, and quietly asked, "Can you hear anything, Mr. Kemp?"

George Kemp took the headphone. Through the static crashes he could hear, faintly, the unmistakable rhythm of three clicks, followed by a pause, then three more and a pause, and so on, until — all too soon — the signals were lost once more in static. Marconi, a cool-headed man if there ever was one, wrote in his laboratory notebook: *Sigs at 12.20, 1.10 and 2.20.*

Marconi a fraud?

Marconi was in a quandry. What conclusive proof did he have? He and Kemp were not exactly unbiased. Should he make a public statement?

Finally on December 14th Marconi cabled his company the news. It was made public on December 16th, 1901.

The first reaction came from the lawyers of the Anglo-American Telegraph Company, whose cable line had carried the message to England two days previously. It was sharp and to the point. Marconi was told that the company had a monopoly on communication in Newfoundland and it forbade any future infringement of their rights under pain of legal action.

The public interest, however, was aroused and both the Canadian and American governments expressed interest in the experiment. The technical journals treated the incident with a combination of skepticism and indignation. Marconi had no proof to substantiate his claim, which challenged the fundamental laws of physics and the proven knowledge of Newton, Maxwell, Hertz, and others. It was not until later, when the reception of signals across the Atlantic was demonstrated beyond any shadow of doubt, that Marconi's achievement was recognized.

Even today, it is difficult to believe that the 366-meter signals could actually have been heard. The receiving equipment after all, consisted of an inefficient antenna coupled to an untuned receiver which had no means of amplification whatsoever and was even less sensitive than crystal detectors, which evolved a few years later. If, in fact, the wavelength was 366 meters, the tests took place at the worst possible time of day because the entire path would have been in daylight. Today we know that radio signals can travel across the Atlantic and far beyond. But in 1901, anyone who believed that they could, and did, believed so as an act of faith based upon the integrity of one man — Marconi.

Marconi at the World's Fair

It was 1932. Marconi, an internationally acclaimed scientist, inventor, and businessman was in the United States. He was scheduled to make an official visit to the Chicago World's Fair, a breathtaking exhibition of the modern world of technology. Fair officials were in a dither as Marconi arrived in the company of other important dignitaries. The Great Man toured the Fair, expressing great interest in the scientific exhibits. News photographers crowded around Marconi and he was followed by a large gathering, all craning their necks to see the Father of radio communication.

As he was about to leave, Marconi expressed a wish to visit the Amateur Radio station at the Fair. So, Marconi's big, black limousine, with colorful American and Italian flags flying from the fenders, drew up in front of a building on the edge of the fairground, followed by a horde of officials and newsmen. Marconi was escorted up the stairs to the World's Fair Amateur station, W9USA.

The young operators of W9USA appeared thunderstruck as the famous visitor strode into the station, introduced himself, and studied the homemade kilowatt trasmitter and the superheterodyne receiver. He examined the station log book. The Fair officials were mystified by the incomprehensible collection of equipment that seemed to fascinate Marconi.

One of the operators apologized to Marconi, saying that the equipment had been built by mere Radio Amateurs. Marconi nodded and smiled, shaking the hand of the operator warmly. "Yes, yes," he said. "I understand — after all, I am a Radio Amateur myself."

radio silence

Marconi died in July, 1937. On the evening of the following day, at the state funeral in Italy, the Italian Radio Service observed an official period of radio silence. In England, and throughout the world, thousands of radio stations — broadcast, commercial, and Amateur — fell silent. The radio silence which Marconi had broken when he switched on his first transmitter came down in sorrow at his passing.

Shortly before he died, Marconi, in an address at St. Andrews University in Edinburgh, Scotland, stressed his original intention to make the high seas safe by giving ships a means of communication. Then, perhaps talking more to himself than to his audience, he added, "Have I done the world good — or have I added a menace?"

in retrospect

Much speculation has taken place during the decades following Marconi's famous transatlantic experiment. Ionospheric studies and a review of the sunspot cycle suggest that propagation across the Atlantic at that time of day, in that month and year, was highly unlikely on 820 kHz.

What, then, might Marconi and his assistant have heard? A few clues exist. Marconi's spark transmitter emitted a rough wave, high in harmonic content. He used a broadband (untuned) receiver. Perhaps Marconi was not hearing the fundamental transmitter signal, but instead a harmonic of the signal, in particular the fourth harmonic on about 3280 kHz. If that is so, then a few hundred watts of harmonic power would have easily made the transatlantic journey.

Of course, with a broadband receiver, Marconi could have heard many harmonics at the same time! So we shall never really be sure what transpired on that stormy day in Newfoundland. It is interesting, however, to think that if Marconi had elected to listen to his tuned receiver, used in the previous day's unsuccessful tests, he might have heard nothing at all!

acknowledgements

Thanks to the Official Historian of the Marconi Company (England) for the background information on Marconi's early experiments. The story of Marconi's visit to the Chicago World's Fair appeared in the November, 1932 issue of *QST*.

*Drawings adapted from *A History of the Marconi Company* by W.J. Baker, Methuen & Co., Ltd., London, 1970. (Distributed by the Marconi Co., Ltd.)

ham radio

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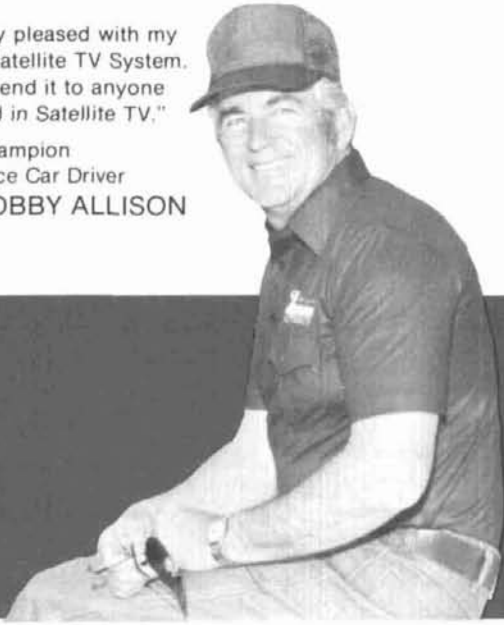
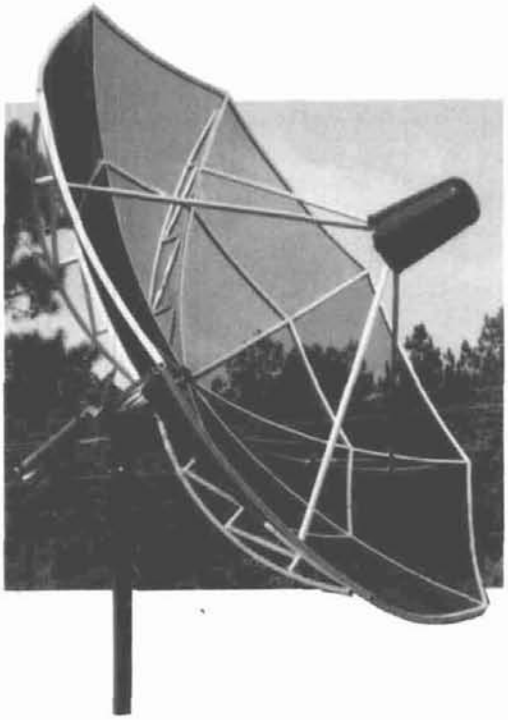


CAYSON
CENTURION ANTENNAS



Look to Cayson Electronics for durable and accurate satellite antennas. We are pioneers in the business and still growing. Here are two 10′ antennas that you can be sure are winners.

The four-piece fiberglass features a highly reflective aluminum foil material for superior reception. The heavy duty polar mount utilizes a 3½ OD ground pole. This antenna has been around since 1979.

The 10′ aluminum mesh antenna is becoming more popular for those who value attractive satellite equipment. The two-tone reflector features black mesh and aluminum ribs. The mount has declination adjustment and also uses a 3½ OD ground pole.

10 FT. MESH DATA

TYPE	EXPANDED MESH
WEIGHT	135 LBS. UPS
DIAMETER	127″
FOCAL DISTANCE	43½″
f/D	.35

10 FT. FIBERGLASS DATA

TYPE	4-PIECE FIBERGLASS
WEIGHT (APPROX.)	200 LBS. SHIPPED
DIAMETER	122″
FOCAL DISTANCE	43″
f/D	.35

CAYSON ELECTRONICS
Rt. 3 Box 160 • Fulton, MS 38843
2235 W. Mound • Decatur, IL 62526
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In MS 1-601-862-2132
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COUNT ON CAYSON FOR DURABILITY AND PERFORMANCE.

a sloping terminated vee beam

Low SWR across ham and SWL bands

This is the antenna that every ham has probably dreamed about: a beam antenna that works on every Amateur band and on all the spaces in between . . . an antenna that's cheap and requires just a single tree or pole for support . . . an antenna that doesn't require precision measurements, special tuning instruments, or almost anything else out of the ordinary. *Everything* needed can be purchased inexpensively or built at home, and the hardest part will be building a toroid transformer with about 25 turns of wire.

This is the same antenna used as a back-up by the Voice of America, so you know it works.

According to transmission line theory, a single conductor placed a few feet above and parallel to the ground can be used as an antenna. If the wire is raised more than a few feet above ground, the impedance approaches a value of 400 ohms according to the following formula:

$$Z_0 = 83.7 \log_{10} (4H/d) \quad \textbf{(1)}$$

where Z_0 = impedance of single wire above ground
H = height of the wire above ground in any units
d = diameter of the wire in the same units

The nonresonant "vee" antenna and a large family of similar antennas such as rhombics are based on transmission line theory. When used as an antenna, however, the transmission line has spacing which is large compared with normal lines. As a result it is leaky and can be used as an antenna. The radiation field from a single wire transmission line may be calculated[1] and the two maximum gain lobes discovered by the equation:

$$E(a) = \frac{60 \sin a \bullet \sin \left[\frac{\pi L}{W} (1-\cos a)\right]}{1 - \cos a} \quad \textbf{(2)}$$

where $E(a)$ = normalized field strength at angle a
a = the angle from the axis of the wire
π = 3.1416
L = length of the wire in any units
W = one full wavelength in the same units

If two terminated transmission lines are aligned so that the major lobes of each wire are additive, the lines then become a "vee" antenna. (Two vees placed end-to-end form a rhombic.) Because the line is terminated in a matching impedance, the wires are nonresonant — just like any correctly matched, well-behaved transmission line — and the antenna will accept power at any frequency.

Several good things happen with terminated transmission line antennas. One desirable result is broadbanding operation; another is that the reverse lobes (toward the pointed side of the vee) are cancelled or greatly reduced. The resulting antenna can be used to both transmit and receive at every frequency within its range, much like a log periodic antenna. But, it will

By Robert Ross, 17904 Muncaster Road, Derwood, Maryland 20855

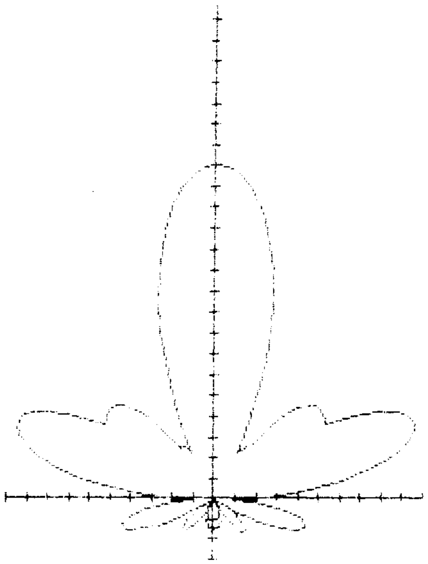

fig. 1. A maximum lobe gain of 5.1 dBi is achieved with a 1-wavelength leg length 68-degree apex angle, non-resonant vee beam.

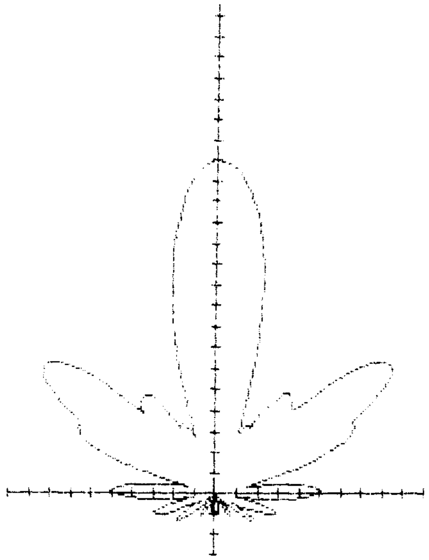

fig. 2. A maximum lobe gain of 5.7 dBi is achieved with a 1.5-wavelength leg length 56-degree apex angle, non-resonant vee beam.

table 1. Relationship between vee beam leg lengths, apex angles, and gains.

vee leg length in half waves	apex angle in degrees	gain in dBi
2	68	5.1
3	56	5.7
4	48	6.1
5	44	6.4
10	32	7.4
20	22	8.4

produce its best gain only over a relatively narrow frequency range where the major lobes align for best gain. This frequency range depends on the angle of the apex of the vee and the length of the legs. For many purposes, +100 percent to −50 percent frequency excursion is reasonable, (see **table 1**). The worst thing that happens is that the beam splits and you find a null in the center with the gain lobes on either side.

In this case the vee has been optimized for the 14 to 15 MHz band — but it also works reasonably well from 40 to 10 and even radiates modestly on 160 and 80 meters. Optimization can be done for any band by calculating the major lobes and adjusting the apex angle for that band. Ordinarily, however, not much is gained by changing the apex angle of such a short vee. **Figures 1** through **6** illustrate the azimuthal pattern of vee beams with leg lengths from 1 to 10 wavelengths.

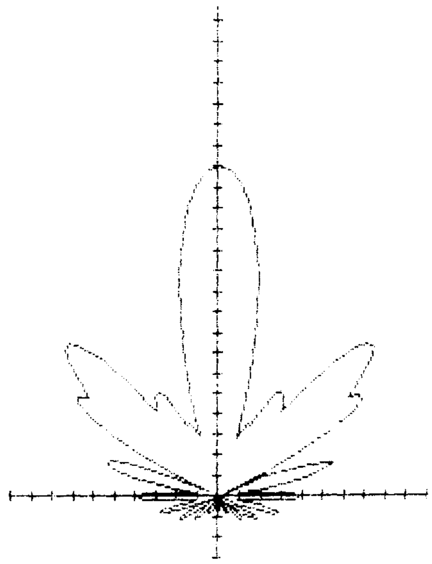

fig. 3. A maximum lobe gain of 6.1 dBi is achieved with a 2-wavelength leg length 48-degree apex angle, non-resonant vee beam.

construction is easy

The vee is probably the simplest of all wide band beam antennas to build. A single support roughly 65 feet (20 meters) tall is required for the high end and two supports about 3 feet (1 meter) tall for the low ends. The only critical item is the pointing of the

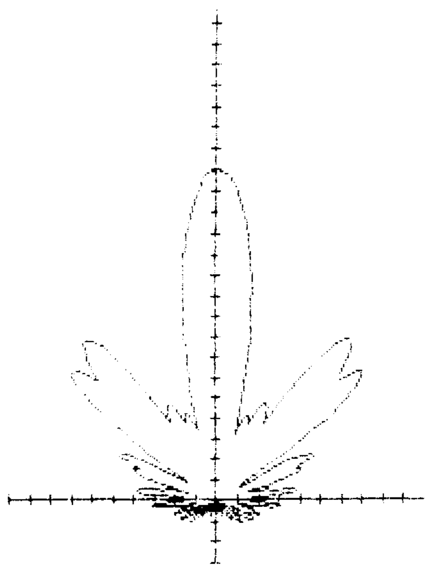

fig. 4. A maximum lobe gain of 6.4 dBi is achieved with a 2.5-wavelength leg length, 44-degree apex angle, nonresonant vee beam.

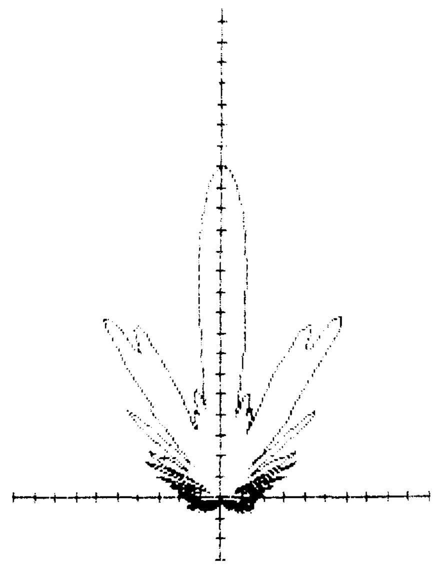

fig. 5. A maximum lobe gain of 7.4 dBi is achieved with a 5-wavelength leg length 32-degree apex angle, nonresonant vee beam.

antenna. The position of the two low point anchor poles must be selected to direct the antenna at your target by using a compass bearing corrected for local magnetic variations. In Washington, D.C., the variation is 8 degrees west; thus 8 degrees must be added to the compass reading to get a true bearing. The legs must be located so that they are 22 degrees on either side of the great circle line of bearing to your target and to make the open end of the vee point toward the target. For example, on my globe London and Europe are 48 true (not magnetic) degrees from Washington, D.C.

materials are inexpensive

The wire and insulators can be of almost any kind. However, I prefer No. 14 AWG copperweld wire and No. 500 strain insulators (also known as guy wire insulators). Strain insulators are particularly good if you use a tree for your antenna pole because they won't break when the tree sways in the wind. I also advise soldering all antenna connections to avoid long-term problems from corrosion and the resulting bad connections.

The transformer can be purchased from at least one company for about $150,[2] but building your own transformer is not difficult. Only a few turns of wire on a 2-inch diameter RF toroid core will do the job.[3] Generally the largest RF toroid core which the manufacturer says will cover the desired frequency range will work reasonably well. On my transformer I used 20 turns of soft No. 12 AWG enameled copper wire for the secondary, spacing it evenly around the core and making sure that there were at least a few millimeters between the two wire ends to prevent RF voltage flash-over. If you leave the ends of the secondary about two feet long you can also use them for antenna connections later. Anchoring the wire in place with silicone rubber is a messy but a very effective measure. Then slip

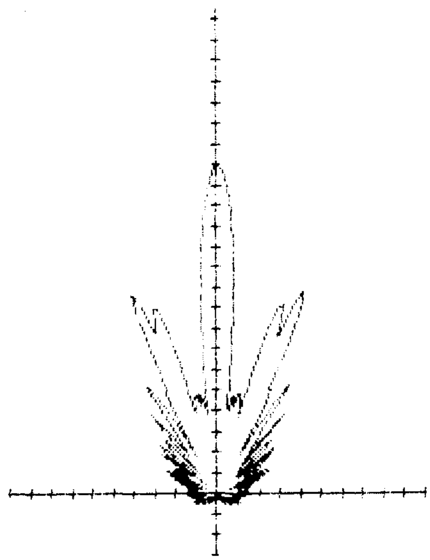

fig. 6. A maximum lobe gain of 8.4 dBi is achieved with a 10-wavelength leg length, 22-degree apex angle, nonresonant vee beam.

some tube insulation over a second piece of the No. 12 AWG enameled wire and wrap five primary turns evenly over the outside of the first twenty turns. Getting even a semblance of a smooth wrap will be the hardest thing you'll have to do for this antenna. Again, use some silicone rubber to tack down the primary and give it at least twenty-four hours to harden. After stripping the enamel from the ends of toroid primary wire, solder on the coax connector of your choice. Resist the urge to use the hole through the middle of the toroid to hold up the high end of the antenna or attach the coax — powdered iron cores are brittle and are subject to breaking at the most inconvenient times.

The 390-ohm termination resistors, are noninductive resistors made specially for terminating antennas, and are available from electronic wholesalers,[4] at ham fests (your best chance) or at surplus houses. On the other hand, you can also make a 200-watt terminating resistor out of one-hundred, 2-watt, 39 kilohm, carbon composition resistors. A simple way to do this is to lay out two tinned No. 12 AWG wires spaced the width of the resistor body and solder the 100 resistors to them.

Operating this antenna is pure joy. It loads my transmitter well from one end of the short wave bands to the other. My antenna also shows a maximum of about 1.5:1 SWR on 15 meters and about 1.2:1 maximum on all other bands. Adding or subtracting a turn or two on the transformer optimizes the SWR for any desired frequency.

At last I have an antenna that works smoothly from 160 to 10 meters and even works as an effective all-band antenna for my general coverage short-wave receiver. For cost and coverage, it's hard to beat this nearly foolproof sloping vee beam.

references

1. Landee, Davis & Albrecht, *Electronic Designers Handbook*, McGraw-Hill, New York, 1957, (see section 21).

2. The vee antenna feeding transformer, 1.8 to 30 MHz, is available from Apcom Inc., 625 Loffstrand Lane, Rockville, Maryland 20850, (301-294-9060). Note: this company and others will supply the complete antenna, mast, ground rods, earth anchors and everything else, optimized for your frequency and adjusted to fit various larger pieces of land. This is a good deal for commercial stations, but the cost is very high by ham standards.

3. Type F240-Q1 toroid core to cover 1.8 to 30 MHz is available from Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607, or Palomar Engineers 1924-F W. Mission Road, Escondido, California 92025.

4. Carborundum Co., Graphite Products Division, Box 339, Niagara Falls, New York 14302. Please note that this is a manufacturer, not a retail outlet. If you can put together a large order, then request noninductive resistor type 888SP, 390 ohms (2 for each antenna). If more power is required, order type 891SP, 450 ohms (2 for each antenna).

ham radio

KDK

DO YOU HAVE AN HEIRLOOM RADIO?

Well . . . they might not last forever. However, there are certainly many older model KDKs out there in 'Ham Radio-land' just chuggin away. Every day calls come from all over asking for information and advice on care and feeding of an FM-144sx or a '2015 and there are even a few older than that but some of them seem to be in disguise. That's a tribute to the folks who design and make the KDK. They care about building a radio to last longer because their name and their pride are on the front of each one. BUT . . . What we are really getting to is we would really like for all you folks who have known and loved your KDK's all these years to go and update yourselves by purchasing a newer KDK, one like, say, the FM-2033 or maybe an FM-7033 UHF. That way you can start your own collection of heirloom KDK radios. Right there in your own hometown. Take a look at the chart of available models and visit your nearest KDK dealer and check them out. We think you will drive home with one.

MAXPAC STACK

SPECIFICATION	FM-2033 144 MHZ	FM-4033 220 MHZ	FM-7033 440 MHZ	FM-6033 50 MHZ
NUMBER OF MEMORIES	10 Memories + CALL CHANNEL organized as two banks of 5 channels each. (CH 1-5, CH 6-10, CALL.)			
MEMORY SCANNING	Memories may be scanned A(1-5), B(6-10), A + B(1-10) or A × B(1-5)			
BAND SCANNING	Programmable band scan between values loaded into memories 5 and 10, step size set in INIT module.			
FREQUENCY RANGE	142.000-149.995 MHZ	220-224.995 MHZ	440-449.975 MHZ	50.00-53.995 MHZ
OUTPUT POWER HI/LO	25/2.5 Watts	25/2.5 Watts	10/2 Watts	10/2 Watts
REPEATER OFFSET	600 kHZ UP or Down	1.6 MHZ UP or Down	5 MHZ UP or Down	600 kHZ UP or Down
SUB AUDIBLE TONE	103.5 @ 500 Hz Dev	103.5 @ 500 Hz Dev	Dipswitch Select	103.5 @ 500 Hz
SENSITIVITY	0.2 uV @ 12dB SINAD	0.35 uV @ 12 dB SINAD	0.4 dB @ 12 dB SINAD	0.2 uV @ 12 dB SINAD
BANDWIDTH	±5 kHZ @ −6 dB	±5 kHZ @ −6 dB	±5 kHZ @ −6 dB	±5 kHZ @ −6 dB
SELECTIVITY	±12.5 kHZ @ −60 dB	±12.5 kHZ @ −60 dB	±12.5 kHZ @ −60 dB	±12.5 kHZ @ −60 dB

THL CORP.

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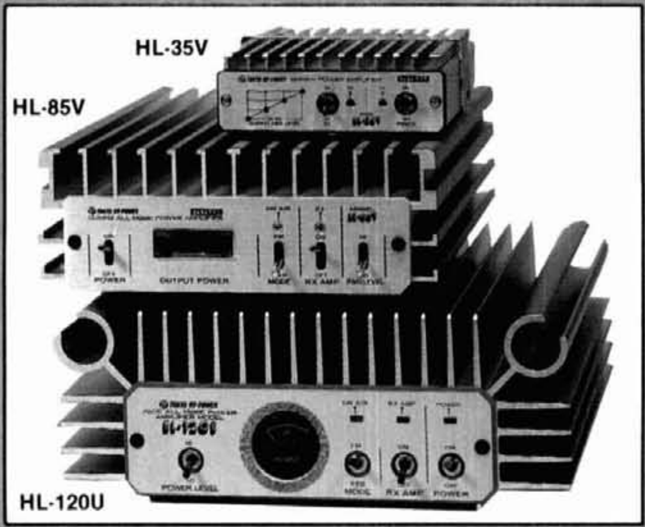
TEAM THL brings competition class performance to everyday operation. Whether you're looking for a little more performance or a "super-charger" boost, TEAM THL products can get you out of the pits and back in the race better and faster almost every time. Three different power performance classes in either VHF or UHF band capability give the TEAM THL a broad spectrum of performance options. So remember the next time you get beat in the race, soup-up yourself with a product from TEAM THL.



Specifications	HL-30V	HL-35V	HL-35VL	HL-85V	HL-110V	HL-160V	HL-160V25	HL-20U	HL-30U	HL-60U	HL-120U
Pre-Amp Type	N/A	Gaas-FET	Gaas-FET	Gaas-FET	Gaas-FET	MOS-FET	MOS-FET	N/A	Gaas-FET	Gaas-FET	Gaas-FET
Power Metering	N/A	LED	LED	Meter	Meter	Meter	Meter	N/A	LED	Meter	Meter
Input (Watts)	.25-5	.25-5	.25-5	10-14	3-14	3-14	20-30	.1-4	1-4	8-14	8-14
Output (Watts)	2.5-30	2.5-30	2.5-30	70-90	90-110	140-160	140-160	18-22	25-30	45-60	90-110
SSB Mode	NO	NO	YES	YES	YES	YES	YES	YES	NO	YES	YES
Sugg. Retail	$69.95	$79.95	$89.95	$169.95	$239.95	$349.95	$299.95	$114.95	$129.95	$229.95	$379.95

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SANTEC®

2M ST-200ET
70CM ST-400ET

Priced at a level to make your budget smile, the ST-200ET and the ST-400ET are direct hardware replacements for the famous ICOM* series of thumbwheel switched hand held radios. Present accessories for the 2AT and the 4AT should work on the ST-200ET (VHF) and ST-400ET (UHF) with no modifications.** Same slip off battery pack style and the same mic and speaker jack arrangements provide as much compatibility as possible.

These units are made in Japan and sold by SANTEC and backed by the famous Encomm **TWO YEAR EXTENDED SERVICE PLAN** and Encomm service facilities located in Plano, Texas. Priced at $199.95 for the ST-200ET (VHF) and $249.95 for the ST-400ET (UHF). No it's not a misprint. Those are the Suggested retail prices. Now smile. Please see your favorite SANTEC dealer for his best price.

SPECIFICATION	ST-200ET	ST-400ET
GENERAL		
Frequency Range	144-147.995	440-449.995
Battery Pack (V/mAHr)	8.4/250	8.4/250
Receive Squelched Norm	18 mA	22 mA
RX At Full Volume	130 mA	130 mA
Transmit (Low Power)	220 mA	300 mA
Transmit (High Power)	550 mA	700 mA
Dimensions mm	60 × 170 × 40	60 × 170 × 40
Weight (with Battery)	490 gms	490 gms
TRANSMITTER		
Output Pwr. (Hi, Lo)	1.5W, 0.15W	1.5W, 0.15W
Spurious Transmitted	< −60dBc	< −60dBc
Deviation Limit	5 kHz	5 kHz
Pickup Device	Condenser Mic	Condenser Mic
RECEIVER		
Receiving System	Dbl. Superhet.	Dbl. Superhet.
I.F. Frequencies	10.695 1st 455 kHz 2nd	21.6 1st 455 kHz 2nd
Receive Sensitivity	<0.25 uV @ 12dB	<0.35 uV @12 dB
I.F. Bandwidth	30 kHz @ −60dB	30 kHz @ −60 dB
Operating Temp	−10-+60 C	−10-+60 C

ACCESSORIES

SKT-BA Battery Case	HSA-1/HBM-1 Headset/Mic
SKT-PA DC/DC Conv.	STK-BP Battery Pack
ST-MC Mobile Charger	STK-BC Battery Charger
SKT-LC Leatherette Case	

NOTICE: These specifications are typical unless stated otherwise. They may be changed in the future without notice or obligation. Conditions of measurement may be obtained from Encomm, Inc.

* ICOM is a registered trademark of ICOM, INC of JAPAN.
** ST-200ET/400ET Batteries are not fully compatible with BC-30/35 drop in chargers.

WELZ CORP.
SUPERIOR ACCESSORIES

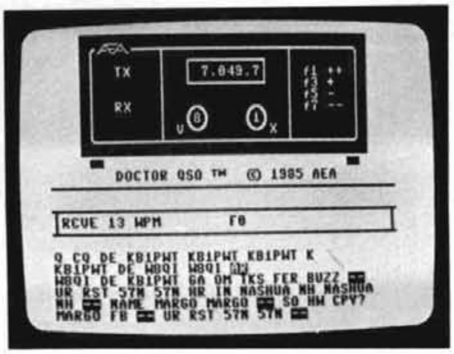
PEP • POWER • VSWR
COMPACT STYLE

SP-122 HF PEP HOLD
SP-220 HF PEP MONITOR
SP-420 VHF/UHF PEP MONITOR

These new compact HF/VHF/UHF meters from WELZ provide multi-mode operation in auto or home station. Utilizing the WELZ toroidial core based wide-band sensor technology, these VSWR/POWER meters are the next generation of accuracy and reliability. Pictured here is the model SP-420 covering the VHF/UHF band from 140-525 MHz. In addition there is the SP-220 covering 1.8 to 200 MHz and the SP-122 covering 1.6-60 MHz with PEP peak hold mode. All three of these new models are ready for PEP output measurement with either the "PEP Monitor" function or the "Instantaneous PEP HOLD" function, back-lighted easy-to-read meters, high sensitivity and very attractive styling. Check your favorite dealer and check out the new WELZ COMPACT VSWR/POWER meters.

MODEL	SP-122	SP-220	SP-420	SP-230	SP-430
Freq. Range	1.6-60MHZ	1.8 ~ 200MHZ	140 ~ 525MHZ	6-1400MHZ	1.8 ~ 150MHZ
Sensor Mnt.	FIXED	FIXED	FIXED	DETACHABLE	DETACHABLE
Pwr Ranges	20/200/2KW	2/20/200	2/20/200	15W/150W	5W/60W
No. Meters	1	1	1	1	1
Peak Mode?	YES + HOLD	YES	YES	NO	NO
Impedance	50 OHMS	50 OHMS	50 OHMS	50 OHMS	50 OHMS
Functions	PWR/VSWR PEP + HOLD	PWR/VSWR PEP	PWR/VSWR PEP	PWR/VSWR CAR VOLTS	PWR/VSWR CAR VOLTS
Accuracy	10% READING	10% READING	5% READING	5% F.S.	5% F.S.

Doctor QSO™
Is The Code Buster



Doctor QSO Relieves All Symptoms Of Morse Code Phobia!

Doctor QSO™ is a plug-in cartridge for the Commodore 64 computer that provides a very realistic simulation of on-the-air two-way Morse Code ragchew contacts (QSOs). AEA, the undisputed leader in Morse training, has introduced Doctor QSO to amateur radio for the purpose of making Morse skill upgrading FUN and EASY. With Doctor QSO you can look forward to practicing your Morse Code skills in a non-confusing manner. Forget about all the drudgery you associated with Morse Code in the past; Doctor QSO ushers in a totally new era in Morse Code learning.

Doctor QSO is based on the same technology that has made the Doctor DX™ contest trainer so famous. The Doctor QSO simulator is so realistic that most skilled operators find it every bit as rewarding as the real thing. You can operate anytime you want; the only extra equipment you need is a Commodore 64 and a TV set.

Doctor QSO also removes the mystery of the CODE BEHIND THE CODE. Many people go so far as to learn the Morse Code characters, only to be frightened of getting on the air the first time because the QSO format is so confusing. With Doctor QSO, you will be a pro before you turn on your first transmitter. The Doctor QSO trainer/simulator is ideal for the aspiring Amateur Radio operator with little or no contact with helpful hams.

With Doctor QSO you will become familiar with all the U.S. call areas and associated call letter prefixes. The standard international QSO format is observed along with all the common amateur radio abbreviations which are explained thoroughly in the operator's manual. All Morse skill levels are addressed by Doctor QSO, from the person who has not yet learned the Code, to the person comfortable with sending and receiving at 40 + WPM.

Who says Morse Code can't be fun? You can even have fun with Doctor QSO before you have learned the Code. To begin with, the operator can view the messages being sent by the computer generated stations in real-time. The operator can also send Morse with the keyboard. In addition, the operator can select simulation of static interference (QRN) and adjacent CW interference (QRM). Normally, the beginner would operate in the novice band where stations will be sending as slow as 3 WPM. Later as the user becomes more skilled, he can move down the band to faster speeds, and he has the choice of using a key or keyer for sending.

If you have tried every other method known to learn the Morse Code and failed, then Doctor QSO has just the prescription for you. Now you can upgrade your Amateur Radio license in record time. Doctor QSO is more than the written word can describe. To fully appreciate all the merits of this trainer, see your dealer for a demonstration or contact AEA for more information.

Prices and specifications subject to change without notice or obligation.

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DX FORECASTER

Garth Stonehocker, KØRYW

what's this Sporadic E?

In these minimum years of the 10.7-year sunspot cycle when the 10-meter band is at best open only a few hours per day and only to the southern directions for long skip, it's still possible for propagation modes to exist on 6 meters and occasionally even the 2-meter band for short-skip openings. Signals appear suddenly, out of nowhere, and frequently rise to amazing strength. They may stay in for just a few minutes at a time — or the band may remain open for hours. Occasionally in June or July DX signals might be heard around the clock. Signals can be received from distances of 500 to 1200 miles and occasionally, due to multiple reflections, from distances as far away as 2500 miles.

How do you recognize such E_s openings? Say you're monitoring a beacon. The band is quiet. Suddenly you hear a buildup of "antenna noise." Almost instantly there are DX stations all over the band. Signal levels fluctuate rapidly as the session opens and as it declines. When the signal is there it usually pegs your S-meter, but it is also subject to rapid fades on the order of 60 dB or more that chop it into a garbled mess.

One way to recognize the probable opening of E_s on 6 meters was reported by George Jacobs, W3ASK, in the June, 1962, issue of *CQ*. Working a lower frequency band, say 15 or 10 meters, listen to the stations being worked. If the minimum skip distance is decreasing, the skywave geometry is such that the maximum usable frequency will be increasing by reflection from an E_s (more dense than F2 and lower height) cloud. W3ASK's rule of thumb states that when stations are heard less than 500 miles away on 10 meters, or less than 350 miles on 15 meters, the chances are good that 6 meters will open in that same direction. It's worth a try! (More on E_s DXing next month.)

last-minute forecast

DX conditions on the higher HF bands, 10 through 30 meters, are expected to be very good the first two weeks of the month and also again during the last week of this five-week month. The propagation at these times can be via long-skip if the radio flux is very high — above about 85 units. Sporadic E (E_s) short-skip is expected to occur occasionally, with the probability of occurrence increasing as the month goes by. The middle two weeks of the month will offer the best nightime DXing. Geomagnetic disturbances are expected to occur around the 4th through the 8th and again on or about the 15th. Concurrently, the thunderstorm noise background level will also be higher on the lower bands.

Moonbounce DXers can take advantage of the lunar perigee (and full moon) that will occur on the 3rd and 4th of this month. An Aquarid meteor shower of interest to meteor-scatter and meteor-burst DXers peaks between May 4th and 6th with rates of 10 and 25 per hour for the Northern and Southern Hemisphere, respectively.

Two eclipse events are calculated to occur in May. The first is a total eclipse of the moon on May 4 from 1817 to 2135 UTC. The path of its shadow starts near New Zealand and travels west through Australia, Asia, Africa into the Atlantic Ocean. The width extends from the Antarctic to Europe. The second event, partial eclipse of the sun, (with 84 percent coverage) will occur on May 19 from 1925 to 2342 UTC. Its path begins at Greenland, travels across Canada and then moves on to Alaska and Japan. The second eclipse provides an opportunity to evaluate propagation effects on the path between the United States and Europe. Schedule contacts for the day before the day of the eclipse and the day after. Compare signal strengths and quality on each band used (suggestion: try 40, 30, 20 and 15 meters). A club-coordinated effort is a good way to cover the bands needed.

band-by-band summary

Six meters may provide an occasional opening to South Africa and South America by short-skip E_s. These will occur around local noontime, toward the end of the month.

Ten and fifteen meters will provide a few short skip E_s openings and many long-skip openings, especially during high solar flux conditions, to most areas of the world during daylight. Some transequatorial (TE) openings, associated with a mildly disturbed geomagnetic field may occur in the evening hours. This is about the last month that affords many good TE openings until next fall.

Twenty, thirty, and forty meters will support DX propagation from most areas of the world during the daytime and into the evening hours almost every day. Forty meters has joined this daytime DX group because of lower signal absorption, lower LUF (lowest usable frequency) during these sunspot minimum years. During unusually high 27-day solar flux days 40 meters may not be usable and both 30 and 40 meters may not be usable in the predawn hours after a high flux day. The DX on these bands may be either long-skip to 2500 miles (4000 km) or short-skip E_s to 1250 miles (2000 km) per hop. The length of daylight is approaching maximum, providing many hours of good DXing.

Thirty, forty, eighty, and one-sixty are all good for nighttime DX. Although the background thunderstorm noise is beginning to be noticeable these bands are still quiet enough to provide good DX working conditions. Sproadic-E propagation may be a contributing factor toward enhanced conditions at local sunset and will occur more often during the next three months.

MAY

WESTERN USA

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

MID USA

MDT	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	
ASIA FAR EAST	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	N
EUROPE	20	20	20	20	20	20	20	20	20	20	20	20	30	30	30	30	20	20	20	20	20	20	20	20	NE
S. AFRICA	15	15	10	10	10	15	15	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	E
S. AMERICA	15	15	10	10	10	10	10	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	SE
ANTARCTICA	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	30	30	20	20	20	20	S
NEW ZEALAND	10	10	10	15	15	15	15	15	20	20	20	20	20	20	20	20	20	15	15	15	10	10	10	10	SW
OCEANIA AUSTRALIA	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	15	10	10	10	10	10	W
JAPAN	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	NW
CDT	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	

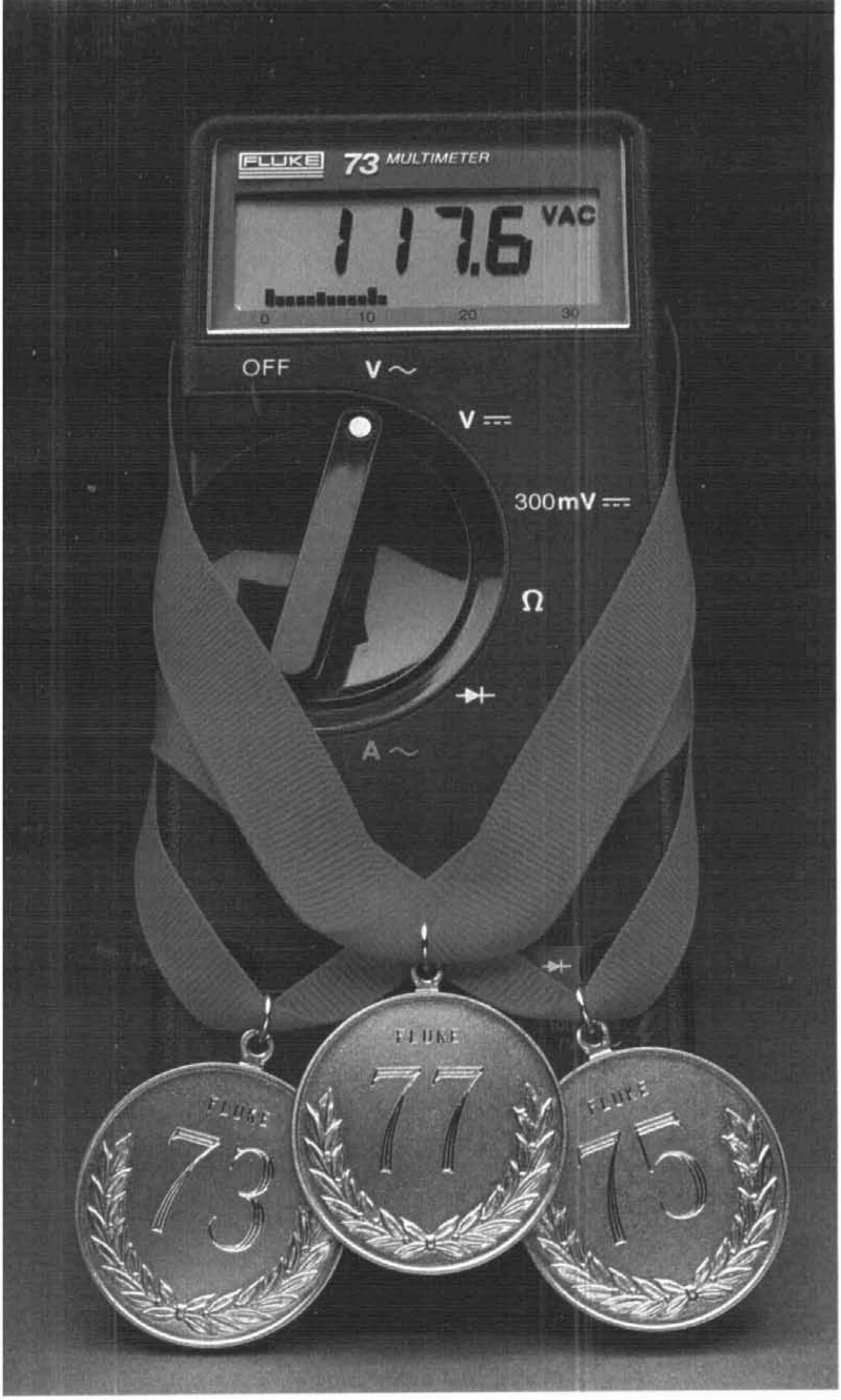
EASTERN USA

EDT	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	
ASIA FAR EAST	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	N
EUROPE	20	20	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	20	20	20	20	20	20	NE
S. AFRICA	15	15	10	10	10	10	15	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	E
CARIBBEAN S. AMERICA	15	15	10	10	10	10	10	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	SE
ANTARCTICA	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	30	30	20	20	20	20	S
NEW ZEALAND	10	10	10	15	15	15	15	15	20	20	20	20	20	20	20	20	20	15	15	15	10	10	10	10	SW
OCEANIA AUSTRALIA	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	15	10	10	10	10	15	W
JAPAN	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	NW

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

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

ham radio



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$85*	$99*	$129*
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Volts, ohms, 10A, diode test	Volts, ohms, 10A, mA, diode test	Volts, ohms, 10A, mA, diode test
Autorange	Audible continuity	Audible continuity
0.7% basic dc accuracy	Autorange/range hold	"Touch Hold" function
2000+ hour battery life	0.5% basic dc accuracy	Autorange/range hold
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** Patent pending

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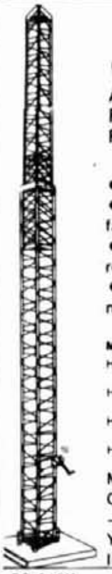

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Check these features:
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- Hot dip galvanized after fabrication
- Complete with base and rotor plate
- Totally self-supporting— no guys needed

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HG54HD	54 ft.	16 sq. ft.	$1699
HG70HD	70 ft.	16 sq. ft.	$2699

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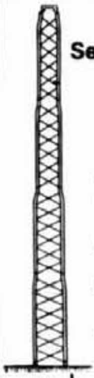

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Self Supporting Towers On SALE!
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- Complete With Base and Rotor Plate
- In Stock Now—Fast Delivery

Model	Height	Ant. Load*	Weight	Delivered Price*
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HBX56	56 ft	10 sq ft	385	$499
HDBX40	40 ft	18 sq ft	281	$399
HDBX48	48 ft	18 sq ft	363	$489

*Your Total Delivered Price Anywhere in Continental 48 States. Antenna Load Based on 70 MPH Wind.

Tri-Ex®

These rugged crankup towers now available from Texas Towers! All models available On Sale for tremendous savings to you!

To save on freight costs, all towers are shipped directly from the Tri-Ex factory to you!

Check these features:
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- **Totally self-supporting—no guys needed**

Model	Height Up	Down	Wind Load	List	Sale
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WT51	51.0 ft	20.5 ft	9.0 sq ft	$1154	$899
LM354	54.0 ft	21.0 ft	16 sq ft	$2010	$1599
LM470D (Motorized)	70.0 ft	22.0 ft	16 sq ft	$4195	$3199
DX86 (Motorized)	86.0 ft	23.0 ft	25 sq ft	$7200	Call

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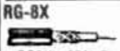
$.29/ft $279/1000 ft
Up to 600 ft via UPS

- RG-213/U—95% Bare Copper Shield
- Mil-Spec Non-contaminating Jacket for longer life than RG8 cables.
- Our RG-213/U uses virgin materials.
- Guaranteed Highest Quality!

RG-8X

$.19/ft $179/1000 ft



- RG8X—95% Bare Copper Shield
- Low Loss Foam Dielectric
- Non-contaminating Vinyl Jacket

Coaxial Cable Loss Characteristics (DB/100 ft)

Cable Type	Imped.	10MHz	30MHz	150MHz	450MHz
RG-213/U	50	.6	.9	2.3	5.2
RG8X	52	.8	1.2	3.5	6.8
RG-58/U	52	1.4	1.9	6.0	12.5
½" Alum	50	.3	.5	1.2	2.2
½" Heliax	50	.2	.4	.9	1.6
⅞" Heliax	50	.1	.2	.5	.9

HARDLINE/HELIAX™

Lowest Loss for VHF/UHF!

½" Alum. w/poly Jacket	$.79/ft
½" LDF4-50 Andrew Heliax ™	$1.69/ft
⅞" LDF5-50 Andrew Heliax ™	$3.99/ft

select connectors below.

HARDLINE & HELIAX ™ CONNECTORS

Cable Type	UHF FML	UHF MALE	N FML	N MALE
½" Alum	$19	$19	$19	$25
½" Heliax ™	$22	$22	$22	$22
⅞" Heliax ™	$49	$49	$49	$49

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UG21B N Male ... $2.95

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450 Ohm H.D. Line	$.16/ft
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H.D. End Insulators	$2/ea
Van Gorden 1:1 Balun	$11
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400W Standard	$16	$17	$19	$22	$26
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HF MONO-BAND ANTENNAS

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15-3CD	$119	15-4CD	$129
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40-2CD	$289	D40	$149

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A50-5	$ 79	617B	$199
214B	$ 79	3219	$ 95
220B	$ 95	424B	$ 79

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A147-20T	$ 63	416TB	$ 59
A14TMB	$ 29	PS4	$ 69

VHF/UHF FM ANTENNAS

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214FB	$ 79	228FB	$219
A449-6	$ 29	ARX2B	$ 39

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TH7DXS 7-el Triband Beam	$439
TH3JRS 3-el Triband Beam	$189
TH2MK3S 2-el Triband Beam	$179
205BAS 5-el 20-mtr Beam	$349
155BAS 5-el 15-mtr Beam	$199
105BAS 5-el 10-mtr Beam	$129
204BAS 4-el 20-mtr Beam	$259
64BS 4-el 6-mtr Beam	$69
66BS 6-el 6-mtr Beam	$135
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- Wind Area - 1.5 sq ft
- Boom - 54 in. long
- 1200W P.E.P. Input

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Alliance HD73 (10.7 sq ft rating)	$109
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Standard 8 cond cable $.19/ft (vinyl jacket 2-#18 & 6-#22 ga)
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45G $112.50 55G $134.50

All 20G, 25G, 45G and 55G Accessories In Stock at Discount Prices - CALL!

Foldover Towers

Model	Height	Ant Load*	Price
FK2548	48 ft	15.4 sq ft	$899
FK2558	58 ft	13.3 sq ft	$949
FK2568	68 ft	11.7 sq ft	$999
FK4544	44 ft	34.8 sq ft	$1199
FK4554	54 ft	29.1 sq ft	$1299
FK4564	64 ft	28.4 sq ft	$1399

25G Foldover Double Guy Kit	$219
45G Foldover Double Guy Kit	$249

*Above antenna loads for 70 MPH winds and Guys at Hinge & Apex.

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3/16"EHS Guywire (3990 lb rating)	$.15/ft
1/4"EHS Guywire (6000 lb rating)	$.18/ft
5/32" 7 × 7 Aircraft Cable (2700 lb rating)	$.15/ft
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1/4"CCM Cable Clamp (1/4" Cable)	$.55
1/4"TH Thimble (fits all sizes)	$.45
3/8EE (3/8" Eye & Eye Turnbuckle)	$6.95
3/8"EJ (3/8" Eye & Jaw Turnbuckle)	$7.95
1/2"EE (1/2" Eye & Eye Turnbuckle)	$9.95
1/2"EJ (1/2" Eye & Jaw Turnbuckle)	$10.95
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1/4" Preformed Guy Grip	$2.99
6" Diam - 4 ft Long Earth Screw Anchor	$14.95
500D Guy Insulator (5/32" or 3/16" Cable)	$1.69
502 Guy Insulator (1/4" Cable)	$2.99
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9902LD Cable End (for 6700 cable)	$8.95
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GALVANIZED STEEL MASTS

Heavy Duty Steel Masts 2 in OD - Galvanized Finish

Length	5 FT	10 FT	15 FT	20 FT
.12 in Wall	$29	$49	$59	$79
.18 in Wall	$39	$69	$99	$129
.25 in Wall	$69	$129	$189	$249

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✓ 155

160-meter transmission line antenna

If height or space is a problem, try this

If you're like me, you don't have adequate yard space to put up a half-wave dipole on the 160-meter band or a tower to load as a short vertical. In the past, I tried not to let this discourage me from getting on 160, but the RF burns and unanswered calls that resulted from loading up a 40-meter dipole forced me to come up with a better antenna!

Short transmission line antennas have been used at UHF and microwave frequencies for quite some time.[1] Small slots carved into the bodies of fast-moving vehicles (airplanes and rockets) have been used to effectively radiate RF energy using transmission line principles. In fact the folded dipole, commonly used with FM receivers, uses these same principles to receive RF signals. Other types of transmission line antennas include the "low-profile" type used on trains and emergency vehicles, where the antenna structure protrudes just fractions of a wavelength above the vehicle body. These antennas are advantageous when antenna size and height are extremely limited.

I live in an apartment complex. The tallest structures are a couple of 30-foot trees in my small backyard. I have also found that good grounding is a problem, making the use of an "RF-free" tuner difficult. After attempting to work the top band with my existing 20-meter and 40-meter dipoles (none too successfully), I decided to give these transmission line ideas a try. The results have been gratifying, to say the least. I now have a resonant 160-meter antenna that requires no tuner, is directly coax-fed, has given no trace of RF in the shack, and provides enhanced reception due to very low noise pick-up.

how it works

Many people associate the term "transmission line" with the coaxial cable or ladder line that feeds their antenna — something that "carries power to the antenna," and not something that should, itself, radiate RF. Of course, it is undesirable to have our feedline radiate, but many successful antennas, such as the longwire, the rhombic, and the Beverage are indeed unbalanced (radiating) transmission line extensions of their feed systems. By configuring these lines properly, resulting current distributions along the wires enable these transmission line extensions to emit and receive far-field RF energy. By analyzing a familiar transmission line antenna, the half-wave folded dipole, we can get a feel for how and why a transmission line antenna works.

Consider a folded dipole made of twin-lead transmission line (**fig. 1**). This type of feedline typically has a 300-ohm characteristic impedance. We can think of this antenna as being driven by our transmitter, an unbalanced RF source voltage. A common and useful technique used to analyze transmission lines is the superposition principle, where the original source voltage is replaced by several different sources which, when combined, add to give the equivalent voltage of the original source. Superposition is used to reconfigure the folded dipole as shown in **fig. 2**. By breaking down the superposition model, it is possible to construct and identify distinctive modes that characterize the behavior of the antenna. **Figure 3A** shows "push-push" or even-mode feeding, in which both wires in the twin-lead transmission line are excited by the same voltage, and have currents traveling in phase. **Figure 3C** illustrates "push-pull," or odd-mode feeding, where the two wires of the twin-lead have currents traveling in opposite directions at any time. The impedances presented by the even and odd modes in terms of the excitation voltage and currents are easily found with the superposition model.

By Ted S. Rappaport, N9NB, Box 283, Electrical Engineering, Purdue University, West Lafayette, Indiana 47907

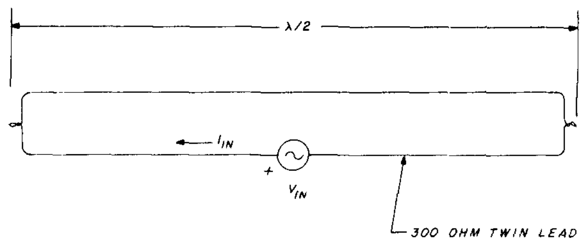

fig. 1. Folded dipole antenna.

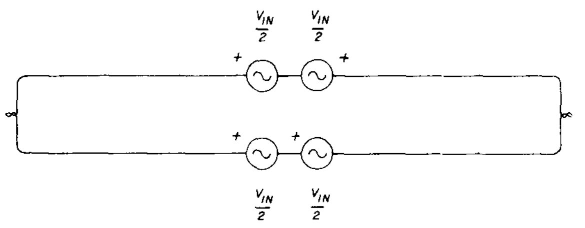

fig. 2. Equivalent folded dipole model using superposition.

For the even mode case:

$$Z_{even} = \frac{\left[\frac{V}{2}\right]}{I_{even}} = \frac{V}{2I_{even}} \text{ (even mode)} \qquad \textbf{(1)}$$

Since the pair of voltage sources in push-push are similar to just a single source voltage V/2 driving two parallel strands of wire (assuming the twin-lead spacing is much less than a wavelength), the even-mode impedence is that of a "wide" dipole (Z_{even} = *50 to 75 ohms)*. This simplification is shown in **fig. 3B.** Because the even (push-push) mode does the radiating, it is sometimes called the antenna mode. Note that the value of current in each of the transmission line wires is half of the total even-mode current.

For the push-pull case, the odd mode impedance is given by:

$$Z_{odd} = \frac{\left[\frac{V_{in}}{2}\right]}{I_{odd}} = \frac{V_{in}}{2I_{odd}} \text{ (odd-mode)} \qquad \textbf{(2)}$$

Z_{odd} is the parallel combination of the impedances of each of the short-circuited ends of the folded dipole, reflected 1/4 wavelength back to the center feedpoint. Recall that a short-circuited transmission-line offers a near infinite impedance when the source is placed one-quarter wavelength from the short. The odd mode (sometimes known as the transmission line mode) impedance is made very high in this manner. Instead of short circuits, resistors can be placed at various nodes to alter even and odd mode impedances, as well as current distributions. This is sometimes done with rhombic antennas and vee beams. For our folded dipole example, we can observe that the antenna mode offers an impedance to RF on the order of a dipole antenna, whereas the transmission line mode offers extremely high resistances to RF.

Specifically, the input impedance to the antenna is easily computed (using superposition) as:

$$Z_{in} = \left(\frac{V_{in}}{I_{in}}\right) = \frac{V_{in}}{\left[(I_{even}/2) + I_{odd}\right]}$$

$$= \frac{V_{in}}{\left[\left(\frac{V_{in}}{4Z_{even}}\right) + \left(\frac{V_{in}}{2Z_{odd}}\right)\right]} \qquad \textbf{(3)}$$

$$= \frac{4Z_{even}Z_{odd}}{(2Z_{even} + Z_{odd})}$$

Observe that for Z_{odd} very large (as is the case here):

$$Z_{in} = 4Z_{even} \cong 300 \text{ ohms}$$

We find that not only does this transmission-line antenna radiate, but it also has an input impedance of four times that of a conventional dipole. Conveniently, this structure can be fabricated out of 300-ohm twin-lead, and can also be fed with 300-ohm twin-lead, providing a good match to a 300-ohm receiver. In the case of Yagi antennas, where the mutual impedance effects drop the antenna feedpoint to below 20 ohms, a folded driven element can be used to increase feedpoint resistance by roughly a factor of four.[2]

using the ground as an image

By using the ground to electrically provide half of the antenna system, we can think in terms of a single wire above ground. **Figure 4** shows something that looks like a folded-dipole using an image. Note that the wire height must be much less than a wavelength for the transmission line principles to hold. Since horizontal image currents always travel in opposite directions as do the wire currents, the horizontal portion of this structure, unlike the original folded dipole, will tend to cancel out in the far-field (i.e., the even mode impedance for this antenna is extremely high). The vertical shorting segments, however, will provide a vertical radiation pattern, enabling this antenna to emit and receive RF energy.

Closer inspection reveals that the antenna of **fig. 4A** is identical to the odd-mode excitation of the original folded dipole. Recall that the odd-mode impedance was calculated by considering the parallel combination of the two transmission lines transferred back to the feedpoint. By this technique, it is easy to predict that the input impedance of the structure in **fig. 4A** will be very high, and the radiation will be due primarily to the short vertical segments at the ends of the structure.

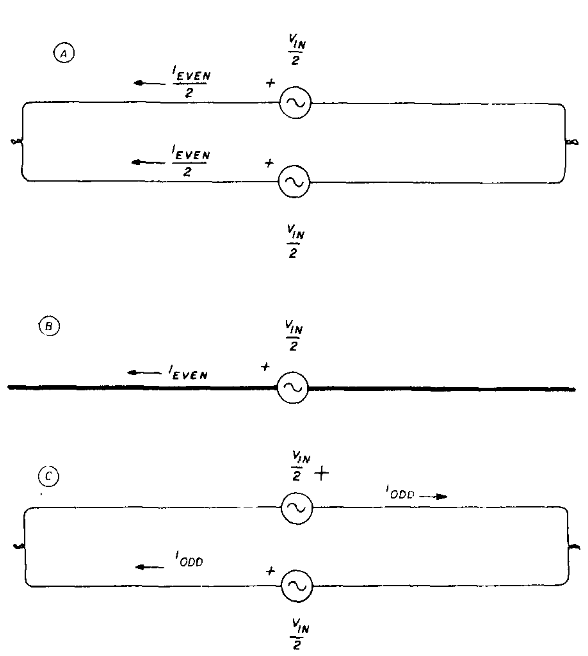

fig. 3. Even and odd antenna mode configurations for a folded dipole: (*A*) even-mode excitation; (*B*) even-mode simplification — dipole antenna; and (*C*) odd-mode excitation.

Now suppose instead of folding both sides of the antenna to ground, we open one of them and move the feedpoint to a "strategic" location **fig. 4B**). This type of antenna is known as a low-profile antenna, and has effectively been used at low frequency (LF) and medium frequency (MF) bands, as well as at microwave frequencies.[3]

low profile antenna

To calculate the input impedance of the low profile antenna at a particular feedpoint we need only deal with the odd mode, since, as was the case for the antenna in **fig. 4A**, the even mode offers an extremely high impedance because of image current cancellation.

Again, we must combine in parallel the impedances of the open and shorted (folded) sides of the structure. For any transmission line, input impedance values may be found by:

$$Z_{short}(x) = Z_0 Tanh(\gamma x) \text{ and } Z_{open}(y) = Z_0 Coth(\gamma y) \quad \textbf{(4)}$$

where $Tanh(\ )$ and $Coth(\ )$ are hyperbolic trigonometric functions, Z_0 is the characteristic impedance of the transmission line, x is the distance from the feedpoint to a short-circuit termination, y is the distance from the feedpoint to an open-circuit termination, and γ is the complex propagation constant of the transmission line, made up of a real attenuation factor, α, and imaginary term, $j\beta$, representing the emission wavelength of the source ($\gamma = \alpha + j\beta$).

The characteristic impedance of the single wire (and its image) is dependent upon many factors. These include height above ground, ground conductivity, and moisture of the air, to cite just a few. At 1.8 MHz, an approximate value for the characteristic impedance of a wire 6 meters above ground is about 800 ohms. The value of Z_0 is really not important, though. The success of this antenna lies in the parameter γ.

Naturally occurring losses in the ground and in the wire cause some slight attenuation in electromagnetic waves as they propagate through the line. This attenuation, α, is expressed in units of relative voltage decrease per unit length (dB/m), and yields the real part of γ. It is instructive to compare a lossy and lossless model of the low-profile antenna to see exactly how it loads.

For lossless transmission lines, where $\gamma = j\beta$, the expressions for short-circuit and open-circuit transmission lines simplify to:

$$Z_{short}(x) = jZ_0 Tan(\beta x) \text{ and}$$
$$Z_{open}(y) = -jZ_0 Cot(\beta y) \quad \textbf{(5)}$$

where $Tan(\ )$ and $Cot(\ )$ are trigonometric functions, and j is the imaginary operator, or a 90-degree phase shift. For this ideal case, the parallel combination of the open and short-circuited line yields an imaginary result for any value of x or y ! Since it is impossible to deliver power to a purely reactive load the SWR is infinity for the ideal case. However, when losses are considered, it is possible to solve for values of x and y which yield a purely real Z_{in}. This indicates that we are using the naturally occurring losses of a transmission line to provide a purely resistive RF load for our transmitter! The end result is an antenna that can be made to resonate at any real impedance, provided the correct lengths of open and short-circuited transmission line are used.

implementation

Solving for the lengths x and y is much too impractical because of the many variables that exist at an antenna site. Trial and error is the easiest way to "zero in" on the particular lengths needed for a desired impedance and a given configuration. For a 50-ohm antenna impedance, I wound up with the dimensions shown in **fig. 5**. Only four tries were required to get the SWR below 1.5:1 in the 1800 kHz to 1850 kHz band, pruning only the longer (open) length of wire. I also discovered that other configurations are possible, at the expense of some bandwidth (**fig. 5B**). Since different locations will use slightly different configurations, it is impossible to derive explicit formulas for the

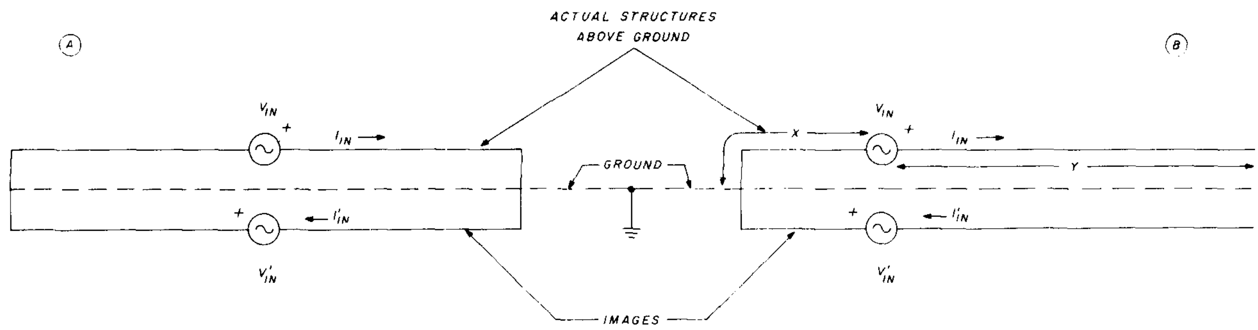

fig. 4. Example of antennas with images: (*A*) pseudo-folded dipole with image; (*B*) low-profile antenna.

wire lengths; however, it is safe to say that the open-circuit length will not exceed 40 meters (0.24 λ), and the short-circuit length should not exceed 9 meters (0.05 λ). To tune the antenna, start with these lengths and trim the longer wire (open-circuited transmission-line) by removing 0.5 meter lengths of wire until the SWR approaches 3:1 at the frequency of interest. Then, very finely prune both the open and short-circuit lines for best SWR. Small lengths of wire may have to be re-inserted after course pruning to optimize the match to the transmitter. It is important to be sure that all antenna SWR measurements are made with the antenna at its operating height, as the wire height above ground critically effects the tuning (in fact, this is another parameter that can be varied in the pruning process to provide the best match). It should be possible to achieve an SWR well below 1.5:1 if patience is exercised in trimming the antenna.

Wire heights from 2 to 8 meters make the transmission line approximation valid, although I would think that heights greater than this could also be made to resonate. The antenna feed system is simply a random length run of RG-58U coaxial cable. The open-circuit wire is connected to the coax center conductor, while the coax braid is soldered to the short-circuit wire, which is terminated at a ground stake (**fig. 6**).

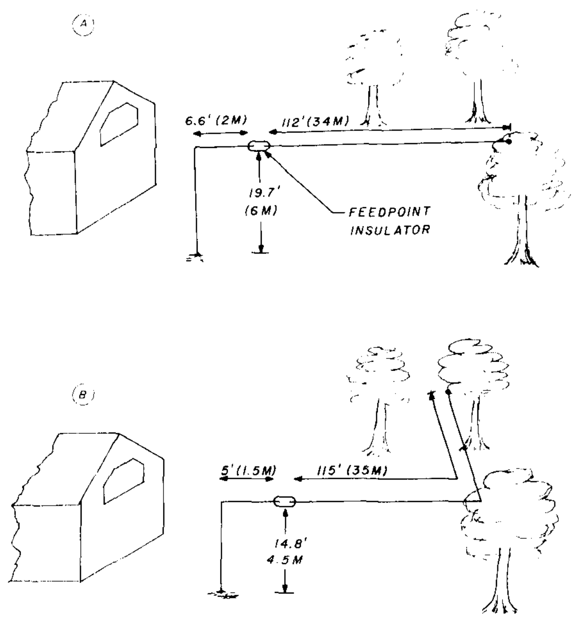

fig. 5. Low profile antenna dimensions for 160-meter operation at N9NB: (*A*) low-profile antenna for 1850 kHz – 100 kHz bandwidth (dimensions: x = 8 meters, y = 34 meters, height = 6 meters); (*B*) low-profile antenna for 1850 kHz – 75 kHz bandwidth (dimensions x = 6 meters, y = 35 meters, height = 4.5 meters).

antenna performance

I was able to obtain an SWR of less than 2.0:1 from 1800 kHz to 1900 kHz using the configuration shown in **fig. 5A** while obtaining the same SWR over a 70 kHz bandwidth for the set-up shown in **fig. 5B**.

My first evening on 160 meters with this antenna was most enjoyable, as I rag-chewed with stations from Delaware to California! Never before have I been able to call CQ and get an answer. It sure beat the RF burns and weak signals I had been used to!

I've worked over 30 states and several DX stations (including two Europeans) in the past month using only a 1-meter long ground pipe and 100 watts of transmitter power. Also incredible is the low receiver noise level. There have been many times when I could copy DX stations, while many other stateside operators could not. This antenna may be of interest to those who don't have room for Beverage antennas but want to get away from the received noise characteristics of verticals and dipoles.

The antenna seems to exhibit a moderately high angle of radiation and has a radiation pattern similar to that of a short dipole combined with a short verti-

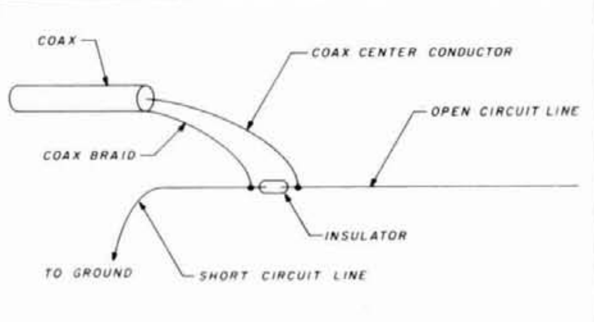

fig. 6. Simple feed method.

cal. The short-circuit line provides a vertical pattern, making this structure similar to a short vertical antenna. The open circuit wire provides some horizontal radiation, and is effective in tuning the antenna to resonance. The efficiency of this antenna is determined primarily by the ground conductivity at the antenna site. Unfortunately, soil is a very imperfect conductor. Ground radials may be used to increase efficiency, although they are not essential. In fact, a poor ground may actually be beneficial as it would prohibit complete cancellation of the horizontal current components in the far-field.

KS9J and WA2JQW have reproduced this structure at their locations using wire heights as low as 6 feet (1.9 meters) and short-circuit wire lengths as short as 8 feet (2.6 meters). They have indicated that low SWR is obtainable using an arbitrary wire configuration, at an arbitrary height, as long as care is taken to prune the antenna patiently.

conclusion

After many frustrating attempts to work the 160-meter band without an adequate antenna, I have finally found something that keeps both me and my transmitter happy. The low SWR allows for operation without an antenna tuner, and the direct coax feedline minimizes RF in the shack. Most gratifying, though, are the many new friends I have made on 160 meters and the enjoyment that contacts on the "gentleman's band" can bring!

Those who are fortunate enough to have plenty of yard space, tall trees, or a tower might not want to use this type of antenna for 160-meter operation. But those of you who think you don't have the room to get on "top band," may want to give this tuner-less, trap-less transmission line antenna a try.

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VHF/UHF WORLD

Joe Reisert W1JR

stacking antennas, part 2

Last month's column discussed the theoretical aspects of stacking antennas.[1] It was pointed out that the optimum stacking distance for two antennas occurs when the beamwidth in the stacking plane is reduced to approximately 50 percent of the original antenna beamwidth and grating lobes are about 13 dB below the main lobe. It was further stressed that the antenna to be stacked should be "clean" (low side-lobe) in order to achieve effective stacking since the 13 dB grating lobe level can't be obtained if the antenna to be stacked has 13 dB or poorer side-lobe levels to start with! Finally, it was shown that *if everything were done correctly,* a gain increase of 2.5 dB, instead of 3 dB, would be a realistic figure every time the number of antennas was doubled.

Several tables and graphs were also presented to enable you to determine the optimum stacking distance for any antenna. While all the electrical parameters are necessary, the practical feeding and physical aspects of stacking antennas are also important. Therefore, this month's column will try to tie the subject of stacking together so that you can choose the optimum configuration for your particular application.

While working on part 2 of this article I noticed that there is one caveat I neglected to point out in part 1. *All the information presented on stacking is based on having no ground reflections* (antennas in theoretical space). However, once an antenna is over 2 to 3 wavelengths above ground (a typical situation on 2 meters and above), the antenna is, for all practical purposes, in free space. At 6 meters there may be a problem since the lower antenna should be at least 40 feet (12 meters) above ground.

stacking configuration

There are literally dozens of ways that antennas can be stacked. However, only a few configurations are typically used by Amateurs.[1] Some of these are shown in **fig. 1**. (For clarity, the mechanical considerations have been omitted from the illustrations.) The simplest stacking configuration places two Yagis in either the horizontal (**fig. 1A**) or vertical (**fig. 1B**) plane. The optimum spacing between the Yagis was discussed in last month's column. I'm often asked the reference point for measuring the spacing: it is the distance between the current points — usually the boom on a Yagi. In the special case of the loop Yagi, it is the center-to-center spacing between the loops.

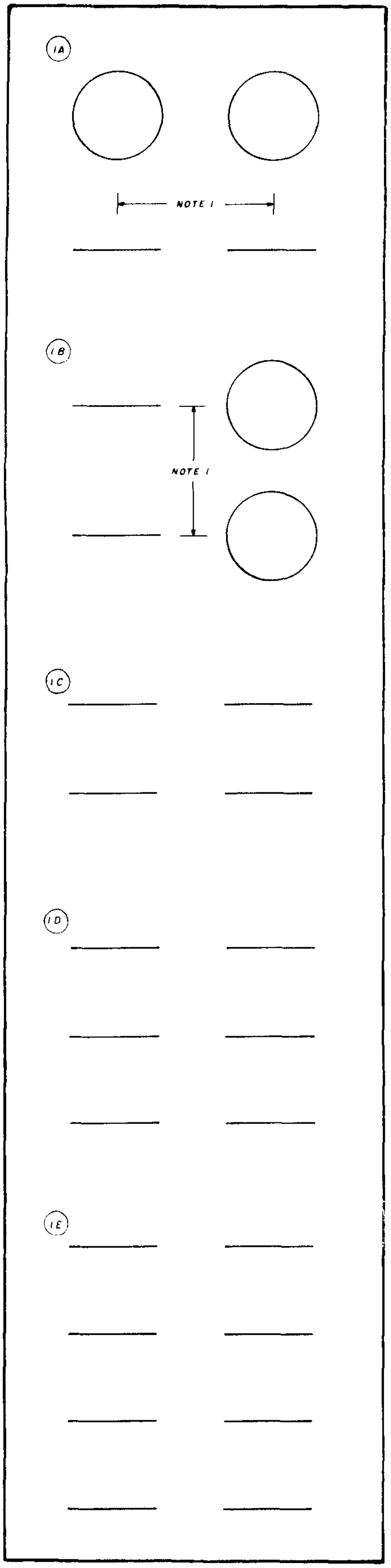
One of the most popular stacking configurations for higher antenna gain is the "quad" or "box" shown in **fig. 1C**. This is usually a simple mechanical arrangement and has almost identical beamwidth in both the vertical and horizontal planes.

An often-overlooked configuration is an array of six Yagis (**fig. 1D**), which yields a theoretical improvement of 1.75 dB and a typical increase of 1.5 dB over a four-Yagi array. This is only about 1 dB below an eight-Yagi array but with a 33 percent smaller area! This configuration is only recommended using vertical stacking as shown and has a more complex mechanical structure. However, it is particularly recommended for those who can't double their arrays but could expand a four-bay array to six antennas with minimum cost and mechanical impact. Other common high-gain configurations especially popular with EME'ers are shown in **figs. 1E, 1F,** and **1G.** These arrangements are usually the easiest to realize mechanically when very high gains are required.

vertical versus horizontal stacking

Last month's column discussed the problems associated with the side lobes in the H-plane (vertical) of a typical Yagi antenna and showed that they are normally 2 to 3 dB worse than in the E (horizontal) plane. Hence, Yagi antennas must often be stacked closer than desired in the vertical plane to control the vertical grating lobes. Consequently, vertical stacking may yield slightly less gain increase than horizontal stacking.

However, despite these negatives, there are reasons for stacking Yagis vertically. First, there is sometimes only one vertical mast available. Secondly, when very high gain is needed such as for EME, four or more antennas may be required and hence stacking some or all of the antennas vertically is often desirable. *Remember that the array beamwidth decreases only in the plane of the stacking.* Hence, if antennas are stacked verti-



cally, the horizontal beamwidth remains the same. This is particularly desirable when you don't want to "miss" stations that are slightly off the main beam such as when using tropospheric propagation. Likewise, vertical stacking is especially desirable when the signals may be up to 5 or 10 degrees off the great circle path such as in meteor scatter communications. Conversely, horizontal stacking is desirable for auroral propagation since the signal returning from the auroral curtain is usually elevated above the horizon. Horizontal stacking does not affect the vertical beamwidth of the antenna being stacked.

Finally, when high gain is required it is almost impossible to not stack in both planes as shown in **figs. 1C-1G.** If six or eight Yagis are used, you can still tailor the pattern by choosing which plane requires the greater beamwidth.

electrical considerations

After choosing the stacking configuration, there are some important electrical considerations such as choice of feed line and the placement of the power splitter/combiner(s). As mentioned in part 1, losses in the feed harness can severely reduce the gain when stacking antennas. The total loss in antenna gain due to the phasing harness is *the sum of the insertion* losses from the input of the first power splitter/combiner to the final antenna feed point on the individual antennas (see **fig. 2**). Generally speaking the major losses are in the transmission lines in the phasing harness. Note that the overall antenna gain loss shown in **fig. 2** *will only be 0.5 dB, not 2.0 dB* as I sometimes hear! However, while 0.5 dB may sound low, remember that this loss reduces the stacking gain. *Furthermore, a 0.5 dB phasing line loss* can decrease the receiver signal-to-noise ratio by 2 or more dB when looking at a "cold" sky on 70 cm EME!

From the above discussion, you can see another reason why I get so upset when I see antennas stacked too far

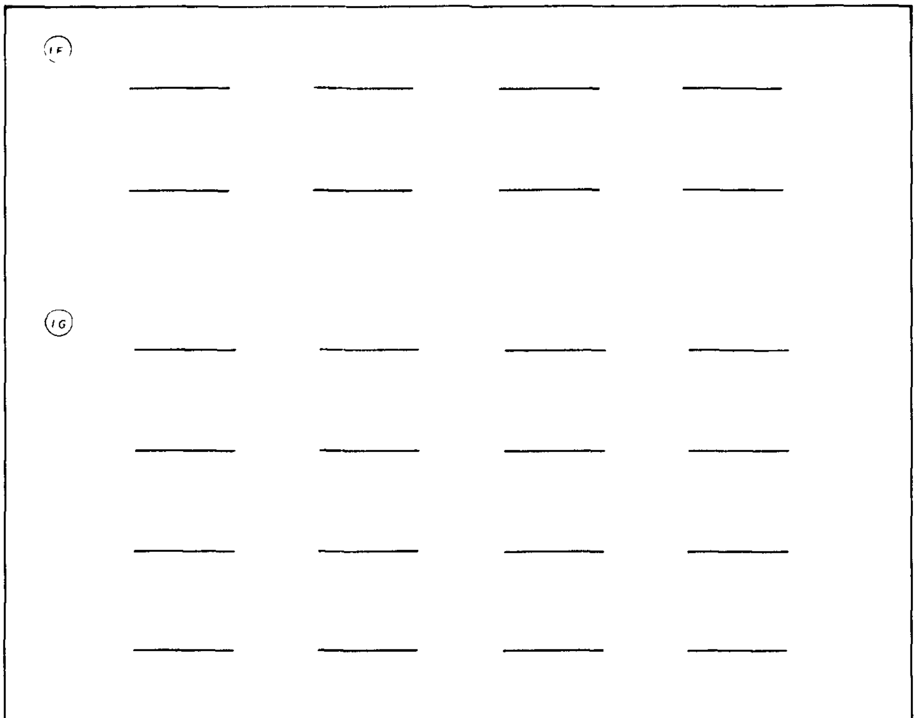


fig. 1. Typical recommended stacking configurations. *A*) horizontal; *B*) vertical; *C*) quad or box; *D*) six-way vertical; *E*) eight-way vertical; *F*) eight-way horizontal; and *G*) sixteen-way symmetrical. Mechanical details have been omitted for clarity. *Note*: reference points for determining stacking distance.

apart. The additional spacing not only increases the grating lobes and decreases the beamwidth unnecessarily but the hoped for gain increase of 0.1-0.2 dB by stacking wider than optimum may easily be offset by the extra phasing line loss. And that isn't all. The clincher against using unnecessarily greater spacing is the increased load that is placed on the rotator and structure.

feeding the array

When stacking antennas, it is common practice to have a separate phasing line on each antenna. This line is then connected to a common splitter/combiner for each 2, 4, or 6 antennas being stacked. Eight-way splitter/combiners are sometimes seen, but I personally feel that they are more difficult to use and can add additional phasing line losses. If coax phasing lines are used, each is usually run down the antenna boom to a common power splitter/combiner which is centrally located on the main mast or boom. This method is mechanically sound but often adds excessive feedline losses.

A more recent trend popular with EMEers is to use a "back plane" feed system. In this arrangement each phasing line is routed to the rear of the array rather than down the boom. The power splitter/combiner is then mounted behind the antennas, usually on a separate small boom extending from the main mast. This allows very short low loss phasing lines. The main feedline(s), which are fewer in number, can now be made from a more expensive but low-loss air or foam dielectric coax.

phasing line requirements

For best results all phasing lines should have the same overall electrical length within 22.5 degrees or 1/16 wavelength. This works out to be approximately 1.7 inches (4.3 cm) at 432 MHz. The longer the physical length of the phasing lines, the greater chance of having an unequal electrical length in these lines.

From my personal experience, I can offer the following suggestions. Always make all phasing lines from the same roll or piece of feedline. Stay away from small diameter (e.g., RG-58/U) and low-cost feedlines. If foam dielectric coax is used in a phasing harness, it should be treated carefully; it can "cold flow" when sharp bends are made and is more susceptible to variations with ambient temperature changes.

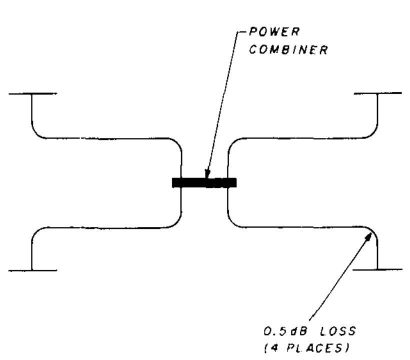


fig. 2. An example of a four-way power split showing the associated line losses. See text for full explanation and overall loss.

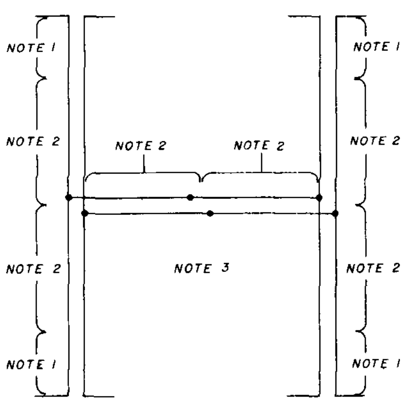


fig. 3. Recommended configuration for an open-wire line type of phasing harness. *Note 1:* quarter-wavelength of 283-ohm open-wire line. *Note 2:* identical lengths of 400-ohm open-wire line. *Note 3:* 200-ohm balanced feed point. Can be connected to a 4:1 balun or connected to another bay using similar matching schemes as shown. See text for further explanations.

From practical phasing line measurements I have conducted at 70 cm using a slotted line, I have found that a physical tolerance of 0.25 inch (6mm) on 20 feet (6.5 meters) of 50-ohm RG-213 type coax cable is more than adequate *when using the same spool or length of coaxial feedline.*

I offer another important observation. *Always lay feedlines out in a straight line and measure them in a cool place such as a garage or cellar out of the direct rays of the sun.* In some tests I conducted in my back yard, it was impossible to hold the null on a slotted line constant long enough to take an accurate reading since the sun kept changing the temperature of my coax line and hence varying the length!

open wire lines

I'm frequently asked, "Why not use open wire lines since they are low cost and low loss?" I will not argue with this statement but add the following caveat: *open wire line is a fair weather feedline. Whenever deposits (water, snow, ice, or industrial wastes) build up on the spacers, the impedance and hence the VSWR changes.*

If you decide to use open wire lines, try to keep a low VSWR on all the lines. The extended expanded collinear has a problem in this regard because the VSWR on the feedlines is very high.[2] An array of Yagis with a resistive (non-reactive) impedance is a good open wire candidate. However, use a "*Q*" or quarter-wave matching section at each point where the impedance changes. A recommended example using 200-ohm antennas and feed point is shown in **fig. 3.**

Low impedance (less than 250 ohms) open wire lines are not easy to realize since spacing is close and the conductors have a large diameter. Always use the fewest number of spacers possible and still maintain the mechanical integrity of the line. My experience with extended expanded collinears showed that the maximum power split for open wire lines should be two per junction since four ways can pose symmetry problems and congestion of lines which often leads to unequal splitting and lower gain.

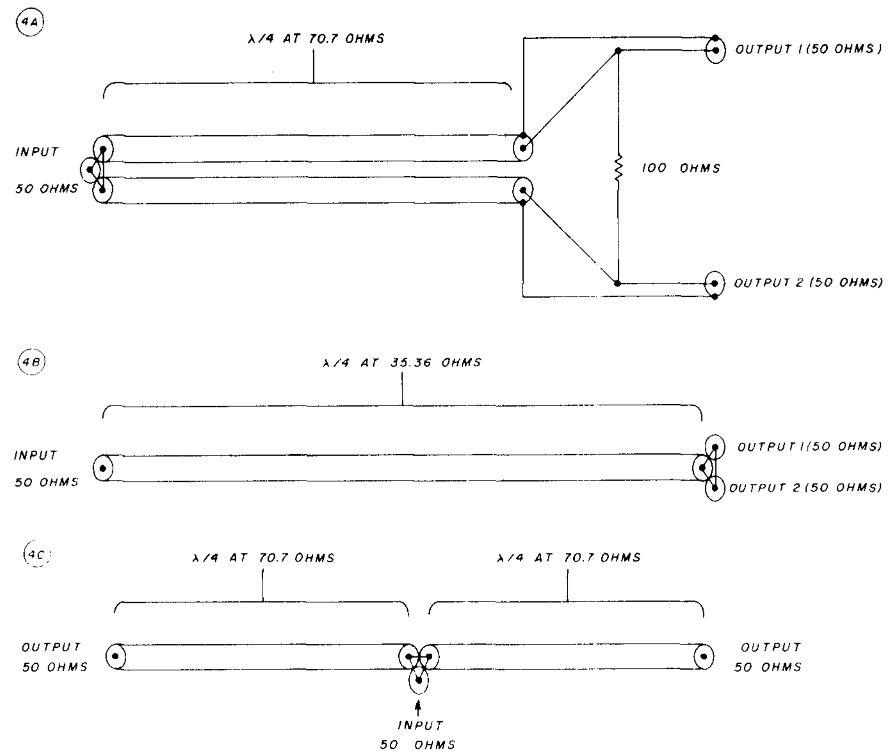


fig. 4. Some typical types of splitter/combiners. ***A*) Wilkinson hybrid; *B*) popular "*Q*" or quarter-wave section; and *C*) half-wave type. (See text for further explanation.)**

phasing line lengths

Finally, I am often asked, "Should the length of the phasing lines be a multiple of half-wavelengths?" This practice apparently started on 2 meters when two antennas were closely spaced and the feedlines were also acting as an impedance transformer.

Ideally speaking, the feedline length is unimportant if the antennas to be stacked have a reasonably low VSWR. However, when antennas are stacked, there is always some mutual impedance. It has been pointed out by Roy Lewallen, W7EL, that whenever any mutual impedance exists between antennas, the ideal phasing line length should be an odd multiple of quarter wavelengths which will enhance the proper distribution of power to each branch of the antenna.[3] He further pointed out that this practice has been in use on TV antennas for many years.[4] Although this may be difficult to realize in practice (especially on 70 cm), *if possible cut your phasing lines to an odd multiple of quarter wavelengths.*

power splitter/combiners

All the foregoing stacking information would be for naught if there weren't a convenient way to do splitting or combining at the antennas in the array. The methods shown in **fig. 3** are fine for open-wire line. Coax, however, requires different handling.

There are two basic types of power splitter/combiner(s) that work well with coax. They are the isolated (hybrid) and the non-isolated quarter wavelength types.

The isolated type shown in **fig. 4A** is often referred to as the Wilkinson power divider.[5] It uses quarter-wavelength lines between a floating resistor. The resistor doesn't consume power unless the loads are unequal or missing. This type of power splitter/combiner is not too popular with Amateurs since the resistors must be able to dissipate high power (at least half the power entering the splitter/combiner) and isolated from ground. Lewallen also indicated that this type of splitter/combiner is not recommended for antenna phasing especially when mutual impedances are present.[6] One of the most popular types of power splitter/combiners used by Amateurs with coax phasing lines is the quarter wave coaxial matching section shown in **fig. 4B**. Its impedance is the geometric mean between the input and output impedances and can be easily calculated using the following equation:

$$Z_{LINE} = \sqrt{Z_{IN}\, Z_{OUT}} \qquad \textbf{(1)}$$

where Z_{IN} is usually 50 ohms and Z_{OUT} is the parallel impedance of the loads. This method can easily be used to split or combine two, three, or four ways. For instance, the impedance of the line should be 25 ohms for a four-way split in a 50-ohm system since the source is 50 ohms and the load is 12.5 ohms (50/4). Likewise a two-way split would require a 35.36 ohm impedance. Both of these impedances are easy to realize using standard square 1 inch (2.54 cm) tubing and hobby shop brass tubing.[7,8,9]

An important attribute of well designed air dielectric splitter/combiners is that they have inherently low loss. There is no reason why they can't be extended internally as described in reference 9. Also, it is often forgotten that most quarter-wave type of power splitters are usable at the third harmonic. Therefore, a good 2-meter power splitter may be also usable at 70 cm and a 70 cm splitter at 23 cm.

Let us not forget to mention the so called half-wave power splitter/combiner. Actually it is still a quarter-wave type since it consists of two quarter-wave sections back to back as shown in **fig. 4C**. It has the added advantage that as a four-way splitter/combiner, the internal impedance is 50 ohms.

mechanical aspects of stacking

In general, try to use symmetrical

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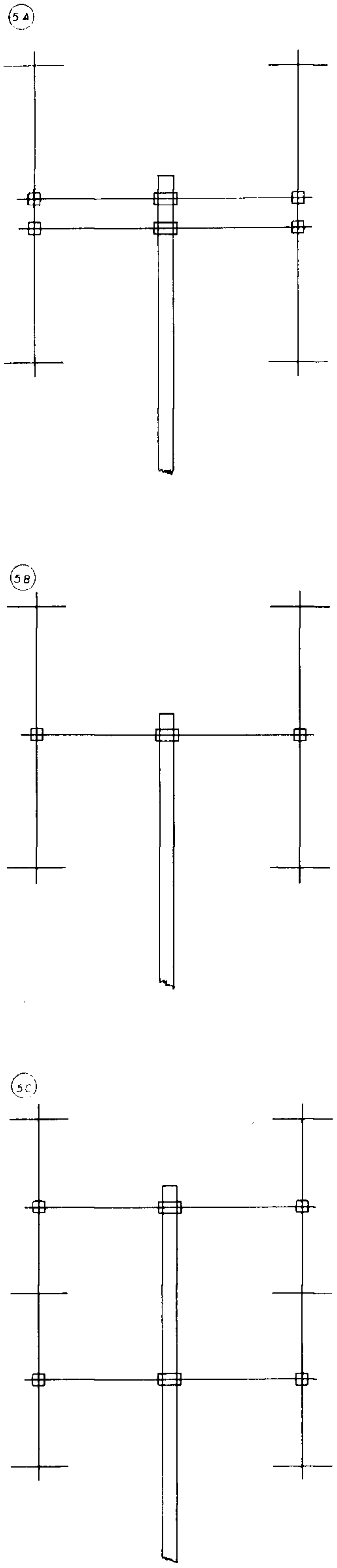
stacking configurations because they are less likely to be distorted by sagging resulting from wind or ice loading and are able to return to their intended shape after any external forces or loads are removed. Furthermore, in symmetrical configurations twisting moments are more likely to only cause a moderate decrease in performance if the mechanical structure varies more than 1/16 wavelength or 22.5 electrical degrees (as discussed earlier). Several configurations are shown in **fig. 5**. Stacking frames should be strong mechanically. Excessive weight should be avoided at all cost because it can cause mechanical distortion. The materials used — as well as their diameter and weight — should be carefully examined. The



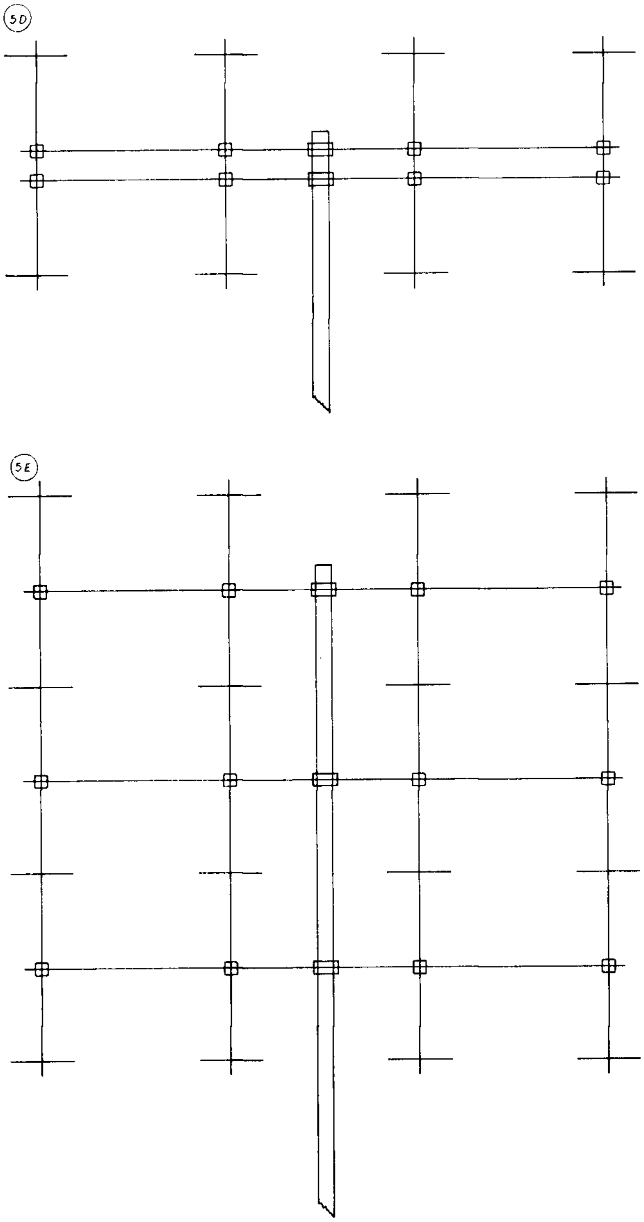


fig. 5. Typical stacking frame configurations for large Yagi arrays. *A)* recommended four-way for a quad of Yagi antennas; *B)* this is not a recommended arrangement since only a single boom connection is used; *C)* recommended six-way stacking frame; *D)* recommended eight-way stacking frame; and *E)* recommended sixteen-way.

table 1. Calculated section moduli for various popular sizes of aluminum tubing using *eq. 2* in text.

outside diameter		wall thickness		
inches	(mm)	inches	(mm)	section modulus
0.250	(6.35)	0.050	(1.27)	0.00134
0.375	(9.53)	0.050	(1.27)	0.00368
0.500	(12.70)	0.062	(1.57)	0.00839
0.750	(19.10)	0.050	(1.27)	0.01810
0.750	(19.10)	0.062	(1.57)	0.02140
1.000	(25.40)	0.062	(1.57)	0.04060
1.000	(25.40)	0.125	(3.18)	0.06710
1.250	(31.80)	0.062	(1.57)	0.06590
1.500	(38.10)	0.062	(1.57)	0.09740
2.000	(50.80)	0.062	(1.57)	0.17870
2.000	(50.80)	0.125	(3.18)	0.32500
2.500	(63.50)	0.062	(1.57)	0.28450
3.000	(76.20)	0.050	(1.27)	0.33610
3.000	(76.20)	0.062	(1.57)	0.41490
4.000	(101.60)	0.050	(1.27)	0.60510
4.000	(101.60)	0.062	(1.57)	0.74930

ARRL *Antenna Book* has an excellent table listing the weight per unit length of most popular aluminum tubing sizes.[10] Furthermore, to prevent bending moments, it is often better to use a slightly thinner wall larger diameter tubing than vice-versa.

The "section modulus" is an excellent way to compare the relative bending moment of various tubing diameters with different wall thicknesses.

$$\text{section modulus} = 0.098\,[(D^4 - d^4)/D] \qquad (2)$$

where D is the outside and d is the inside diameter of the tubing. Typical values of section moduli on some popular tubing sizes are shown in **table 1**. Note, for example, that a 3 inch (7.6 cm) diameter tube with a 0.050 inch (1.27 mm) wall has a higher section modulus and is lighter weight than a 2 inch (5 mm) diameter tubing with a 0.125 inch (3.2 mm) wall thickness. Other values not listed on the table can be easily calculated using **eq. 2**.

Mechanical symmetry of the stacking frame also tends to keep all antenna pattern blockages equal. Likewise, wherever possible, the phasing and feedlines should be neatly and symmetrically dressed and secured to a boom. Stacking frames should have several points of support. Sometimes tower sections are used for the main boom on large arrays! Judicious use of guy wires preferably at right angles to each other with adjustable turnbuckles is also recommended.

Finally, try to pass booms and masts at a mid-point between antennas rather than adjacent to them. If the material or boom used in the stacking frame passes through an antenna pattern, it will have little effect as long as it is at right angles to the plane of polarization and/or is less than 1/10 wavelength in diameter when passing through in the plane of polarization.

other configurations

So far I have been discussing the common arrays. There are many other possibilities. When really high gain is required, a large array of antennas may be constructed. Amateur arrays using 24 Yagis are already in use on 2 meters and 70 cm and a 32-Yagi 2-meter array is under construction! Basically, these arrays are configured using combinations already mentioned. For instance, a 24-bay array can be constructed by stacking three eight-Yagi bays per **fig. 1E** along a main boom. A single three-way splitter/combiner at the center of the array combines the three eight-bay sub-arrays.

Besides the monstrous mechanical problems associated with very large arrays, feedline losses and phasing errors are probably the biggest source of performance degradation. Always try to use the largest and lowest loss phasing lines available. Finally, before constructing a large array, consider whether you are willing to accept all the mechanical risks — it will be large enough! Failure to do so may reduce performance to the point that you may have no more gain than with a smaller array!

final checkout

Whenever stacking is employed, each item should be checked in a methodical fashion. First off, the VSWR of each antenna in the array should be low, preferably 1.2:1 maximum. If coaxial lines are used, *each antenna should be VSWR tested after the antennas are mounted in the array*.

Next, connect the individual antennas into the associated power splitter/combiner in each grouping and test the VSWR again. Then, if applicable, test the entire array.

Be absolutely certain that all antennas are fed on the same side of the array so that 180-degree phase reversals do not occur. Preferably, mount all antennas the same way. If you decide to mount some upside down, make sure to reverse the feed attachment point. Recently, one major antenna manufacturer had a connector plate reversed on some of their antennas.[11] This did not affect performance until two antennas were stacked. Phase reversals of this type can cause radiation patterns to skew or even produce nulls where radiation would normally be present.

Finally, after final assembly and testing, measure antenna azimuthal and elevation patterns, if possible, using the methods described in reference 11. If the antenna pattern does not peak right on boresight (within 1 to 2 degrees) or if the anticipated beamwidth or level of the side lobes is not the value anticipated, as discussed earlier, recheck all electrical and mechanical parameters to find the problem.

summary

In this two-part series, I have tried to cover the major electrical and mechanical considerations required for properly stacking antennas for increased gain. Stacked antennas should be used only when the gain required is beyond that attainable using a single antenna. Remember at the outset that you will be lucky to achieve 2.5 dB of gain increase for every doubling of the array size.

Before building an array that requires stacking, plan carefully. Review both parts of this article several times. Many alternative configurations have been discussed, with pros and cons. Stacking antennas is not a simple job and there are many pitfalls. Both electrical and mechanical decisions must be made. If properly executed, the results can be rewarding. Hopefully the material presented will be useful in building your new super-high-gain array!

acknowledgements

I would like to thank C.J. Beanland, G3BVU, for introducing me to the use of section modulus when comparing different tubing sizes.

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important VHF/UHF coming events

May 1:	*ARRL 70-cm Sprint Contest*
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May 4:	*EME perigee*
May 4:	*1300 UTC, predicted peak of the Eta Aquarids meteor shower*
May 9:	*ARRL 23-cm Sprint Contest*
May 17-19:	*Eastern VHF/UHF Conference, Nashua, New Hampshire, (Contact W1EJ for information)*
May 19:	*ARRL 6-Meter Spring Contest (tentative date)*
June 1:	*EME perigee*
June 5:	*1930 UTC, predicted peak of Arietids meteor shower*
June 8-9:	*ARRL VHF QSO Party*
June 29-30:	*SMIRK 6-Meter Contest*
June 15:	*0400 UTC, predicted peak of June Lyrids meteor shower*
June 21:	*Mean date of the two-month annual peak of sporadic-E propagation*
June 29:	*EME perigee*

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The correct selection of RF transmission cable requires proper analysis of the electrical and physical parameters of the system.

The amateur microwave enthusiast should be aware that even though materials and dimensions specified by manufacturers are usually accurate, changes in physical and environmental conditions as well as different types of manufacturing equipment or different manufacturing conditions can lead to cable with **substantially** different performance characteristics.

VSWR uniformity

The VSWR of a cable assembly is the summation of reflections due to the connectors, the connector termination technique and the cable. The VSWR of the cable is the summation of random and periodic reflections within the cable, most commonly caused by variations within the processing equipment. The VSWR **will** vary with frequency. A common occurrence is the VSWR "spike" which is illustrated in **fig. 1.**

characteristic impedance

The characteristic impedance of a coaxial cable is determined by the ratio of the inner diameter of the outer conductor to the outer diameter of the inner conductor and by the dielectric constant of the insulating material between the conductors. Select impedance to match your system requirements.

The most common values for coaxial cables are 50, 75, and 95 ohms. Other impedances from 35 to 185 ohms are available in coaxial configurations, but these are normally of interest only to the industry.

Note that the actual input impedance at a particular frequency may be quite different from the characteristic, or surge impedance of the cable due to reflections in the line. The VSWR of a particular length of cable is an indicator of the difference between the actual input impedance of the cable and its average characteristic impedance.

The impedance **will** vary along the length of the cable. Variations of 5 percent are common and some mil spec cables are manufactured to 2 percent tolerance.

capacitance

Capacitance values for standard coax lines depend only on cable impedance and dielectric material.

nominal capacitance pF/foot	cable types
30.8	50 ohm solid polyethylene
25.4	50 ohm foam polyethylene
29.4	50 ohm solid PTFE (Teflon)
20.6	75 ohm solid polyethylene
16.9	75 ohm foam polyethylene
19.5	75 ohm PTFE
16.3	95 ohm solid polyethylene
13.5	95 ohm air space polyethylene RG62B
15.4	95 ohm solid PTFE
10.0	125 ohm air space polyethylene RG63B
6.5	185 ohm air space polyethylene RG114A

capacitance and impedance stability

The capacitance and impedance of long lengths of cable will exhibit very little change over their operating temperature ranges (less than 2 percent). Semi-flexible foam dielectric cables normally exhibit the least change in short cable lengths at frequencies over 1 GHz, although the VSWR can vary significantly if dielectric movement at the connector interface occurs.

average CW power rating

Coaxial cable power ratings must be derated by correction factors for the ambient temperature, altitude (admittedly not of much concern to the Radio Amateur) and VSWR encountered in a particular application. High ambient temperature and high altitude reduce the power rating of a cable by impeding the

By Howard Weinstein, K3HW, 15 Lakeside Drive, Marlton, New Jersey 08053

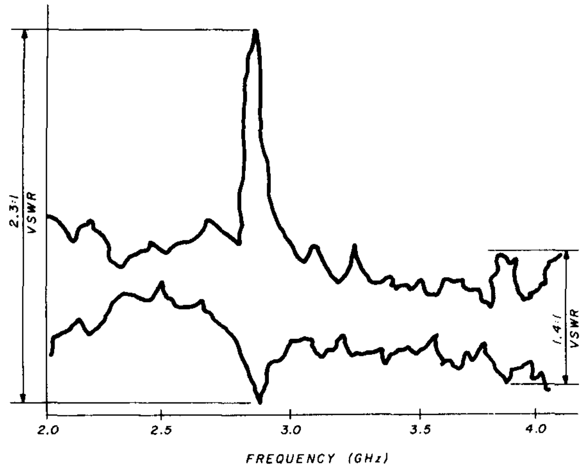


fig. 1. Dual trace pattern illustrates VSWR excursion versus frequency for a 16-foot (5 m) length of 3/4 inch (1.9 cm) 50-ohm cable.

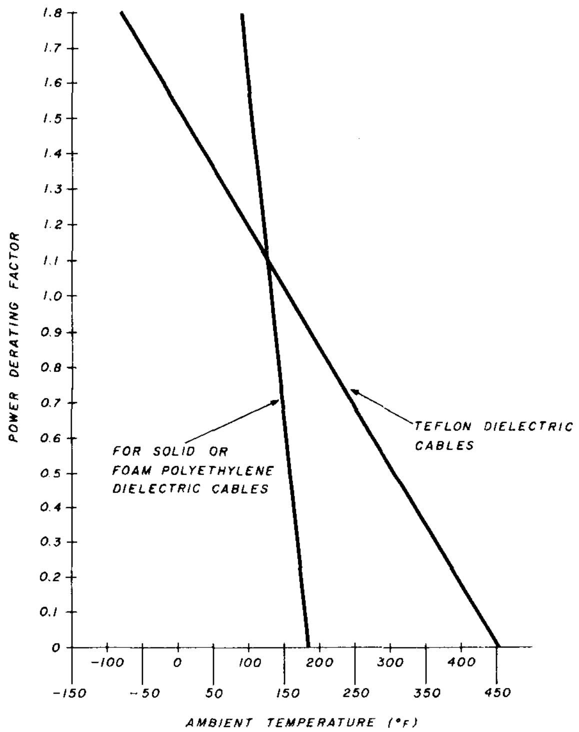


fig. 2. Temperature correction for polyethylene and teflon cables.

heat transfer out of the cable. VSWR reduces power ratings by causing hot spots.

To select the cable construction for a particular requirement, determine the average input power at the highest frequency from your station's requirements.

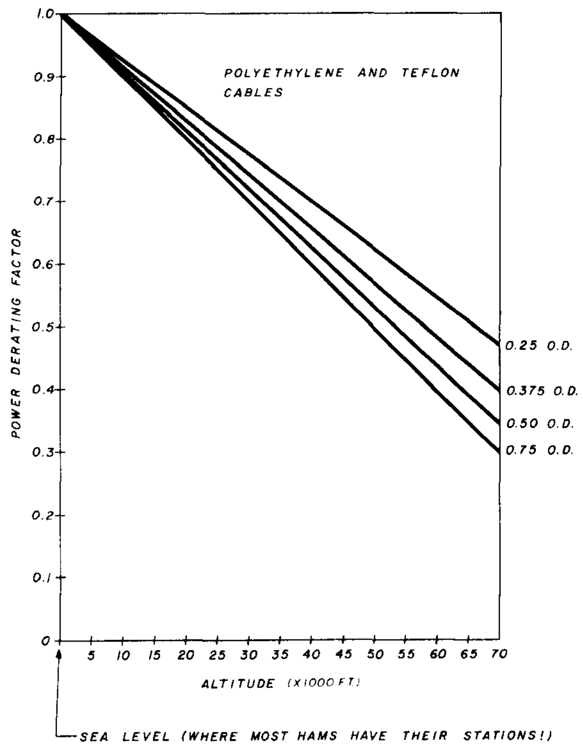


fig. 3. Altitude correction for polyethylene and teflon cables.

Then determine the effective average input power with the following formula:

$$\textit{effective power} = \frac{\textit{average power} \times \textit{(VSWR correction)}}{\textit{(Temp. correction)} \times \textit{(Alt correction)}} \quad \textbf{(1)}$$

Temperature and altitude corrections are illustrated in **figs. 2** and **3.**

VSWR correction factor

$$= 1/2(VSWR + 1/VSWR) + 1/2K' \bullet (VSWR - 1/VSWR) \quad \textbf{(2)}$$

(K' is shown in **fig. 4.**)

maximum AC operating voltage

A cable cannot operate continuously with corona because it causes noise generation, dielectric damage and eventual breakdown. The maximum operating voltage must be less than the corona level (extinction voltage) of the cable. This is not to be confused with the dielectric strength of the cable, which is the test voltage applied for one minute during manufacture.

Maximum operating AC (RMS) voltage levels or peak voltages are given for each type of cable in many manufacturer's catalogs. Usually the maximum permissible DC voltage level is 2.5 to 3 times the AC level.

To determine the actual RMS value, divide peak voltage by 1.4. To determine the peak voltage, multiply RMS by 1.4. Then determine the effective input voltage by multiplying the actual input voltage by the square root of VSWR.

The cable you select should have a maximum operating voltage specification greater than the effective RMS voltage.

attenuation

The attenuation of any cable may not change uniformly as the frequency changes. Random and periodic impedance variations give rise to different attenuation responses. Narrow band attenuation spikes can occur.

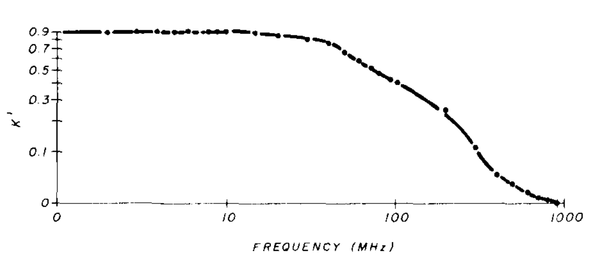


fig. 4. VSWR correction (multiplier K') for average curve.

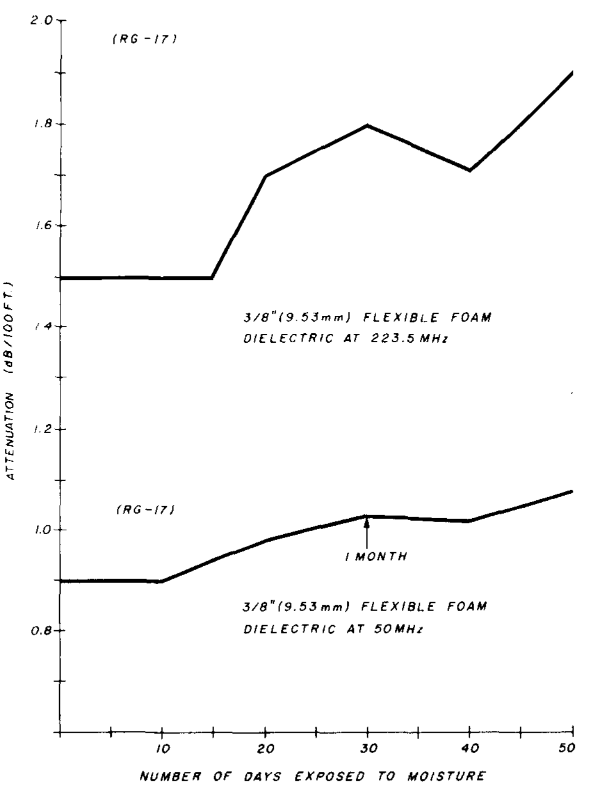


fig. 5. Cable attenuation increases with both frequency and duration of exposure to moisture.

The attenuation of braided cables can increase with time and flexure. The change with time can be caused by corrosion of the braided shield, by contamination of the primary insulation caused by chemicals in the cable jacket, and by moisture penetration through the jacket. Attenuation degradation is more pronounced at frequencies above 1 GHz. Cables having bare copper and tinned copper braids exhibit far greater attenuation degradation than do cables having silver plated copper braids. Refer to **figs. 5, 6,** and **7.**

The following "rules of thumb" apply in Amateur service:

Tin-plated braids. Below 1 GHz, cables manufactured with tin-plated braids have at least 20 percent more attenuation than copper braids in the "as manufactured" condition, but are more stable than bare copper-braided cables.

Foam polyethylene. Flexible braided cables with foam polyethylene dielectrics have approximately 15 percent less attenuation that solid polyethylene cables of the same core size and impedance. However, as many of us have discovered, the attenuation of foam cables will increase if moisture is absorbed. In high humidity environments I suggest that foam cables not be used above 148 MHz. All of these problems can be eliminated by the use of semi-flexible cables; semi-

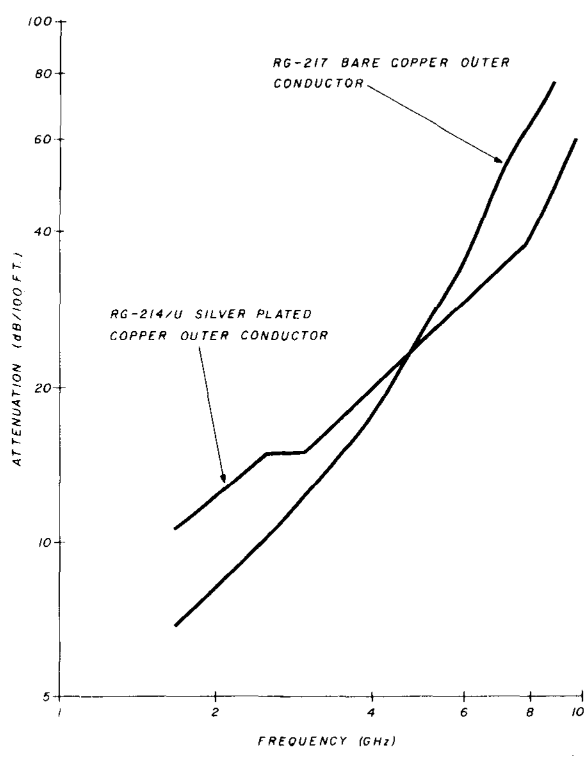


fig. 6. Both RG214 and RG217 exhibit similar attenuation characteristics vs. frequency.

table 1. Formulas common to all coax cable.

$$Capacitance\ (C) = \frac{7.36E}{LOG(D/d)}\ Picofarads/ft$$

$$Inductance\ (L) = 0.140\ LOG(D/d)\ Microhenries/ft$$

$$Impedance\ (Z_0) = \sqrt{\frac{L}{C}} = \frac{138}{\sqrt{E}}\ LOG\ (D/d)\ ohms$$

Velocity of propagation as percentage of speed of light $= \dfrac{100}{\sqrt{E}}$

$$Time\ delay = 1.016\ \sqrt{E}\ nanoseconds/ft$$

$$Cutoff\ frequency = \frac{7.50}{\sqrt{E}\ (D + d)} = F_{co}\ (GHz)$$

$$Reflection\ coefficient = \Gamma$$

$$= \frac{Z_r - Z_0}{Z_r + Z_0} = \frac{VSWR - 1}{VSWR + 1}$$

$$VSWR = \frac{1 + \Gamma}{1 - \Gamma}$$

$$Peak\ voltage = \frac{1.15\ S \cdot d\ (LOG\ D/d)}{K}$$

$$\alpha = \frac{0.435}{Z_0\ (D)} \left[\frac{D}{d} \cdot K_1 + K_2\right] \sqrt{F} + 2.78\ \sqrt{E}\ (P.F.)\ (F)$$

where: α = attenuation in dB/100 ft
d = the outside diameter of inner conductor in inches
D = the inside diameter of outer conductor in inches
S = the maximum voltage gradient of the cable insulation in volts per mil (thousandth of inch)
E = the dielectric constant of the insulation of the cable
LOG = logarithm to base 10
K = safety factor
K_1 = strand factor
K_2 = braid factor
F = frequency in MHz
$P.F.$ = power factor

property of insulating material (dielectric constant "E")

material	dielectric constant "E"
TFE	2.1
polyethylene	2.3
cellular polyethylene	1.4-2.1
polyvinylchloride	3.00-8.00
silicone rubber	2.08-3.50
ethylene propylene	2.24

flexible cable is generally not available to the average ham. Its price is also prohibitive, rising into the *dollars-per-foot* price range.

It is possible however, to use foam polyethylene cable up to 12 GHz. The only catch is that it must be protected from the environment by either running it through a conduit with forced dry air pumped under pressure or sheathing it in a seamless metallic tube.

velocity of propagation

The velocity of propagation of cable is determined primarily by the dielectric constant of the insulating

materials between the conductors. This property is expressed as a percentage of the velocity of light in free space.

cable dielectric	time delay nanosec/ft	velocity percentage
solid polyethylene	1.54	65.9
foam polyethylene	1.27	80.0
foam polystyrene	1.12	91.0
air space polyethylene	1.17	86.0
solid teflon	1.46	69.4
air space teflon	1.16	87.5

cable noise

An area often overlooked by Amateurs is self-generated cable noise, a phenomenon noted whenever a cable is flexed. Both acoustical and electrical noise are generated. This problem can be minimized by properly securing cable to rigid physical structures during antenna system installation.

Most prevalent in the "RG" series cables (RG-8, RG-213, RG-58, etc.) and should be carefully considered by hams who are concerned with feedline performance.

environmental resistance

The life of a coaxial cable depends on many factors other than the materials used in manufacture. The following factors all contribute to cable failure.

UV exposure. Polyethylene-jacketed cable has twice the life expectancy when exposed to direct sunlight as cable manufactured with PVC (Polyvinyl chloride) jackets.

Humidity. All cables experience vapor transmission through their plastic jackets. In Amateur applications it is advisable to install cable where it will not lie in or pass through an area where standing or running water is present.

Salt-water immersion. The electrical characteristics of cable will be rapidly affected if the conductors are exposed to salt water. If you live near a large body of salt water inspect your coax regularly for salt build-up. If your cable should become immersed, try to test the cable with a TDR (time-domain reflectometer) or find someone who can "sweep it" over the frequency range that your antenna system operates.

Underground burial and galvanic action. If you are going to install antenna cable underground, use armored/waterproof coaxial cable or regular "RG" cable installed in conduit or similar protective pipe or tubing.

selection guide

For the Amateur interested in communications through 50-MHz, RG-58 and RG-59 are prudent and inexpensive choices, though their power handling

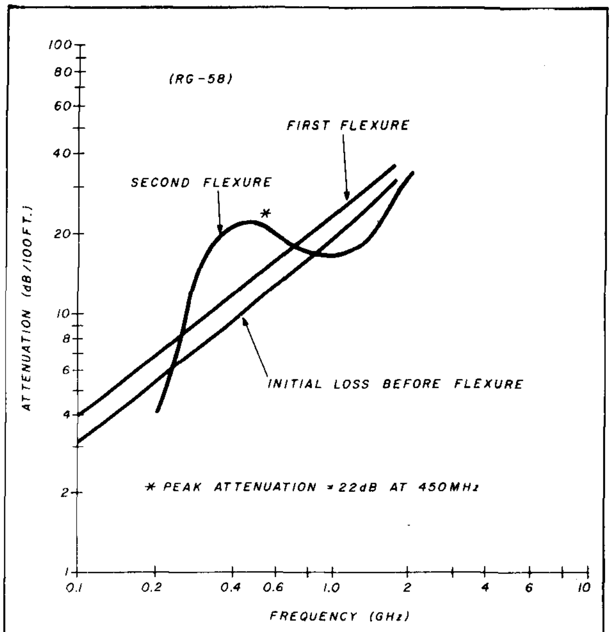


fig. 7. Repetitive flexure of RG-58 cable increases its attenuation characteristics.

capability is limited to 250 watts for RG-58 and 450 watts for RG-59.

A station designed to operate through 148 MHz should incorporate RG-8 or RG-213 coaxial cable. Unfortunately, the 3-dB roll-off point is just below 200 MHz. 220-MHz operation is possible, but 50 percent of transmitted power will be lost in a typical 100 foot run.

Many exotic transmission lines are available for 220 MHz and above. Flexible foam dielectric cable (FM-8 or FM-11, similar to RG-8 and RG-11) is useful up to 450 MHz but very susceptible to moisture penetration.

Flexible low loss cables are manufactured with braids of flat strips of silverplated copper. This helps to lower the VSWR and reduce attenuation above 1 GHz. Type SF-226, for example, is good through 10 GHz and its outside diameter is not much larger than that of RG-8.

For operation above 10 GHz I suggest using corrugated tubular aluminum with foam teflon dielectric, which is available in 3/8-inch OD for operation through 15 GHz. This cable is similar in appearance to the "BX" type of electrical conduit. The bend radius of this cable is 2.0 inches — an important fact to remember during installation.

The most popular coaxial cable among microwave enthusiasts is "hardline" or semi-flexible foam dielectric cable. It is available in various ODs, but for coverage through 22 GHz 1/4-inch OD is your best choice. Although this cable is quite expensive, CATV companies will occasionaly discard it because of minor imperfections or oxidation on the outer jacket. This discarded cable is suitable for Amateur service. The only real problem with its use and installation is the proper attachment of connectors; this task should be farmed out to your local Amateur microwave expert or to your local cable connector technician!

For use above 22 GHz, tubular copper telfon dielectric cable has *no* radiation loss except at the connector interface. An example is CL-50087T, which is good through 60 GHz. Difficult to work with and very expensive, this type of cable is used in military avionics.

conclusion

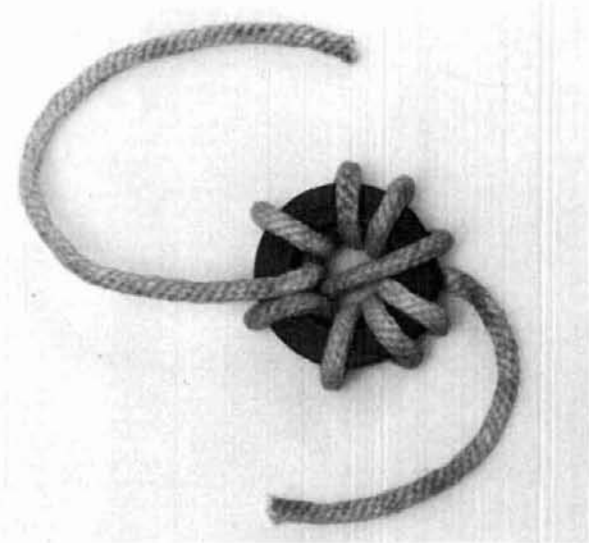
Considering the many electrical and physical characteristics that must be analyzed, selection of RF coaxial cable is really quite complicated. Knowing these parameters is important when attempting to design a communications system for optimum performance.

I am willing to provide additional information on cable, connectors, and installation procedures. Please send requests to my home address, which appears at the beginning of this article. (Please be sure to enclose a legal-size SASE with 3 first-class stamps or IRCs; only inquiries with SASEs can be answered.)

ham radio

balun chop suey

A collection of odds and ends on 1:1 transmission-line baluns



A toroidal core with a super-toroid winding. This core is wound with clothesline for photographic purposes.

In San Francisco's famous Chinatown, I learned a secret: the words "chop suey" mean "odds and ends," which is apparently what that familiar Chinese dish is composed of. This article, a collection of odds and ends about 1:1 transmission-line baluns, is based on comments and questions I have been asked as a result of my previous balun articles. None of the individual comments is long enough to warrant separate articles — hence the peculiar title. These odds and ends also refer to balun articles presented by other writers. I hope this discussion will interest balun users and designers alike.

introduction

First, to establish a frame of reference, I plan to discuss transmission-line baluns with input-output impedance ratios of 1:1. The transmission line is wound into an inductance, usually on a ferrite form, either a rod or a toroid.

A balun serves two purposes: first, to provide equal and opposite voltages to a balanced load, and second, to provide isolation between the coax outer conductor and the half of the balanced antenna connected to the outer conductor. Because the second is the more difficult problem, I will limit my discussion to it.

The isolation requirement of a balun has been well defined qualitatively by Walter Maxwell, W2DU.[1] Maxwell's article was the first to describe, in the Amateur literature, the concept of separate currents flowing on the inside and outside of the outer conductor, representing the signal current and unbalanced currents, respectively. I have found this concept helpful in describing the isolation function of a balun, both in a previous article[2] and in this one. I will expand on Maxwell's comments by giving some numbers to specify isolation quantitatively.

isolation

The isolation function of a balun is to provide a high impedance between the outside of the outer conductor, and that half of the dipole antenna connected to the outer conductor, without affecting the current flowing on the inside of the outer conductor to its half of the dipole. Very little appears to have been published, at least in the Amateur literature, either quantitatively or qualitatively, on the isolation property of a balun.

Briefly, isolation is necessary to ensure that the signal current flowing on the inside of the outer conductor flows into the antenna, not back down the outside of the outer conductor to ground. Lack of sufficient isolation is one reason antenna currents become unbalanced.

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In its simplest terms, the situation can be considered as a circuit problem. To ensure that the transmission-line current flows into the antenna and not back down the outside of the outer conductor, the impedance provided by the path down the outside of the outer conductor should be many times that of one-half the dipole antenna. For example, if the impedance of the dipole antenna is assumed to be 70 ohms, the impedance of one-half the dipole will be 35 ohms. By making the impedance of the balun to these "outside" currents 10 times this impedance, or 350 ohms in this case, at least 90 percent of the transmission-line current will flow into the antenna and less than 10 percent back down the outside of the coax.

A balun impedance of five times the load impedance (as used above) is an arbitrary figure, although I feel it should be adequate for a general-purpose balun. For a precision balun, one might prefer an isolation of, say, 10 or more times the impedance presented by one-half the total load. In a transmission-line balun, the isolation is provided by the inductive reactance of the winding. The isolation actually provided by a given balun can be determined by measuring the inductive reactance as described in reference 2.

Assuming a linear inductor, as long as the operating frequency is well below the self-resonant frequency of the inductor, the inductive reactance will be directly proportional to frequency. Therefore, there will be a frequency below which the inductive reactance will not be sufficient to provide the required isolation between the antenna and the coax feedline. This determines the low frequency limit of the balun.

The maximum usable frequency of a balun is limited by the stray capacitance across the winding. As the operating frequency increases, a frequency will be reached where the stray capacitance across the balun resonates with the inductance of the winding so that the winding is in parallel resonance. At this frequency the impedance of the balun, and hence its isolation, is the maximum it will be, so that this is a desirable frequency at which to operate. As the operating frequency is further increased, the reactance of the balun becomes capacitive and decreases with frequency until the balun becomes series-resonant. At this frequency the balun impedance is very low and the balun provides virtually no isolation at all. The upper useful frequency limit of the balun is usually between the parallel and series resonant frequencies. The actual frequencies are a function of the construction techniques, the object being to maximize the inductance and minimize the stray capacitance across the winding. (This problem is a subject in itself.)

Fig. 1 shows the inductive reactance versus frequency of a typical transmission-line balun. From a graph such as this, the useful frequency range of the balun can be easily determined for any value of load

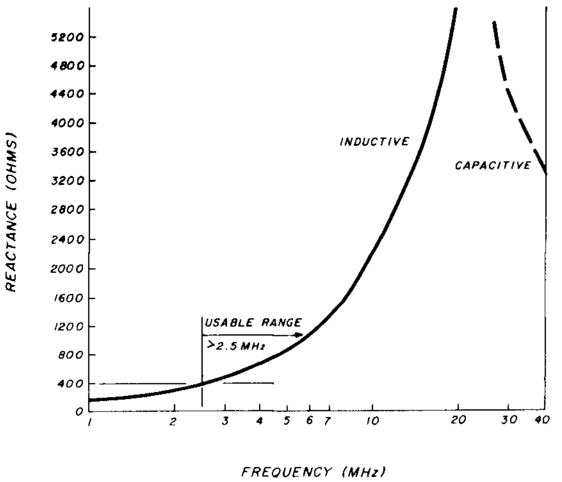

fig. 1. A typical balun reactance versus frequency characteristic. Isolation is at least five times the characteristic impedance from 2.5 MHz to above 40 MHz. (From reference 2.)

impedance. The assumed isolation impedance of five times the load impedance, based on VSWR considerations, has been arrived at by others.

To put the isolation property of a balun on a sound technical basis from the user's point of view, I believe balun manufacturers should specify the minimum ratio of the balun winding impedance to the characteristic impedance over the specified frequency range.

testing core saturation

The methods used for testing a balun for core saturation are simple; one method is to wrap a few turns of insulated wire around the balun, as shown in **fig. 2**, and then connect this winding to an oscilloscope to observe the waveform. Gradually increase the output power of the transmitter until a distorted waveform appears. Then back off the power until the waveform again becomes sinusoidal. This represents the maximum peak power a given balun can handle.

A more sensitive version of this method involves connecting the test winding to a spectrum analyzer, instead of an oscilloscope, and measuring the amplitude of the various harmonics. Care must be taken here, however, to make certain the harmonics measured are generated by the balun and not by the transmitter.

An even more sensitive test is to use the RF equivalent of the two-tone test used to measure intermodulation distortion on high-fidelity audio equipment or receiver front-ends. Here two transmitters operating on slightly different frequencies are connected to the balun (and a dummy load) through a diplexer. This test

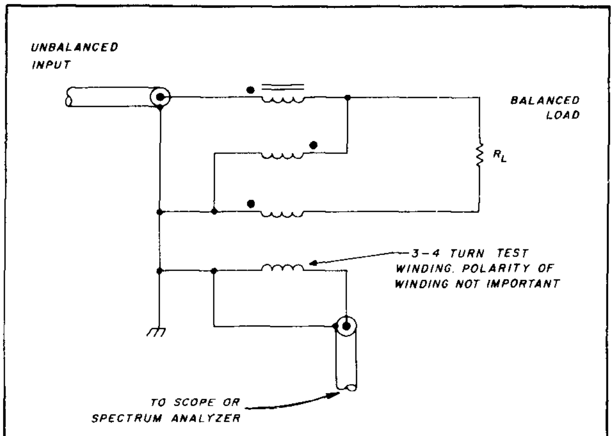

fig. 2. Circuit for core saturation test.

was proposed by Rich Rosen, K2RR, editor-in-chief of *ham radio*; I have not tried it myself.

If saturation is present, it can be corrected by increasing the number of turns, or by using a larger core (cross section), or both.

Increasing the number of turns will also have the effect of improving the performance of the balun at the low end of the frequency range. It will also lower the high-frequency end of the range by reducing the self-resonant frequency of the winding.

If the existing winding efficiently uses the available winding area, it will be necessary to increase the size of the core to accommodate the additional turns unless it is possible to use smaller wire. However, in a transmission-line balun the wire size may be dictated by the desired (or required) characteristic impedance of the winding; the wire diameter and spacing — being parameters — determine the characteristic impedance of the winding.

While the equipment needed and the procedures are relatively simple, the practical problems of testing baluns can be substantial. First, it takes a high-power transmitter and a high-power, preferably balanced, dummy load. Most Amateurs, however, will probably use an unbalanced load because this type is the most readily available. Care must be taken that the load case is well insulated from ground because the case will be at one-half the unbalanced line voltage when used as a balanced load.

The transmitter must be capable of providing the highest power level at which the balun is expected to operate. The balanced dummy load, of course, must be capable of dissipating this amount of power.

A more convenient load, at least if you are testing the balun for your own use, is to use the regular station antenna. (Choose a time when the band is dead!) The problem here is that the balun will be high in the air, requiring long test leads in a high-power antenna field, because RF can be picked up by the line and result in inaccurrate measurements.

transformers or inductors?

One of the principal sources of confusion in balun design, construction, and use seems to be the belief that all baluns are transformers. One well-respected writer recently stated "It is important to recognize that a 4:1 or a 1:1 balun . . . is essentially a broadband transformer." If he had stopped to think about it, I'm sure this writer would have known better. Strictly speaking, any device or collection of components which transforms a balanced line to an unbalanced line *can* be called a transformer; in electronics the expression "transformer" is usually reserved for one particular type of device where all, or part, of the energy passes from input to output by means of magnetic induction. The usual two-winding or three-winding 1:1 transmission-line balun, however, is not a transformer because none of the energy is transmitted from input to output by magnetic induction. This type of balun should not be designed, tested, or used as a transformer. A 1:1 transmission-line balun is an inductor wound with a transmission line and must be designed, tested, and used as an inductor wound with a transmission line. Failure to recognize this difference in design or application is almost certain to lead to disappointment in the use.

Further complicating the situation is the fact that a transmission-line balun can be constructed with impedance transformation ratios other than 1:1, although I have not seen this done in Amateur applications. The common 4:1 balun is really an auto-transformer and not a transmission line device.

A broadband transformer, on the other hand, must be designed in accordance with well-known transformer equations relating the number of turns, the peak voltage, and the allowable maximum magnetic flux density in the core.

A second means of distinguishing between transformer and transmission-line baluns is that with a transformer balun, the relationship between the load impedance and input impedance is the turns ratio squared. With a transmission-line balun, the load-to-input impedance ratio is calculated using the more complex transmission-line equation:

$$Z_{in} = \frac{Z_{ch}\,(Z_r \cos\theta + jZ_{ch} \sin\theta)}{(Z_{ch} \cos\theta + jZ_r \sin\theta)} \tag{1}$$

There are two problems in designing transmission-line baluns. The principal problem is designing a wideband inductor, i.e., an inductor whose reactance is above a given value — usually five to ten times the load impedance — over the desired range of frequencies. The second problem is designing a suitable trans-

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103	115	127	139	151	163	175	187	199	211	223	235	247	259	271	283	295	307	319	331	343
104	116	128	140	152	164	176	188	200	212	224	236	248	260	272	284	296	308	320	332	344
105	117	129	141	153	165	177	189	201	213	225	237	249	261	273	285	297	309	321	333	345
106	118	130	142	154	166	178	190	202	214	226	238	250	262	274	286	298	310	322	334	346
107	119	131	143	155	167	179	191	203	215	227	239	251	263	275	287	299	311	323	335	347
108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	312	324	336	348
109	121	133	145	157	169	181	193	205	217	229	241	253	265	277	289	301	313	325	337	349
110	122	134	146	158	170	182	194	206	218	230	242	254	266	278	290	302	314	326	338	350
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mission line, with the required characteristic impedance, capable of being wound on a ferrite core.

Briefly summarizing, because of the similarity in the appearance and circuit configuration of different types of baluns and transformers, both of which use magnetic cores, there is considerable confusion about their operating characteristics. This in turn leads to improper design and application of the devices. Before criticizing a device, one should make certain it has been properly designed and used.

the super-toroid

The super-toroid balun design was introduced to the Amateur community by Reisert in his article on the two-winding transmission-line balun.[3] The concept of a super-toroid, however, was developed by Tom Gross in the early 1960's; Gross is a designer of precision magnetic components who specializes in devices operating at supersonic frequencies — 20 kHz to 500 kHz and up. The purpose of the super-toroid design is to reduce the sensitivity of the conventional toroidal coil to external magnetic fields.

Contrary to popular belief, a single-layer toroidal inductor is sensitive to external magnetic fields because of what is known as the one-turn effect. With a conventional, single-layer toroid, the winding is spirally wound around the core, as seen in **fig. 3**. Each turn is composed of two winding components: one component is aligned with the center of the toroid. The other component is at a right angle to the radial component and is known as the circumferential component. These two components are emphasized in **fig. 4**. The circumferential component provides the progression of the winding around the core. If there were no circumferential component, each turn would lie on top of the preceding turn.

The circumferential components constitute a single-turn loop antenna which, as is well known, has a response to extraneous signals originating in the plane of the toroid, as shown in **fig. 5**. This is known as the "one turn" effect of a toroidal winding. If the winding has more than one layer, the single-turn effect becomes an N-turns effect, where N is the number of layers.

The super-toroid design eliminates the one-turn effect by winding half the turns in one direction, then running the winding across the diameter of the core to the opposite side and winding the other half of the core in the opposite direction. The voltages induced in the circumferential components are therefore equal and opposite and therefore cancel. The photo shows a core wound in this manner. The winding in this case is clothesline rope to show up better in the photograph.

This technique assumes that the *external* magnetic field is uniform through the diameter of the core and

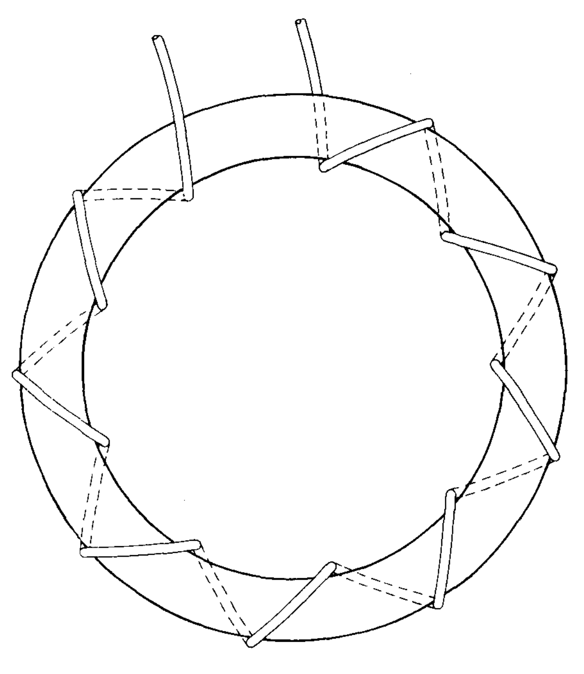

fig. 3. A conventionally wound balun emphasizing the winding pitch, which causes the 1-turn effect.

the core material is homogeneous. If both these conditions are not met, even more complex types of windings must be used to provide isolation from external magnetic fields.

A secondary advantage of the super-toroid design, and one that is much more important to balun designers, is the fact that the effective capacitance across the winding is reduced, which increases the usable bandwidth of the device.

Any inductor consists of stray capacitance as well as inductance. In the design of an inductance, the object, of course, is to maximize the inductance and minimize the capacitance. As seen in **fig. 6**, this capacitance consists of an infinitely large number of incremental capacitances such as the capacitance between adjacent turns, capacitance between turns that are not adjacent, and between the ends of coil. From an engineering standpoint, it is not practical to evaluate an infinite number of small capacitances. Therefore, the "effective capacitance" of an inductor is defined as that of a physical capacitor connected across the ends of the inductor, which stores the same amount of energy as that stored by the incremental capacitors.

The energy stored in a capacitor is proportional to the product of the physical capacitance and the voltage across the capacitor squared: $Energy = \frac{1}{2} CV^2$. If the two plates of a capacitor are at the same potential, the energy stored by the capacitor is zero

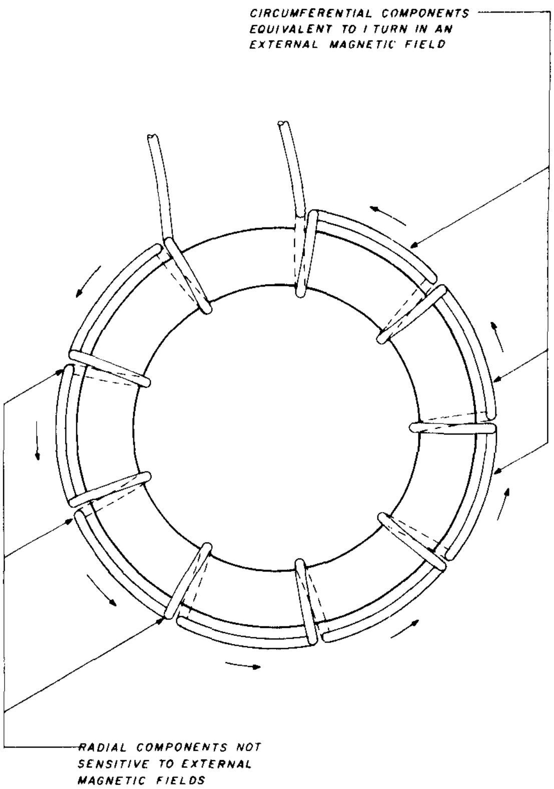

fig. 4. A conventionally wound toroid equivalent to *fig. 3* but emphasizing the 1-turn effect.

and the effectiveness of the capacitor is nil. It is, therefore, important that the portions of an inductance that are at the greatest potential difference have the lowest possible physical capacitance. The ends of the winding are at the greatest potential difference, hence they should have the greatest separation to minimize the physical capacitance.

A super-toroid has the ends of the windings at opposite ends of the core diameter, which is about as far apart as it is possible to place them. A conventionally wound balun, on the other hand, has the ends of the windings adjacent to each other, where they have the highest capacitance. It is, therefore, easy to see why the super-toroid winding would have a lower effective capacitance and hence a greater bandwidth. Then why not use the super-toroid winding exclusively?

For a two-winding balun, the super-toroid winding is preferable. For a three-winding balun, the situation is complicated by the tertiary interconnections between the opposite ends of the two main windings. With a continuously wound toroid, these interconnections can be short and can have a low impedance. With a super-toroid winding, the two leads of the tertiary winding come out on opposite sides of the core, so that both tertiary leads must cross the core. This greatly increases the leakage reactance between the main winding and the tertiary winding and will prove detrimental to proper balun operation above 20 MHz.

Thus, even though the super-toroid winding inherently gives greater bandwidth, it should not be used for a three-winding balun. For three-winding baluns, it is necessary to use a continuous winding to ensure short, low impedance interconnections between the tertiary and main windings.

wide bandwidth?

Numerous *ham radio* readers have questioned the desirability, or necessity, of the wide bandwidths advertised for commercial baluns — typically 3.5 to 30 MHz, and more recently, 1.5 to 56 MHz. Are bandwidths this wide really necessary? Or desirable? The argument is that since few, if any, Amateurs use the same antenna for 80 through 10 meters, much less 160 through 6 meters, why insist that a balun cover a greater, wider bandwidth than the antenna?

My own opinion is that these wide bandwidths are unnecessay and may not be desirable. The antenna installation for a typical Amateur active in the HF region might be a dipole on 80/75 meters or 40 meters plus a triband beam for 20, 15, and 10 meters. If space permits, maybe a 6-meter beam, too. Therefore, a balun that gave high performance, say, from 3.5 to 10 MHz and a second balun optimized for 14 to 30 MHz could be designed to provide higher performance at the extreme edges of these bands than a single wideband balun covering the entire frequency range.

This has been substantiated by my own experience in building and measuring baluns. Wideband baluns — 80 through 10 meters — gave marginal but acceptable performance at the low end of 80 meters and at the high end of 10 meters. The isolation impedance was just barely equal to five times the characteristic impedance of the transmission line.

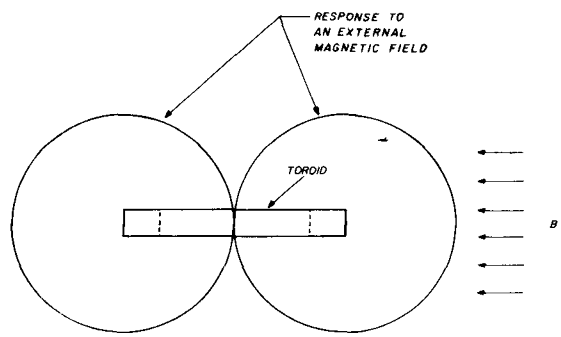

fig. 5. Response of the 1-turn effect of a conventionally wound toroid caused by the circumferential components to a magnetic field, B, parallel to the plane of the toroid.

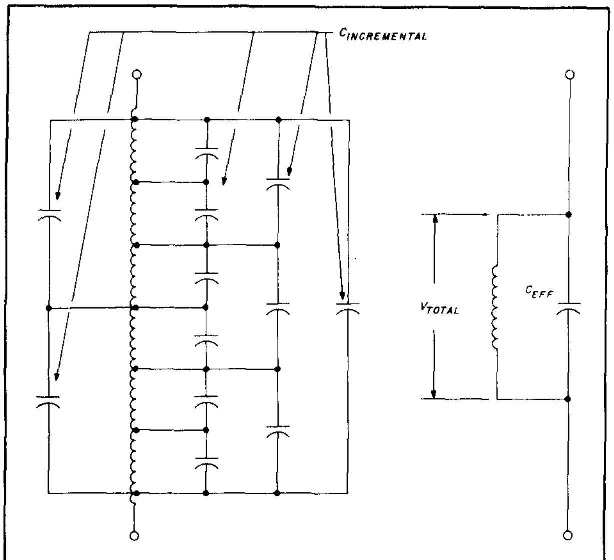

fig. 6. The effective capacitance, C_{EFF}, of an inductor stores the same amount of energy as the sum of the incremental capacitors, C_{INC}.

By adding one or two turns to the winding I could dramatically improve the performance at the low end of 80 meters, but the series resonant frequency occurred in the middle of the 10-meter band. Similarly, by removing a turn or two I could improve the isolation at 10 meters, but only at the expense of the 80-meter band.

In my opinion, the bandwidth performance of presently available baluns is limited by the following factors:

- State-of-the-art in presently available core materials — for example, higher permeabilities at the higher frequencies.
- The limitations imposed on the design by having to wind the core with a transmission line of a specified characteristic impedance rather than a single conductor as with the usual inductor.
- The need to handle an appreciable amount of power.

The reasons commercial baluns for Amateur applications are all wideband devices may include:

- Competition: no manufacturer can afford to offer a balun with less bandwidth than any other manufacturer.
- Lack of published specifications concerning isolation impedance, balance, and isolation make it impossible to tell how effective a given balun may be at the band edges.
- Economy: it is much less expensive for manufacturers and distributors alike to stock a single balun than several different "sizes."

For these reasons, I believe that if Amateurs want high-performance baluns optimized for particular bands, they will have to wind the balun themselves.

final comments

Physically, transmission-line baluns are very simple devices. This simplicity often causes some of the more subtle characteristics to be overlooked during design or use. Recognizing these subtleties may be the biggest problem in designing and using baluns.

reference

1. Walter Maxwell, W2DU, "Some Aspects of the Balun Problem," *QST*, March, 1983, page 38.
2. John J. Nagle, K4KJ, "Testing Baluns," *ham radio*, August, 1983, page 30.
3. Joe Reisert, "Simple and Efficient Broadband Balun," *ham radio*, September, 1978, page 12.

ham radio

short circuits

May 1985

digital HF radio

In "Digital HF Radio: A Sampling of Techniques" (April, 1985) the author's name was misspelled. "Dr. Ulrich L. Rhode," as it appears on page 18, should be corrected to read, "Dr. Ulrich L. Rohde." *ham radio* regrets the error.

May 1985

harmonic mixer

In **fig. 2** of K1ZJH's "Harmonic Mixer for VHF Signal Generation" (March, 1985, page 40), T1 should be identified as a T37-6 toroid available from Amidon Associates, Inc., 12033 Otsego Street, North Hollywood, California 91607.

May 1985

low-voltage power supplies

In fig. 9 of the March article, "Designing Low-Voltage Power Supplies," Q1, Q2, and Q3 are shown incorrectly wired. The base leads of Q1 and Q2 should be connected to the *collector* of Q3, not its base.

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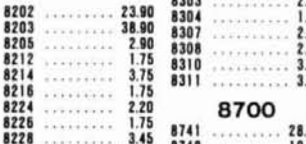

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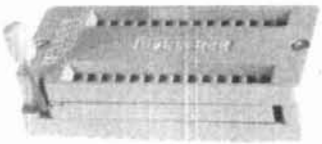

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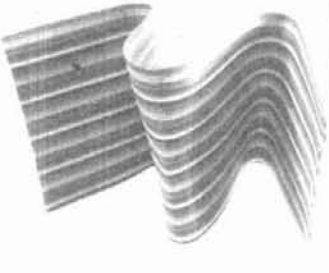

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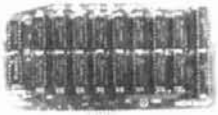

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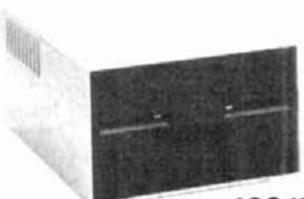

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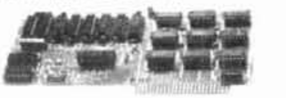

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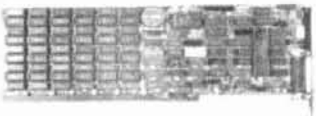

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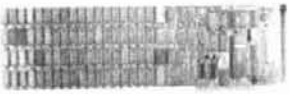

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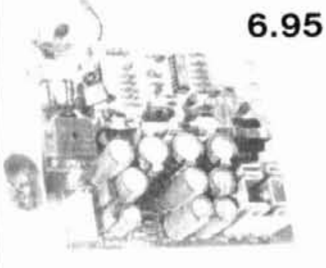

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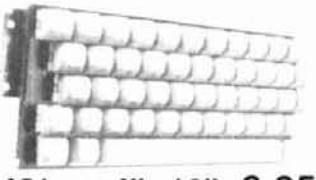

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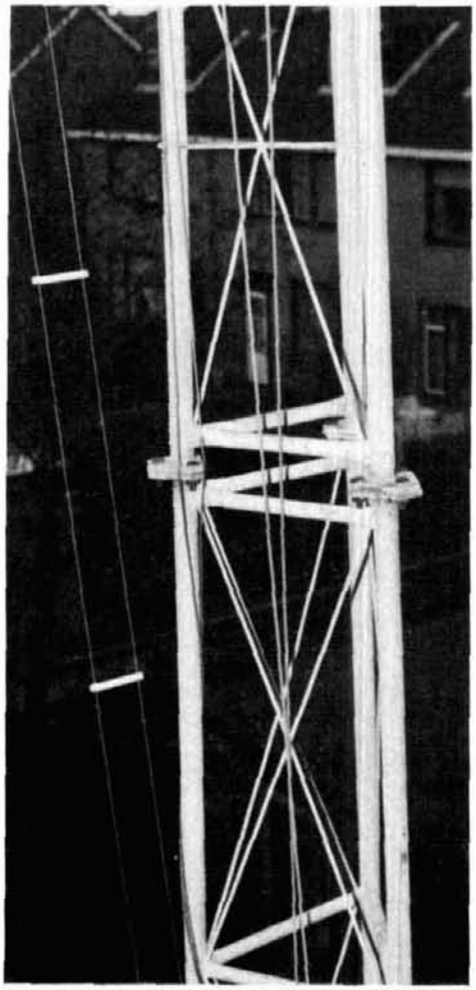

fig. 1. The tower before conversion. Hinge plates will be attached between the flanges connecting the upper and lower part of the tower.

By Dick Rollema, PAØSE, v.d. Marckstraat 5, 2352 RA Leiderdorp, Netherlands

Since 1973 I have been the proud owner of a self-supporting triangular steel lattice antenna tower. But because I'm afraid of heights, climbing this tower is out of the question. Changing antennas means engaging helpers, and even then it's not easy because the mast has an additional 10-foot (3 meter) long tube on top, making the rotator and antennas almost inaccessible.

It took a long time before I realized how I could convert my mast to a tilt-over. The 40-foot (12 meter) tower consists of two sections, each 20 feet (6 meters) long. (With the 10-foot, 3 meter tube on top, the total height comes to 50 feet, or 15 meters.) As shown in **fig. 1** the two sections are connected by three flanges with three bolts each; this division appeared to be the logical place for a hinge that would permit the upper section to pivot and be lowered to ground level.

The next problem to be solved was how to effect the tilt-over action by means of a winch and hoist line.

Sketches of the parts constructed by PAØDON are available from the author. Send a large self-addressed envelope; enclose three IRCs.

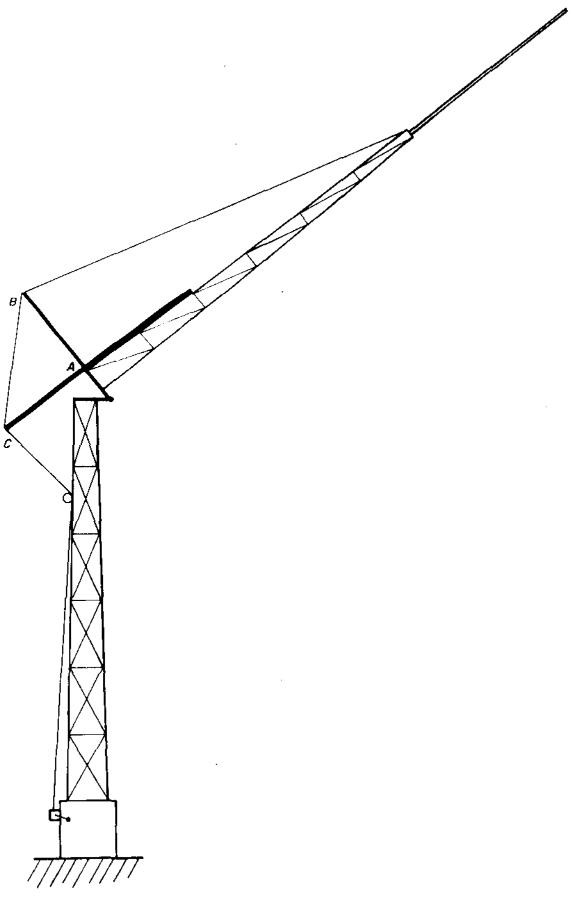

fig. 2. The initial plan for the tilt-over conversion was dropped because forces in outriggers *AB* and *AC* and the hoist line would be excessive.

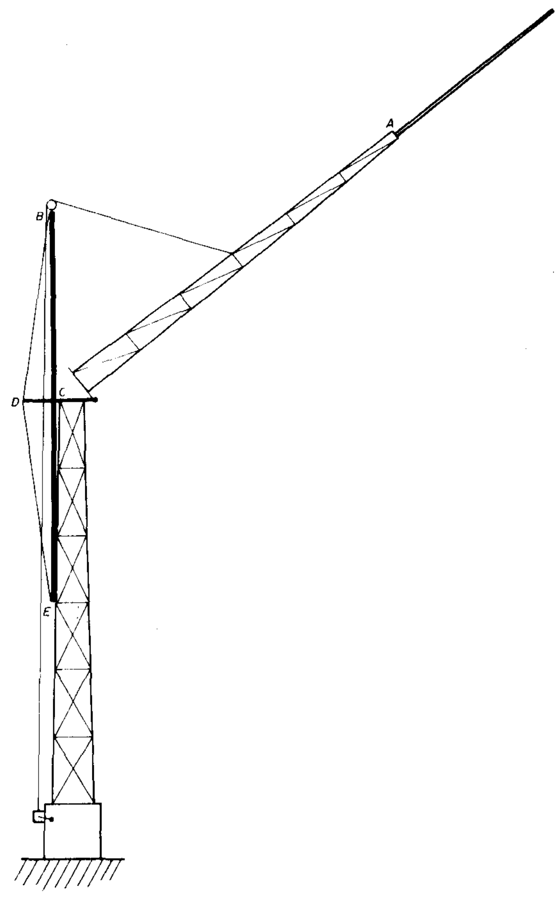

fig. 3. The final design: gin pole *BE* is 20 feet (6 meters) long. At *C* the gin pole is fastened to the lower hinge plate. The highest bending moment occurs at *A*.

I first thought of using a method such as the one shown in **fig. 2**, similar to the cranes used by building contractors. But with the tower positioned immediately behind our house, outriggers *AB* and *AC* would have to be short enough to clear the structure. This would lead to high tension in the hoist line and cause too much stress on the overall system. So the idea was dropped.

The breakthrough occurred when I visited PA0WCW, who has a similar tower that had been converted into a tilt-over. PA0WCW used two adjacent gin poles permanently fixed to the tower. A pulley is mounted on top of each pole. Two hoist lines in parallel run from the winch over the pulleys to a point halfway up the upper section of the mast.

My final design is shown in **fig. 3**. Here a single gin pole (*BE*) is fixed to the tower at the lower end *E* and in the middle at *C*. A few calculations showed that bending moment at *C* is so large that no pipe of acceptable size could endure this stress, so two stays designed to bear most of the load were introduced. These are fastened to the gin pole at both ends and pushed away from the middle of the pole by a triangular outrigger. **Figure 4** shows the finished system.

calculation is a must

Before working out a project such as this, it is absolutely essential to determine the forces exerted on the different parts. Calculating stresses in mechanical construction projects is definitely not part of my daily routine, but after consulting some textbooks — and with some professional advice from PA0TO — I managed to do the job. It was not very difficult after all. I quickly discovered that the most critical point is at *A* in **fig. 3** where the pipe top mast leaves the tower. The bending moment here should not exceed a certain maximum value set by the resistance moment and the tensile strength of the material.

My starting point is a pipe mast of 2-inch (50.8 mm) inner diameter with a resistance moment of 0.63 inches^3 (10.25 cm^3) that protrudes 10 feet (3 meters) out from the lattice mast. From a maximum admissible

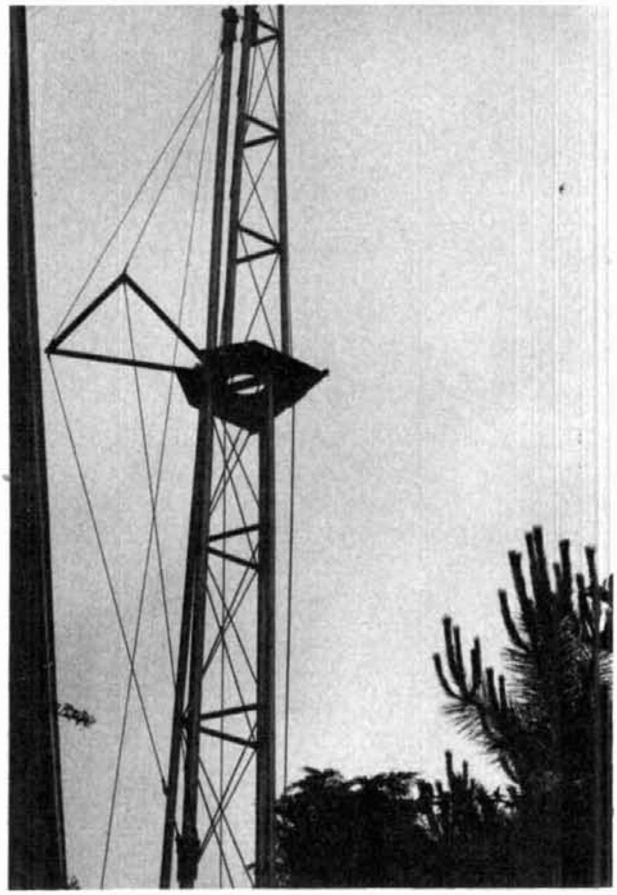

fig. 4. The completed structure.

stress of 23,205 pounds/inch^2 (160 N/mm^2) it follows that the maximum admissible lateral force at the top of the pipe is 123 pounds (547 N). This is the maximum wind load on antenna plus rotator, if we neglect the wind load on the pipe itself for just a moment.

A second limitation occurs when the mast has been tilted to a horizontal position. Again at *A*, a bending moment occurs as the result of the gravitational force on the top mast, rotator, and antenna. Taking into account the mass of the top mast itself, we find a maximum admissible mass of about 99 pounds (45 kg) for the rotator plus antenna. With these numbers, the forces in the different parts of the system can be computed. Rather than bore you with the results, only the maximum force in the hoist line will be mentioned: almost 1,034 pounds (4,600 N), which represents the static load. During tilting of the tower, shocks can easily occur that considerably increase the force in the line.

construction

As already mentioned, a hinge has been installed at the 20-foot (6 meter) level where the lower and upper parts of the tower are joined by flanges. The flanges are bolted to steel plates that carry the hinge at one edge.

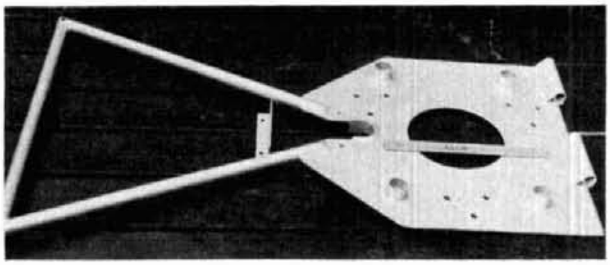

fig. 5. Lower hinge plate, made of 23/64-inch (9-mm) thick steel. The triangular outrigger is fabricated of 1-inch (25 mm) diameter steel tubing. The angle iron bracket secures the gin pole that is held in place in the half circular cutout. The central hole helps reduce the weight (64 pounds/29 kg).

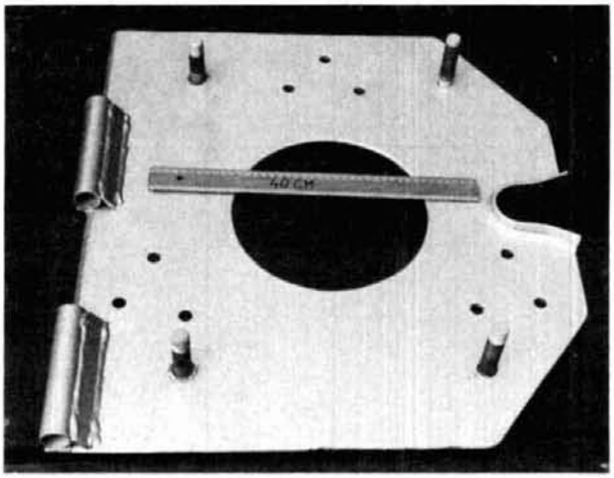

fig. 6. Upper hinge plate, made of 23/64-inch (9-mm) steel. The four bolts, welded on, keep the hinge plates together when the tower is upright. (Weight: 50 pounds/22.5 kg).

Figure 5 shows the lower plate and **fig. 6** the upper. The hinge is fabricated from a piece of 2-inch (50.8 mm) steel tube sawed into four parts. These were welded, two by two, to both plates. Extra strength was provided by welding strips of steel to both pipe and plates, as can be seen in **fig. 6**. The hinge pivots around a 1-inch (25-mm) diameter shaft with bushings at both ends. One is permanently fixed to the shaft; the other is fitted after mounting and secured by a bolt and nut that traverse the shaft and bushing.

In the resting position, the two hinge plates are held together by four 25/32-inch (20-mm) bolts that have been welded to the upper plate and pass through oblong holes in the lower plate. Pieces of tubing are welded around these holes to keep the plates at the proper distance.

Before tilting the tower, the four nuts must be removed from the bolts on the bottom side of the lower plate.

In my original design one plate lay directly on top of the other without any distance in between. To pre-

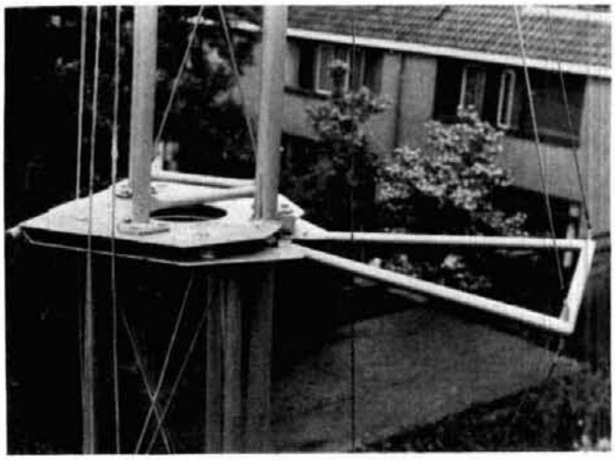

fig. 7. Tower in vertical position. The stainless-steel tubes that guide the stays through the outrigger can be seen at right.

vent the bolt heads in the upper and lower plates from interfering with each other, the upper part of the tower was rotated 60 degrees with respect to the lower part. This allowed the bolt heads of one plate to fall directly into holes drilled in the opposite plate. That 60-degree rotation has been maintained, though it is not necessary in the present construction. But while it presents neither advantage nor disadvantage, it does lead to an optical illusion: from whatever side the tower is viewed, it always seems that the center lines of the upper and lower part do not coincide.

The tower is hinged so that the top mast can be reached from the roof of the barn in the back of our garden, so it is easy to work on rotator or antenna. **Figure 7** shows the tower and hinge in its normal position. **Figure 8** shows it tilted over about 90 degrees.

The gin pole is a seamless steel tube 20 feet (6 meters) long and 2.5 inches (60.3 mm) outer diameter; its inner diameter is 2 inches (53 mm). The lower end is supported by the parts shown in the lower section of **fig. 9**. **Figure 10** shows the lower end in position on the tower.

The legs of the tower have a wall thickness of only 1/16 inch (1.5 mm). To spread the forces exerted by the U-bolts, my friend PAØDON fitted half-cylinder-shaped shells between the U-bolts and the tower legs. On the angle-iron bracket, a piece of tubing was welded over which the gin pole was placed. After mounting, a hole was drilled for a long bolt that pierces the gin pole and prevents turning.

On top of the gin pole a pulley was mounted by means of the method shown in **figs. 11** and **12**. As shown, precautions have been taken above and behind the pulley to prevent the hoist line from running off. The pulley, made of Novotex,™ has an outer diameter of 4.7 inches (120 mm). It rotates around a piece of steel tubing of 1.3 inches (32 mm) diameter. The steel strips that hold the pulley on top of the gin

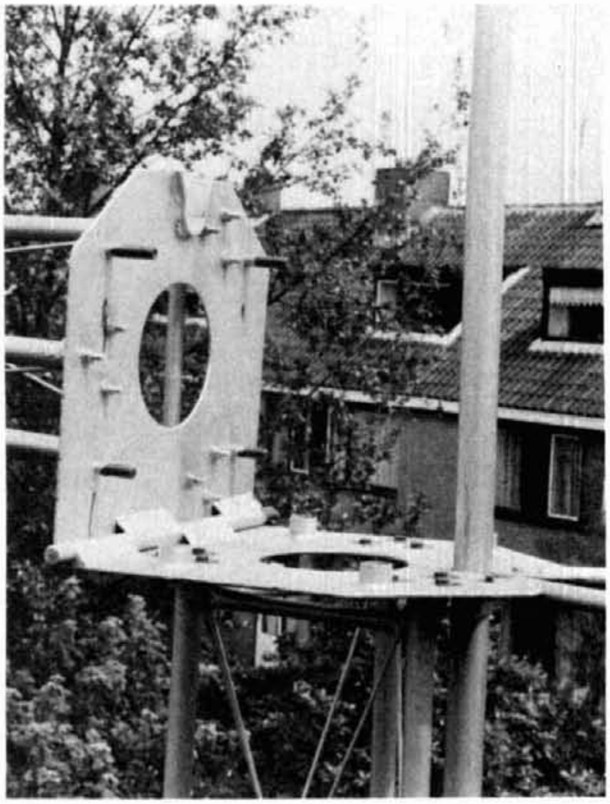

fig. 8. Tower tilted 90 degrees.

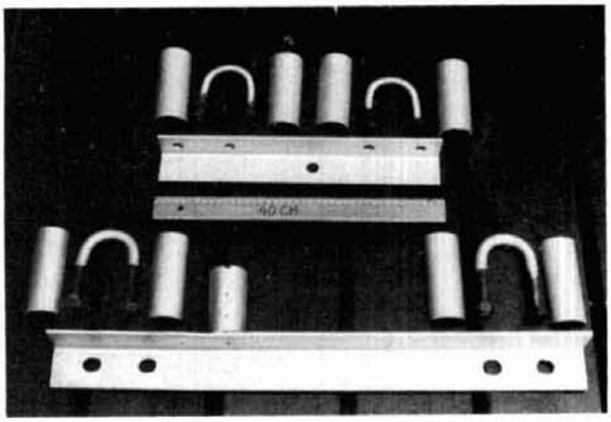

fig. 9. The parts that connect the hoist line to the upper tower section are shown above; the support for the gin pole is shown below.

pole also carry bolts for the stays. At the lower end the stays are connected with stainless steel turnbuckles with a breaking strength of 4,271 pounds (19,000 N). The lower hinge plate carries a triangular outrigger that keeps the stays at the proper distance from the middle of the gin pole (**fig. 7**). To prevent chafing, stainless steel tubes have been inserted in the outrigger that guides the stays. A nylon bushing inside the tubes provides extra protection.

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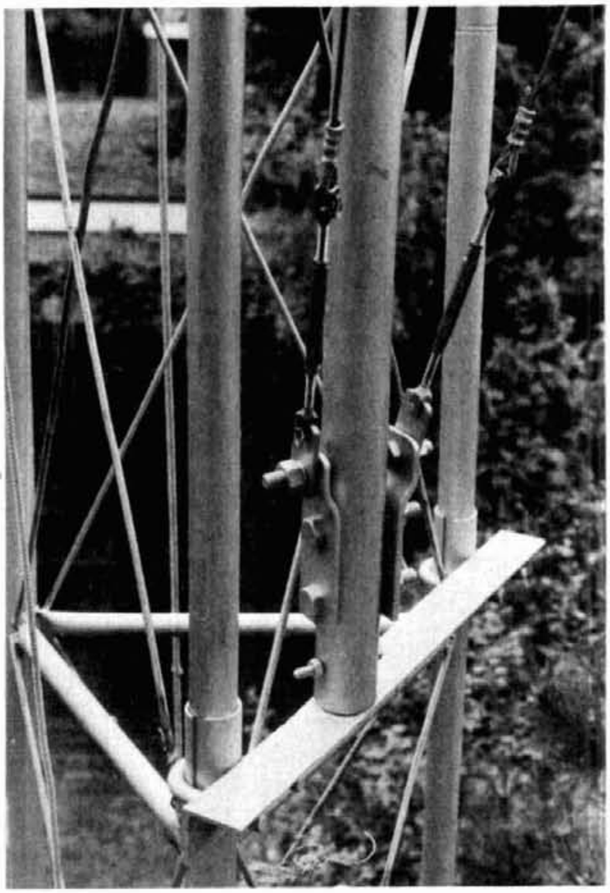

fig. 10. The lower end of gin pole, with stays.

steel cable measuring 0.2 inch (5 mm) in diameter and having a breaking strength of 3,147 pounds (14,000 N). The hoist line ends in a winch with a capacity of 1,200 pounds (5,338 N) and a reduction of 4.1:1. (If I were to build this system again I would select a larger reduction). The tower rests on a concrete block, and the winch is fitted to this block by three "chemical" anchors measuring 0.31 inch (8 mm) (**fig. 13**). The upper end of the hoist line ends halfway up the top section of the tower. A bracket of angle iron is shown in the upper half of **fig. 9**. This bracket is mounted to the tower legs with U-bolts, and half-cylinder shells are installed to distribute the pressure more evenly. The hole in the bracket is for a 0.625-inch (16 mm) bolt. (The hoist line is fitted to this bolt with parts purchased at a marine shop; I am, unfortunately, unable to translate their names into English.)

The hinge plates and all parts visible in **figs. 9** and **11** have been treated with zinc epoxy followed by two coats of aluminum paint. The gin pole, galvanized by the manufacturer, was given a coat of rust-preventive primer and two coats of aluminum paint. Although the tower was also galvanized, some traces of rust were visible at the upper end, so the whole thing was also treated with rust-preventer and aluminum paint.

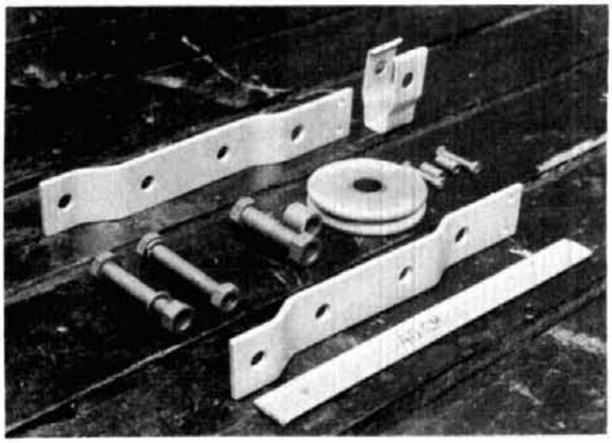

fig. 11. These parts support the pulley on top of the gin pole.

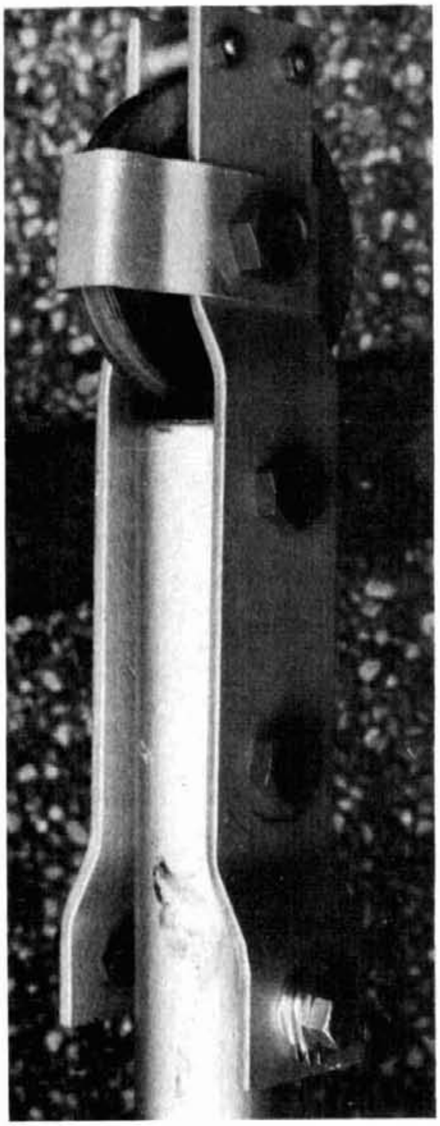

fig. 12. Pulley in position.

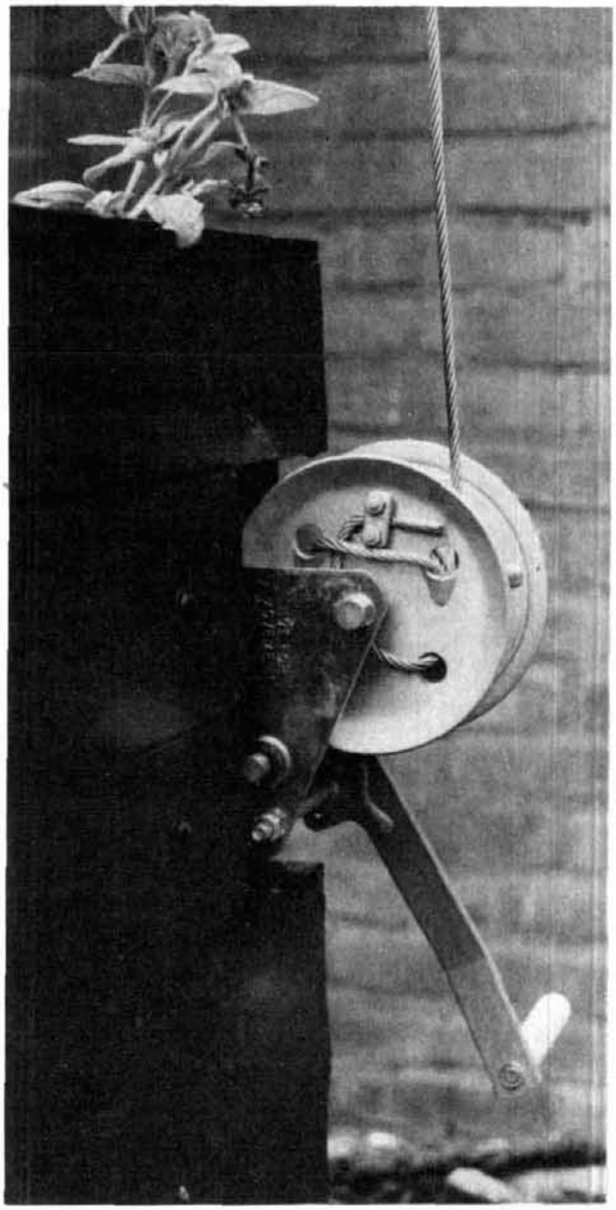

fig. 13. The winch is fastened to the concrete block that serves as base for the tower. Concrete block is concealed under a wooden cover for aesthetic purposes.

assembly

The first phase of the operation took place in early December, 1983, when the temperature was just below freezing. Our object was to take down the upper part of the tower, the top tube mast, the rotator, and the 2-meter beam. The gin pole was fitted temporarily to the tower. Because the hinge plates were not yet in place, the gin pole was tied to the upper end of the lower section with rope. The hoist line was also fitted. Using the winch, we gently lowered the upper part of the tower to ground. Now the holes in the flanges could be transferred to a template to be used later in drilling the holes in the hinge plates.

fig. 14. High level work: Jos (PA3ACJ) and SWLs Bert and Ed.

Final assembly and rigging of the tilt-over conversion occurred in mid-May, 1984, under more favorable weather conditions. Everything fit exactly, and it was a real pleasure to see the converted tower come together step by step (**fig. 14**).

acknowledgement

My sincere thanks to Ber van Dongeren, PAØDON, for his superb realization of my design. No operation like this can be performed without helpers: Piet de Bondt, PA3BGP; Jos Disselhorst, PA3ACJ; Ton Verberne, PA2ABV; Ben van Capel, PE1KCG; Gerrit van Zwam, PE1KAX, and SWLs Jo Chin-Chan-Sen, Bert Kraan and Ed Wassenburg helped disassemble the original tower and erect the new one.

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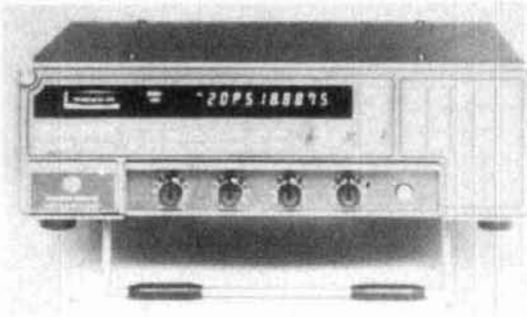

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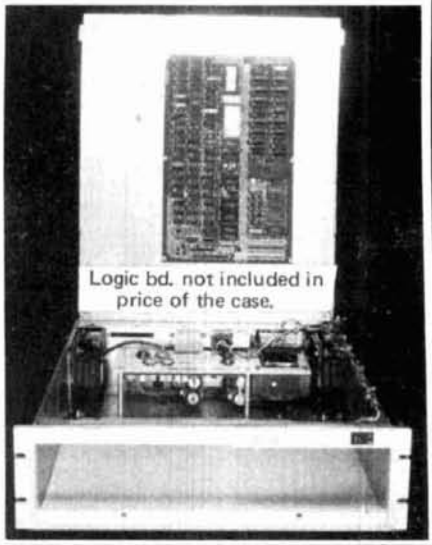
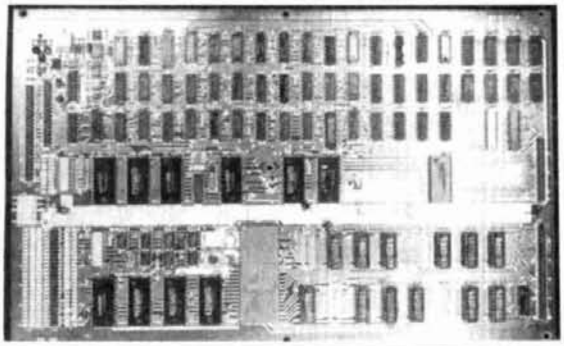
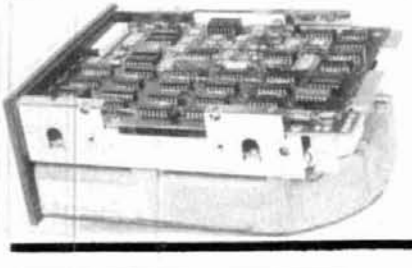


We were very fortunate to find these beautifully designed & constructed rack mount disc drive cases in the surplus field. These cases were made for Scientific Micro Systems for their FT Series of equipment. They are manufactured from heavy guage steel w/ a cast metal designer bezel. They were designed to house 2 8" floppy or hard drives. We offer you the case with the following components & features: hinged cover with restraining cable for simplified servicing of the interior components, 2 muffin fans for assured cool operation, studs for mounting the controller card listed below, and a heavy duty Power One power supply (their model no. CP 281A). The outputs of the power supply are as follows: +5 vdc 11 amps, +24 vdc 3.5 amps, +12 vdc .25 amps, -12 vdc .25 amps, & −5 vdc .25 amps. The input to the power supply is 115/230 vac 50/60 Hz. and is both filtered and fused. This assembly must have originally sold for well over $300.00 each ! Only 25 on hand, so order early or be left out on this super bargain ! Shpg. wt. 38 lb. SPL-479-35 $135.00 each

Scientific Micro Systems IBM 3740 Compatible 8" FDD Controller Card



The SMS FD 0502 8" floppy disc drive controller is a complete preprogrammed controller for single or double density recording on either single or dual headed disc drives. It performs control functions required to transfer data between 1 to 4 drives and a host system, performs all formatting functions required to read and write data and utilizes both IBM single and double density standards to achieve up to 630 Kilobytes of storage per disc surface. Some features are: programmable sector size, 128, 256, 512, or 1024 bytes, jumper selectable drive type, block transfer mode, sector buffer, overlapped head seek, on board General Purpose Host Interface with asynchronous 19 TTL signal lines for eight bit host system and input of only 5 vdc 6 amps. This board provides a direct interface to the following drives: Shugart 800 –2/850, Pertec 511, Memorex 550/552, MFE 751B, Qume Data Trak and similiar drives. These boards were removed from the above cabinets which were in service prior to our reception of them. The manufacturers price on these IBM compatible boards is currently $900.00 each. These boards all appear to be in excellent condition. If more information is needed, please call us. Shpg. wt. 3 lb. SPL 480 $150.00



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The Seagate Technology ST 506 hard disc drive utilizes proven Winchester teacnology for reliable storage of up to 5 megabytes of formatted data. Some features of this very popular drive are: 5 megabit/second data transfer rate, simple floppy like interface, high speed band actuator & stepper head positioning, requires only +5 & +12 vdc, and same physical size and mounting paramters as a mini floppy drive. This Shugart compatible drive is the same as used on many home personal computers. Each drive is checked out prior to shipment. Comes with data. Only a few on hand, so order early.
Shpg. wt. 8 lb. ST-506 $225.00

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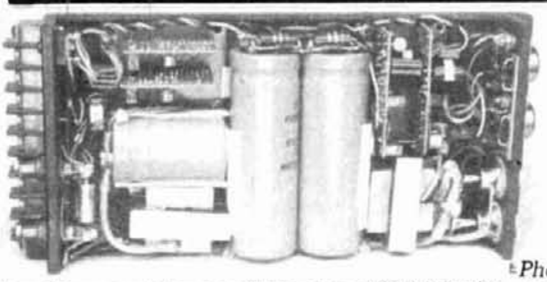
Finally, affordable, intelligent disc drive controllers are available at low, low surplus prices. The OMTI 20C controller boards we offer are unused, late style, surplus from a now defunct system house. OMTI is a division of Scientific Micro Systems. These boards will handle up to (2) 5¼ inch Winchester type hard drives that utilize a standard 34 pin SASI interface. Perfect for using with the above Seagate ST 506 drive, or other hard drives from 5 megabytes of storage on up. The controllers have buffered slew/seek modes, overlapped seeks, auto seek & verify, extensive fault detection, auto head & cylinder switching, full sector buffering, 256/512 bytes/sector, 33 or 18 sectors/track (jumper selectable), programmable disc parameters and much more. The board runs on +5 vdc & +12 vdc.. We supply users manual & pinout data. Guaranteed O. K.. Shpg. wt. 3 lb. OMTI 20 C $150.00 each 2/$275.00 Qty. pricing available.



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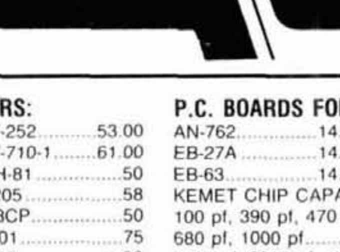

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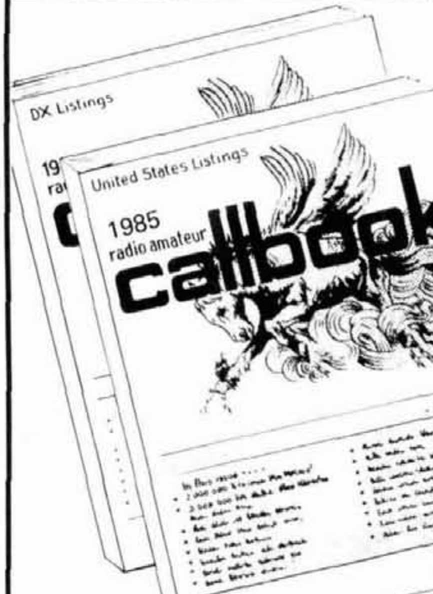

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Coming Events

ACTIVITIES

"Places to go..."

INDIANA: Hamfest and Computer Show, Sunday, June 9. Sponsored by the Muncie Area Amateur Radio Club. 8 AM to 3 PM. Rain or Shine. Delaware County Fairgrounds. Tickets $2.00 advance, $3.00 at door. Large Flea Market. Overnight camping on grounds. Hookups $5.00. Talk in on 146.13/.73. For tickets, table reservations or information: SASE to MAARC, PO Box 2102, Muncie, IN 47302.

OHIO: The Athens County Amateur Radio Association's sixth annual Hamfest and Computerfest. Sunday, May 19, City Recreation Center, East State Street, Athens. 8 AM to 3 PM. Admission $3.00. Free paved outdoor tailgating or bring your own tables. Indoor space by advanced registration only. Contact Joe Follrod, NE8R, 15 Roy Avenue, The Plains, OH 45780. (614) 797-4874. This year there will be all level license exams. Mail completed FCC Form 610 and $4.00 check payable to ARRL/VEC to John Cornwell, NC8V, exam coordinator, 101 Coventry Lane, Athens, OH 45701. Forms must be received by April 19. Talk in on club repeater 146.34/.94. For information: Carl J. Denbow, KA8JXG, Chairman, ACARA Hamfest Committee, 63 Morris Ave., Athens, Ohio 45701.

LOUISIANA: The Central Louisiana ARC (CLARC) will sponsor a Hamfest, Saturday and Sunday, June 8 and 9, Bolton Avenue Community Center, 315 Bolton Avenue, Alexandria. Free admission. Swap tables available. VEC exams. Talk in on 147.93/33 or 146.04/64. For more information: CLARC, PO Box 7772, Alexandria, LA 71306.

GEORGIA: The John Ross Amateur Radio Club's annual Hamfest, June 8 and 9. New location — Lakeview — Ft. Oglethorpe High School, Ft. Oglethorpe on Hwy. 2A. Air conditioned dealer spaces. Indoor/outdoor flea market. Tables available. FCC exams both days. Refreshments and plenty of free parking. Talk in on 145.35/down. For reservations and information: JRARC, PO Box 853, Rossville, GA 30741. (404) 861-5610.

MICHIGAN: The Chelsea Swap and Shop, Sunday, June 2, Chelsea Fairgrounds. Gates open for sellers at 5 AM. General public 8 AM to 2 PM. Donation $2.50 advance or $3.00 at gate. Children under 12 and non ham spouses admitted free. Talk in on 146.520 simplex and 147.255 Chelsea repeater. For information: William Altenberndt, 3132 Timberline, Jackson, MI 49201.

MINNESOTA: The North Area Repeater Association will sponsor the state's largest swapfest and exposition, Saturday, June 1, Minnesota State Fairgrounds in St. Paul. Free overnight parking for self-contained campers May 31. Exhibits, dealers, giant flea market. Amateur license exams given. Admission $4 in advance, $5 at Fair. Talk in on 25/85 or 16/76 repeaters. For tickets, information: Amateur Fair, PO Box 857, Hopkins, MN 55343. (612) 566-4000.

MARYLAND: The Maryland FM Association's annual Hamfest, Sunday, May 26, Howard County Fairgrounds, West Friendship, I-70, 30 miles west of Baltimore. Gate opens 8 AM to 4 PM. Inside tables by advance registration $6.00. At the door $10.00 if available. Donation $3.00. Talk in on 146.16/76, 222.16/223.76, 449.1/444.1. For tables or information: Craig Rockenbauch, WA3TID, 429 Severnside Drive, Severna Park, MD 21146. (301) 987-6042 (6-10 PM).

GEORGIA: The Anderson, Hartwell and Toccoa Amateur Radio Clubs will hold the 6th annual Lake Hartwell Hamfest, May 18 and 19, Lake Hartwell Group Camp, Highway 29, Hartwell. Free admission, free camping, and free flea market space. Left footed CW contest, horseshoes, fishing, swimming and camping available on site. Campgrounds open 6 PM Friday. Talk in on 146.19/.79, 147.93/.33 and 146.895/.295. For further information: Ray Pettit, WB4ZLG, Rt. #1, Dooley Drive, Toccoa, GA 30577.

MARYLAND: The Frederick Amateur Radio Club's 8th annual Hamfest, June 16, Frederick Fairgrounds. Admission $3.00. YL's and children free. 8 AM to 4 PM. Tailgaters $2.00 extra. Gates open for exhibitors 8 PM June 15. Overnight parking welcomed. Tables $10.00 first, $5.00 each extra. For information: Jim Kasunic, KA3LPC, 9419 Highlander Ct., Walkersville, MD 21793.

ILLINOIS: The Chicago Amateur Radio Club (CARC) is sponsoring a Mini Hamfest, Wednesday, May 15, 6 to 10 PM, Edgebrook Golf Course Fieldhouse, 5900 N. Central Avenue, Chicago. (North of Elston Avenue, south of Devon Avenue). For more information: (312) 545-3622.

NEW HAMPSHIRE: The 11th annual Eastern VHF/UHF Conference, May 17-19, Rivier College, Nashua. Friday night hospitality room. Saturday tech talks by well-known VHFers. Pre-registration $13.50 to David Knight, KA1DT, 15 Oakdale Avenue, Nashua, NH 03062 before May 5. Registration at the door $20.00. Saturday night banquet $14.00 payable before May 5. Dormatory housing available, $16.50 per night single, $28.00 per night double, includes buffet breakfast. Include payment at time of pre-registration. Make checks payable to Eastern VHF/UHF Conference. There are also numerous hotels and motels nearby. For information: Lewis D. Collins, W1GXT, 10 Marshall Terrace, Wayland, MA 01778. (617) 358-2854 (6-10 PM).

OHIO: The 5th annual Columbus Hamfest sponsored by the Battelle Amateur Radio Club, Sunday, June 2, 8 AM to 3 PM. Ganyard Building on Franklin County Fairgrounds. Admission $2 advance and $3 at the door. Advance tables $3; at the door $4. Talk in on 146.37/97. For information Bill, W8LLU (614) 261-7053 or Kevin, WA8OHI (614) 766-5313. Advance sales SASE to Bill Welch, W8LLU, 396 Brevoort Rd., Columbus, Ohio 43214.

OHIO: The Sandusky-Ottaway Counties annual Hamfest, May 19, 8 AM to 3 PM. Ottawa County Fairgrounds, St. Rt. 163 east of Oak Harbor. Donation $3.00 at gate; $2.50 advance. Tables $3.00. Gate opens 6 AM for dealers and 8 AM for general public. Trunk sale (donation 50¢), plenty of parking, food and refreshments. To reserve tables: Raymond Kruse, K8IDA, 18980 W. S.R. 51, Elmore, Ohio 43416. (419) 862-2619 (8 AM - 5 PM).

PENNSYLVANIA: The Warmister ARC Hamfest, May 19, Middletown Grange Fairgrounds, Penns Park Rd., Wrightstown (about 15 miles north of Phila.) Admission $3.00. XYLs and children free. Indoor space with table and elec $5.00. Tailgating space $5.00. Gates open 7 AM. Talk in on 147.69/09 and 147.52. Computer hardware/software vendors welcome. For information: Bill Cusick, W3GJC, Apt. 706, Garner House, Hatboro, PA 19040. (215) 441-8048.

NEW YORK — Long Island: The Suffolk County Radio Club's Indoor/Outdoor Electronic Flea Market, Sunday, May 5, 8 AM to 3 PM, Republic Lodge No. 1987, 585 Broadhollow Road (Rt. 110) Melville. Refreshments and plenty of free parking. General admission $2.00. Wives and children under 12 free. Indoor seller's tables $7.00. Outdoor space $5.00 includes one free admission. Talk in on 144.61/145.21 and 146.52. For information: Richard Tygar, AC2P. (516) 643-5956 evenings.

NEVADA: The 10th International Convention of the YLRL will be held June 20, 21, 22 and 23 at the Sahara Hotel, Las Vegas. Deluxe accommodations and RV parking available at reasonable rates. Activities include a Hoover Dam tour, Lake Mead cruise, desert tour, gala stage show, cocktail party, luncheon buffet and awards banquet plus a DX YL show, slide shows and business meetings. A convention station will operate on 14,288 kHz and other frequencies. Registration forms are to be found in recent issues of YLRL's "Harmonics". For information packet send business SASE with 2 oz. of postage to Jan Weaver, N7YL, 2195 East Camero Avenue, Las Vegas, NV 89123.

NEW JERSEY: The Tri-County Radio Association's Hamfest, Sunday, May 19, rain or shine, Passaic Valley Community Center off Valley Road, Stirling. 9 AM to 4 PM. Indoors, free parking, refreshments. Tables $10. Registration $2.50. Reserved tailgating only. All reservations to: Dick Franklin, W2EUF, PO Box 182, Westfield, NJ 07090. (210) 232-5955 or 270-3193.

SOUTH DAKOTA: The Black Hills Amateur Club is celebrating its 50th anniversary by sponsoring the 1985 ARRL Dakota Division Convention, July 5, 6, 7, Howard Johnson's (I-90, exit 59) Rapid City. Registration Friday from 4 to 7:30 PM followed by a social hour. Saturday exhibits, registration, indoor flea market (free tables while they last) ladies' activities and fun for the whole family. VE exams (limited walk-ins) 1 PM. Banquet at 7 PM. Sunday brunch at 8:30 followed by the ARRL forum. Exhibits will be open. Pre-registration & banquet $18.00. Pre-registration only $6.50. Must be made prior to 6/10/85. Additional banquet tickets $12.50. Sunday brunch $6.75, children 12 and under $3.75. Registration after 6/10/85, $7.50. Make check payable to Black Hills ARC, c/o Gene F. Bauer, KXØU, 713 Blaine Avenue, Rapid City, SD 57701. Confirmation by return mail.

WISCONSIN: The Central Wisconsin Radio Amateur's annual Swapfest/Family Picnic, June 16, Bukolt Park, Stevens Point. Swapfest will feature volunteer exams (by advanced registration only), dealers, food, refreshments and fellowship. Tables and tailgating $2.00. Talk in on 146.07/67 and .385/985. For further information: Jim Benak, KA9ACE, 1775 Strongs Avenue, Stevens Point, WI 54481. To register for exams (by May 16): Gene Santoski, K9UTQ, 1220 — 18th Street South, Wisconsin Rapids, WI 54494.

KENTUCKY: The Armored Force Amateur Radio Nationwide Emergency Team (A FAR NET) will hold an Eyeball Bivouac, June 7 - 9, at the Best Western Gold Vault Inn in Radcliff, just outside Fort Knox. Campers will use the Fort Knox campground at Camp Carlson. On Friday, June 7, there will be an informal picnic. Saturday, the group will take a guided bus tour of Fort Knox ending at the Patton Museum. Saturday evening's cocktail party is followed by dinner at 8 PM. There will be a farewell breakfast Sunday morning. For additional information contact Carl Quickmire, WB4UBS, 6341 Cloverdale Drive, Columbia, SC 29209. Any Amateur Radio operator who has ever served with or been assigned to an armored unit of the U.S. armed forces or its allies is eligible for membership in A FAR NET. Family members holding an Amatuer license are eligible for associate memberships. Anyone interested in joining this unique organization can obtain information and an application from Harry B. Thomsen, W2PJH, 348 Jefferson Avenue, Apt. 15, Canandaigua, NY 11424. Please include business SASE.

PENNSYLVANIA: The 31st annual Breeze Shooters Hamfest, Sunday, June 2, 9 AM to 5 PM, White Swan Amusement Park, Rt. 60 near Greater Pittsburgh International Airport. Free admission and flea market. Family amusement park. Registration $2.00, 3 for $5.00 or 7 for $10.00. Vendors tables by advance registration. Talk in on 146.28/.88 or 29.000 MHz. For information: John Colbert, K3SDL, 1831 Highland Ave., Irwin, PA 15642. (412) 863-5167 evenings only.

COLORADO: The Longmont Amateur Radio Club's annual Boulder Spring Hamfest, Sunday, May 5, 9 AM to 2 PM rain or shine, Colorado National Guard Armory, 4750 North Broadway, Boulder. Donation $3 per family. No sellers charge but bring own tables . . . Hamswap, plus tech demonstrations and seminars. Food and drink available. Talk in on 146.16/.76 and 146.52. For information: William Currie, WDØEHJ, 1232 East Fourth Ave., Longmont, CO 80501. (303) 776-2829.

NEW YORK: Long Island Hamfair sponsored by LIMARC, Sunday, June 9, 9 AM to 4 PM, Electricians Hall, 41 Pinelawn Road, Melville, Long Island. General admission $3.00. $2.00 after 1 PM. Table space in advance from Hank Wener, WB2ALW, 53 Sherrard St., East Hills, NY 11577-1712. 4 x 6' table space $10.00 or your own for $6.00. Contact Hank at (516) 484-4322 evenings to 11:30 PM.

INDIANA: The 39th Annual Hamfest sponsored by the Wabash Valley ARA, Sunday, June 2, Vigo County Fairgrounds, Terre Haute. For information SASE to WVARA, PO Box 81, Terre Haute, In 47808.

CONNECTICUT: Flea Market, sponsored by the Newington Amateur Radio League, June 9, Newington High School, 9 AM to 2 PM. Admission $2.00. Tailgating $5.00. Talk in on 146.52 or W1AW/R 145.450, 224.840.

NEW YORK: The Rome Radio Club's 33rd annual Ham Family Day, Sunday, June 2, Beck's Grove in Rome. Games, contests and large Flea Market. Good food and beverages available throughout the day. Educational and scientific presentations. The day will end with dinner and the presentation of "Ham of the Year Award". For further information: Rome Radio Club, PO Box 721, Rome, NY 13440.

NEW YORK: The 26th annual Southern Tier Amateur Radio club's Hamfest, Saturday, May 4, Treadway Inn, Owego. Flea market opens 8 AM. Vendor displays and sales. Dinner at 6:30 PM by advance tickets only. Talk in on 22/82, 16/76 and 146.52. For further information SASE to KF2X, RD #1, Box 144, Vestal, NY 13850.

NEW YORK: The Antique Radio Club of America will hold an international convention at Niagara Falls, June 5-8. The club has 1000 members who collect and restore antique wireless and radio equipment and who study and record the history of early radio. For information on the convention or membership in ARCA please write NFWA, PO Box 68, Central Park Station, Buffalo, NY 14215.

WASHINGTON: The Yakima Amateur Radio Club will hold the Central Washington State Hamfest, May 18 and 19, Hobby Building at Central Washington State Fairgrounds, Yakima. Saturday 9 to 5 with lunch available. Sunday 7 to 2 with breakfast and lunch available. Registration $4.00 advance, $5.00 at the door. Free swap and shop with plenty of tables. Talk in on 146.01/61 and 146.34/94. For pre-registration contact Tom Plaisance, PO Box 9211, Yakima, WA 98909.

OPERATING EVENTS

"Things to do..."

MAY 5 AND 5: The Mason County ARC will operate commemorative stations KB7MJ and W7KTI on SSB, KN7D RTTY and K7UAR on Packet to celebrate the Shelton, Washington, Centennial. Certificates will be exchanged for a QSL card and 9 x 12 SASE. Send to Loren Mercer, KA7GSV, 2213 Olympic Hwy. North, Shelton, WA 98584.

JUNE 2: SRRC Hamfest, Princeton, Illinois. Plans include FCC/VEC exams. Registrations $2.50 before May 20. $3.00 June 2. For advance registrations and/or complete information, furnish a long SASE to Starved Rock Radio Club, W9MKS, RFD #1, Box 171, Oglesby, Illinois 61348. (815) 667-4614.

JUNE 1 AND 2: The Southside Amateur Radio Club will operate station NØEWP in honor of President Harry Truman's 101st birthday. The station will operate near the old Truman farm home in Grandview, MO during the annual "Harry's Heydays" celebration. For a commemorative certificate send 9 x 12 SASE with 33¢ postage to Southside ARC, PO Box 412, Grandview, MO 64030.

MAY 4: The Sand Hills Amateur Radio Club will operate KZØM during a DXpedition to Moscow, KS to commemorate May Day. For a special QSL SASE via Box 88, Moscow, KS 67952.

MAY 25: The Bay Area Amateur Radio Society, Pasadena, Maryland, will operate KM3I and KA3HKB to commemorate "Samuel F.B. Morse Day". For a special certificate send QSL and large SASE to B.A.A.R.S., PO Box 805, Pasadena, MD 21122-0805.

CQ CONTEST: VHF'ers please note! The first annual CQ World Wide VHF WPX Contest is July 20-22, 50 thru 1296 MHz. For details, logsheets, etc., write to SCORE, PO Box 1161, Denville, NJ 07834 or to CQ Magazine. We need your entry to make this a success.

MAY 18: ARRL/VEC License Exam at 9 AM, United Community Services Building (Red Cross), 39 North Park Street, Mansfield, Ohio. Send SASE, 610 and check for $4 payable to ARRL/VEC to Peggy Boyle, KC8NH, 1464 Marion Avenue Road, Mansfield, Ohio 44906.

MAY 18 AND 19: The Amateurs of Lima and Allen County, Ohio will commemorate the discovery of oil in Lima. Stations participating will sign /OIL and operate in the Novice, Technician or General portions of the bands. For a certificate SASE to Northwest Ohio ARC, PO Box 211, Lima, Ohio 45801.

JUNE 1: The Wireless Institute of Northern Ohio (W.I.N.O.) will be operating a special event station from an actual winery in Madison, Ohio to commemorate Ohio Wine Month. Listen for KO8O Saturday evening 7 and 11 PM EDST and Sunday 11 AM to 3 PM EDST. A special 8½ x 11 QSL certificate will be available from KO8O — WINO Weekend, 7126 Andover Drive, Mentor, Ohio 44060.

JUNE 8: Tri-City ARC will operate W7VPA from Ice Harbor Dam the highest lift navigable locks in the United States. Operation will be from 1700 to 2400Z. For a special QSL SASE to W7VPA, PO Box 73, Richland, WA 99352.

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

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SD1212-16	4.95	SD1308	3.00	SD1453H1	20.00	SRF2053-3	60.00	SD1263-1	15.00	SD1422-2	24.00	SD1544	26.00	SRF3071PF	50.00
SD1214-7	5.00	SD1311	1.00	SD1454-1	48.00	SRF2092	50.00	SD1272	10.95	SD1428	24.00	SD1545	33.00	SS4006	25.00
SD1214-11	5.00	SD1317	8.00	SD1477	35.00	SRF2147	22.00	SD1272-1	10.95	SD1428- 6084	12.00	SD1546H1	55.00	SS4152	15.00
SD1216	12.00	SD1319	2.50	SD1478	21.00	SRF2225	15.00	SD1272-2	10.95	SD1429-2	15.00	SD1561	79.00	TA7686	15.00
SD1219-4	15.00	SD1345-6	5.00	SD1480	53.00	SRF2264	25.00	SD1272-4	10.95	SD1429-3	14.90	SD1574-1	6.95	TA8559	15.00
SD1219-5	15.00	SD1347-1	1.00	SD1484	1.50	SRF2265	100.00	SD1278	13.75	SD1429-5	15.00	SD1575	6.95	TA8561	15.00
SD1219-8	15.00	SD1365-1	2.50	SD1484-5	1.50	SRF2281	5.00	SD1278-1	13.75	SD1430	12.00	SF4557	25.00	TA8562	15.00
SD1220*	8.00	SD1365-5	2.50	SD1484-6	1.50	SRF2371	15.00	SD1278-5	13.75	SD1430-2	18.00	SK3048	5.00	TA8563	15.00
SD1220-1	9.50	SD1375	7.50	SD1484-7	1.50	SRF2347	50.00	SD1279-1	18.00	SD1434	28.00	SL501-59	15.00	TA8564	15.00
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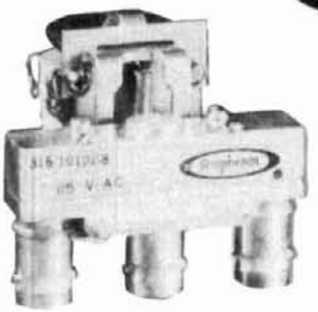

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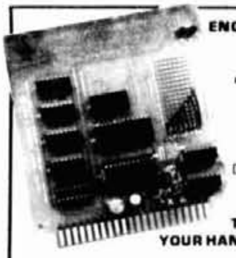

ENGINEERING CONSULTING
INTRODUCES

'REMOTE A PAD®' MODEL RAP-1

2 FOUR DIGIT DTMF DECODERS, PLUS 16 DIGIT KEYPAD CONTROL

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- Audio tones from any source, are converted to solid state switches which control any 16 digit keypad of a radio or other device.
- Some examples you can control include the Pro-Search™ Rotator (rotate beam remotely), ICOM IC-701 or ICOM IC-211 when using the RM-2 controller, ICOM 7950 & 751, Azden PCS 4000, handhelds such as Yaesu FT-208, FT-708, ICOM IC-02AT, and many more.
- Anything you can do manually with your 16 digit keypad, the RAP-1 will do remotely using audio touch tones from any source.
- Two (four digit) programmable access codes are used to operate relays or other on/off functions.
- LED decoder status indicators and momentary plus steady state decoder outputs are provided.
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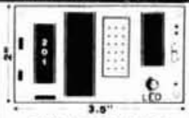
- Kit includes 3.58Mhz crystal, 22 pin IC socket, resistor, capacitors, data sheet and schematics

4 DIGIT SEQUENCE DECODER



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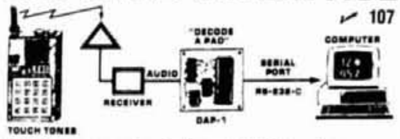
INTRODUCES

TOUCHTONE™ DTMF to RS-232-C 300 BAUD INTERFACE

✓ 107



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- Easily program your computer in BASIC to decode multi-digit "strings", display digits, sound alarms, observe secret codes, control relays, remote base.
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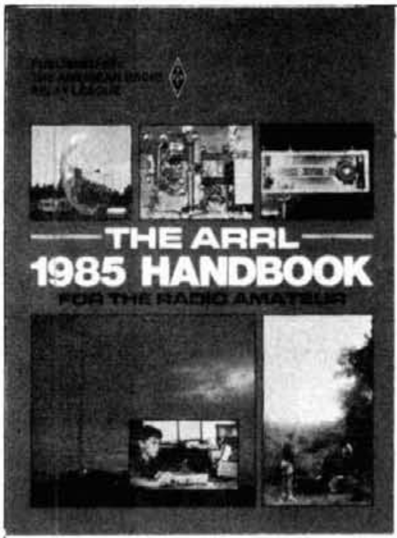

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This second edition is broadly updated in terms of device coverage. It includes the latest in state-of-the-art developments such as J Fet and MosFet in both single and multiple formats. This cookbook is edited into three basic parts. Part I introduces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

Despite the advent of CMOS, there is still design work being done with TTL circuitry. This book gives you a broad overview of exactly what TTL is, how it works and is full of design ideas and practical circuits. Areas that receive attention include: flip-flops, clocked logic, counters, counting techniques, noise generators and much more. You also get a complete discussion of practical TTL applications including digital counter, events counter, stopwatch and voltmeter to name just a few. ©1974, 1st edition, 333 pages.
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✓ 206

NEW products

new IC-735 HF transceiver

ICOM has announced the IC-735 ultra compact all-ham band HF transceiver and general coverage receiver, said to be the most compact and advanced HF SSB unit on the market. Measuring only 3.7 inches high by 9.5 inches wide by 9 inches deep, the IC-735 is suited for mobile, marine, or base station operation.

To enhance receiver performance, the IC-735 has built-in receiver attenuator and preamp. It also has a 105-dB dynamic range and a new low-noise phase locked loop for rock-solid reception.

The IC-735 features a large LCD readout and conveniently located controls that allow simple operation, even in the mobile environment. VOX controls, mic gain, and other infrequently changed controls are kept out of sight behind a hatch cover on the front panel of the radio, but are immediately accessible.

Other standard features included at no additional cost are: built-in FM, a 500-Hz CW filter (FL-32), an electronic CW keyer, an HM-12 scanning mic, FM/CW/LSB/USB/AM (TX and RX). 12 tunable memories with lithium memory backup, and both program and memory scan. Adjustable AGC, automatic SSB selection by band, an RF speech processor, and 12 volt operation are also standard. Output power is continuously adjustable up to 100 watts.

A new line of accessories, including the AT-120 automatic programmable antenna tuner and the PS-55 power supply, will also be available. The IC-735 is also compatible with most of ICOM's existing line of HF accessories.

The IC-735 will be available in May, 1985, and pricing will be announced the end of April. The IC-735 will be displayed at the Dayton Hamfest.

For additional information, contact ICOM America, Inc., 2380-116th Avenue, N. E., Bellevue, *Washington 98004*.

Circle #301 on Reader Service Card.

PV voltage regulators

Photocomm, Inc., of Scottsdale, Arizona, has announced new design features on its Power Control Series voltage regulators for photovoltaic applications.

A *removable printed circuit board has been* incorporated to simplify servicing and repairs; spare boards can also be purchased separately. These regulators now have a 30-amp load handling capability that allows for up to 12 40-watt *solar modules in parallel to be controlled simultaneously*. This benefit helps to lower overall system cost by using fewer regulators.

Standard features include temperature compensation, low voltage disconnect, analog meter package, transient protection and adjustable voltage setpoints. The controller is housed in a NEMA 3R weather-proof enclosure. 12 and 24 volt units are available off the shelf; other voltage units (36, 48, and 120 volts) can be provided upon request. Special options include Array Power Diversion, Manual Array Switching and a *Severe Environment Package*.

For further information, contact Photocomm, Inc., 7735 E. Redfield Road, Scottsdale, Arizona 85260.

Circle #302 on Reader Service Card.

multi-mode tuning indicator

Get on frequency quickly and accurately with the new HAL SPT-1 "Spectra-Tune" multi-mode tuning indicator. The SPT-1 may be used in the following modes of operation: RTTY (high tones) and RTTY (low tones), Fascimile (FAX), Slow-Scan Television (SSTV) and Morse Code (CW).

The frequency spectra of the received signal is displayed on a calibrated linear 40-segment red LED bar graph. The front panel calibration control allows the selection of which 1000 Hz range

NEW products

from 300 Hz to 3000 Hz is to be displayed. Best of all, hookup is very simple — and audio input line from the receiver/transceiver and a +12 VDC line are all that's required for operation. The SPT-1 comes with a one-year limited warranty.

The SPT-1 Spectra Tune is priced at $169.00.

For more information, contact HAL Communications Corporation, P.O. Box 365, Urbana, Illinois 61801.

Circle #303 on Reader Service Card.

KENPRO rotator products

The KENPRO brand line of rotators and accessories — including the KR-400 and KR-500 pair of rotators for satellite and space communications — are now available from Encomm, Inc. Also available are the KR-600RC medium-duty and the KR-2000RC heavy-duty units for use on the U.S.A. voltage system.

For further details, contact Encomm, Inc., Suite 800, 2000 Avenue 'G', Plano, Texas 75074.

Circle #304 on Reader Service Card.

VHF and UHF transmitter and receiver modules

Hamtronics, Inc. recently announced commercial versions of its popular high-band and UHF FM transmitter and receiver modules, FCC Type Accepted under parts 15, 22, 74, and 90. The TA-51 VHF transmitter and the TA-451 UHF transmitter are each capable of operating at 2 watts continuous duty and up to 3 watts intermittent service. The companion R144 and R451 receivers feature high sensitivity and superior front-end and IF selectivity, automatic frequency control, and hysteresis squelch to lock onto drifting or fading signals.

The Hamtronics® transmitter and receiver modules are supplied as printed circuit board assemblies that can be housed in a variety of ways and adapted to many applications. The low-cost units are suitable for use in voice and data links to replace phone lines, for remote control, for wireless alarm systems, for telemetry, for monitor receivers, and for many other applications.

Other Hamtronics® products of interest include "202" type FSK modulators and demodulators to provide digital data operation with FM transmitters and receivers, low-noise receiver preamps, 806-MHz band scanner converters, VHF AM receivers, repeater CORs, CWIDs, simplex and duplex autopatches, DTMF control and many other products related to VHF and UHF transmission and reception.

For a copy of Hamtronics' new 40-page catalog, contact Hamtronics, Inc., 65-F Moul Road, Hilton, New York 14468-9535. (For overseas mailing, send $2 or 4 IRCs.)

Circle #118 on Reader Service Card.

More Details? CHECK—OFF Page 166

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THE GUERRI REPORT

Ernie Guerri W6MGI

a busy signal from space

For over twenty-five years various nations have been launching satellites of one type or another. Many of the early satellites were experimental in nature, primarily intended to develop and test space hardware. However, the past fifteen years have been devoted to the more utilitarian aspects of space. Because our only link to satellites has been through RF paths, the amount of the spectrum devoted to this purpose has grown dramatically.

The geosynchronous equatorial orbits are particularly popular. This is because satellites placed in this position appear to remain in one place all the time, and can illuminate a large portion of the earth's surface. Because of the desirability of this location, it has become imperative that there be global cooperation with respect to the placement of satellites in the general equatorial area. Current agreements allow satellites to be positioned every 2 degrees over the populous equatorial coverage areas.

The resulting proliferation in the number of equatorial satellites puts a significant burden on antenna designers. The 2- degree equatorial spacing requires that antennas have very narrow beams, in addition to low sidelobes, in order to prevent interference to transponders on adjacent satellites. The transmitters and receivers used in these satellites are very sophisticated, and must utilize adaptive techniques in order to maintain predetermined signal-to-noise ratios without interference problems.

The RF spectrum assigned to satellites includes band segments from 400 MHz to over 30 GHz. The most densely used portions are in the region between 1.5 and 12.5 GHz. Because of the limited availability of electric power, satellite transmitters tend to be limited to about 50 to 100 watts, but antenna gains of 20 dB or more are not uncommon. Obviously, satellites intended to provide broad geographic coverage cannot employ highly directive antennas. Some key applications for modern satellites include the following:

Earth resources and position location. Most of us have seen some of the dramatic photographs taken from earth resources satellites showing crops, earthquake faults, volcanoes, and of course, daily weather patterns. These satellites rely on a wide variety of sensors employing optical, thermal, and radar techniques to form images of the earth's surface. In most cases the resolution is sufficient to reveal major highways, airports, and other key land-based features.

Most of these satellites operate in the 137 MHz and 1.6 GHz portions of the spectrum. Fairly simple receiving equipment will permit the home experimenter to receive exciting weather photographs from the APT and GOES satellites.

An important additional function of this general class of satellites is mapping and position location. Virtually any satellite with high resolution sensors can function as an excellent mapping satellite since its orbit can be precisely determined and its position accurately known at any given time. Twenty continuous years of this process has resulted in highly accurate mapping of the earth's entire surface, permitting significant improvements in the efficiency and safety of commercial shipping and aviation. A series of Global Positioning Satellites (GPS) is being developed by the United States; when its 18 satellites are completed and in place a few years from now, the signals from these satellites will enable appropriately equipped vessels to determine their exact position on the earth's surface to within about 100 feet (30 meters).

Telecommunications. It is the telecommunications function performed by modern satellites with which most of us are familiar. Telephone communications, data transmission, video links, and broadcast television now unite the world in a massive satellite-linked network. Satellites designed for this purpose do not originate signals, but are simply repeaters in the sky. They typically consist of a number of channels, called "transponders," that repeat signals in a 24 or 36 MHz band.

ADVERTISER'S INDEX AND READER SERVICE NUMBERS

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Limit 15 inquiries per request.

Please use before June 30, 1985.

Each satellite can have as many as ten transponders. This means that a single satellite may handle as many as 50,000 phone calls simultaneously. The availability of these high quality RF links has dramatically improved intercontinental voice and data communications. These links can now reliably transmit a page of FAX data to another part of the world in just a few seconds. Satellites enable commercial broadcasters to bring us important events from virtually every corner of the earth as they occur; the societal ramifications of this news immediacy are still developing.

Defense. Not to be upstaged, the military establishments have also been busy in space. Since profitability, in the commercial sense, is not an issue for military users, some of the tasks which satellites are called upon to perform are indeed exotic. These include such things as very high-speed data links (1 Gbit/sec.) and very high resolution imagery for reconnaissance purposes. Charged coupled sensors, cooled with liquid helium to increase sensitivity and mounted at the focal plane of precision lenses, provide orbital images with stunning detail. The ability of radar to penetrate cloud coverage and provide high resolution images is particularly attractive to military users. In some cases, the orbital path of the satellite is used to synthesize an antenna of large aperture and provide a simulated very narrow beam. This technique, called "synthetic aperture radar" (SAR), is capable of revealing subtle details, not visible by any other means, hidden in the earth's surface. Techniques of this type are used by defense organizations to locate submarines concealed below the ocean's surface.

Next time you look at the evening sky, be sobered by the thought that at that very instant, there are probably more conversations being repeated through satellites than if all the world's Amateurs were on the air at the same time. The pros do it without QRM. Now *that's* what I call a band plan!

ham radio

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Built-in-Monitor: 5" high resolution, delayed persistence green monitor — provides sharp clear image with no jiggle or jitter even under fluorescent lighting. Also has a provision for composite video signal output.
Time Clock: Displays Month, Date, Hour and Minute on the screen.
Time/Transmission/Receiving Feature: The built-in timer enables completely automatic TX/RX without operator's attendance.
Selcal (Selective Calling) System: With this feature, the unit only receives messages following a preset code. Built-in Demodulator for High Performance: Newly designed high speed RTTY demodulator has receiving capability of as fast as 300 Baud. Three-step shifts select either 170Hz, 425Hz or 850Hz shift with manual fine tune control of space channel for odd shifts. HIGH (Mark Frequency 2125Hz)/LOW (Mark Frequency 1275Hz) tone pair select. Mark only or Space only copy capability for selective fading. ARQ/FEC features incorporated.
Crystal Controlled AFSK Modulator: A transceiver without FSK function can transmit in RTTY mode by utilizing the high stability crystal-controlled modulator controlled by the computer.
Photocoupler CW, FSK Keyer built-in: Very high voltage, high current photocoupler keyer is provided for CW, FSK keying.
Convenient ASCII Key Arrangement: The keyboard layout is ASCII arrangement with function keys. Automatic insertion of LTR/FIG code makes operation a breeze.
Battery Back-up Memory: Data in the battery back-up memory, covering 72 characters × 7 channels and 24 characters × 8 channels, is retained even when the external power source is removed. Messages can be recalled from a keyboard instruction and some particular channels can be read out continuously. You can write messages into any channel while receiving.
Large Capacity Display Memory: Covers up to 1,280 characters. Screen Format contains 40 characters × 16 lines × 2 pages.
Screen Display Type-Ahead Buffer Memory: A 160-character buffer memory is displayed on the lower part of the screen. The characters move to the left erasing one by one as soon as they are transmitted. Messages can be written during the receiving state for transmission with battery back-up memory or SEND function.
Function Display System: Each function (mode, channel number, speed, etc.) is displayed on the screen.
Printer Interface: Centronics Para Compatible interface enables easy connection of a low-cost dot printer for hard copy.

Wide Range of Transmitting and Receiving: Morse Code transmitting speed can be set from the keyboard at any rate between 5-100 WPM (every word per minute). AUTOTRACK on receive. For communication in Baudot and ASCII Codes, rate is variable by a keyboard instruction between 12-300 Baud when using RTTY Modem and between 12-600 Baud when using TTL level. The variable speed feature makes the unit ideal for amateur, business and commercial use.
Pre-load Function: The buffer memory can store the messages written from the keyboard instead of sending them immediately. The stored messages can be sent with a keyboard command.
"RUB-OUT" Function: You can correct mistakes while writing messages in the buffer memory. Misspellings can also be erased while the information is still in the buffer memory.
Automatic CR/LF: While transmitting, CR/LF automatically sent every 64, 72 or 80 characters.
WORD MODE operation: Characters can be transmitted by word groupings, not every character, from the buffer memory with keyboard instruction.
LINE MODE operation: Characters can be transmitted by line groupings from the buffer memory.
WORD-WRAP-AROUND operation: In receive mode, WORD-WRAP-AROUND prevents the last word of the line from splitting in two and makes the screen easily read.
"ECHO" Function: With a keyboard instruction, received data can be read and sent out at the same time. This function enables a cassette tape recorder to be used as a back-up memory, and a system can be created just like telex which uses paper tape.
Cursor Control Function: Full cursor control (up/down, left/right) is available from the keyboard. Test Message Function: "RY" and "QBF" test messages can be repeated with this function.
MARK-AND-BREAK (SPACE-AND-BREAK) System: Either mark or space tone can be used to copy RTTY.
Variable CW weights: For CW transmission, weights (ratio of dot to dash) can be changed within the limits of 1:3-1:6.
Audio Monitor Circuit: A built-in audio monitor circuit with an automatic transmit/receive switch enables checking of the transmitting and receiving state. In receive mode, it is possible to check the output of the mark filter, the space filter and AGC amplifier prior to the filters.
CW Practice Function: The unit reads data from the hand key and displays the characters on the screen. CW keying output circuit works according to the key operation.
CW Random Generator: Output of CW random signal can be used as CW reading practice. **Bargraph LED Meter for Tuning:** Tuning of CW and RTTY is very easy with the bargraph LED meter. In addition, provision has been made for attachment of an oscilloscope to aid tuning.
Built-in AC/DC: Power supply is switchable as required; 100-120 VAC; 220-240 VAC/50/60Hz + 13:8VDC.
Color: Light grey with dark grey trim — matches most current transceivers.
Dimensions: 363(W) × 121(H) × 351(D) mm: Terminal Unit.
Warranty: One Year Limited
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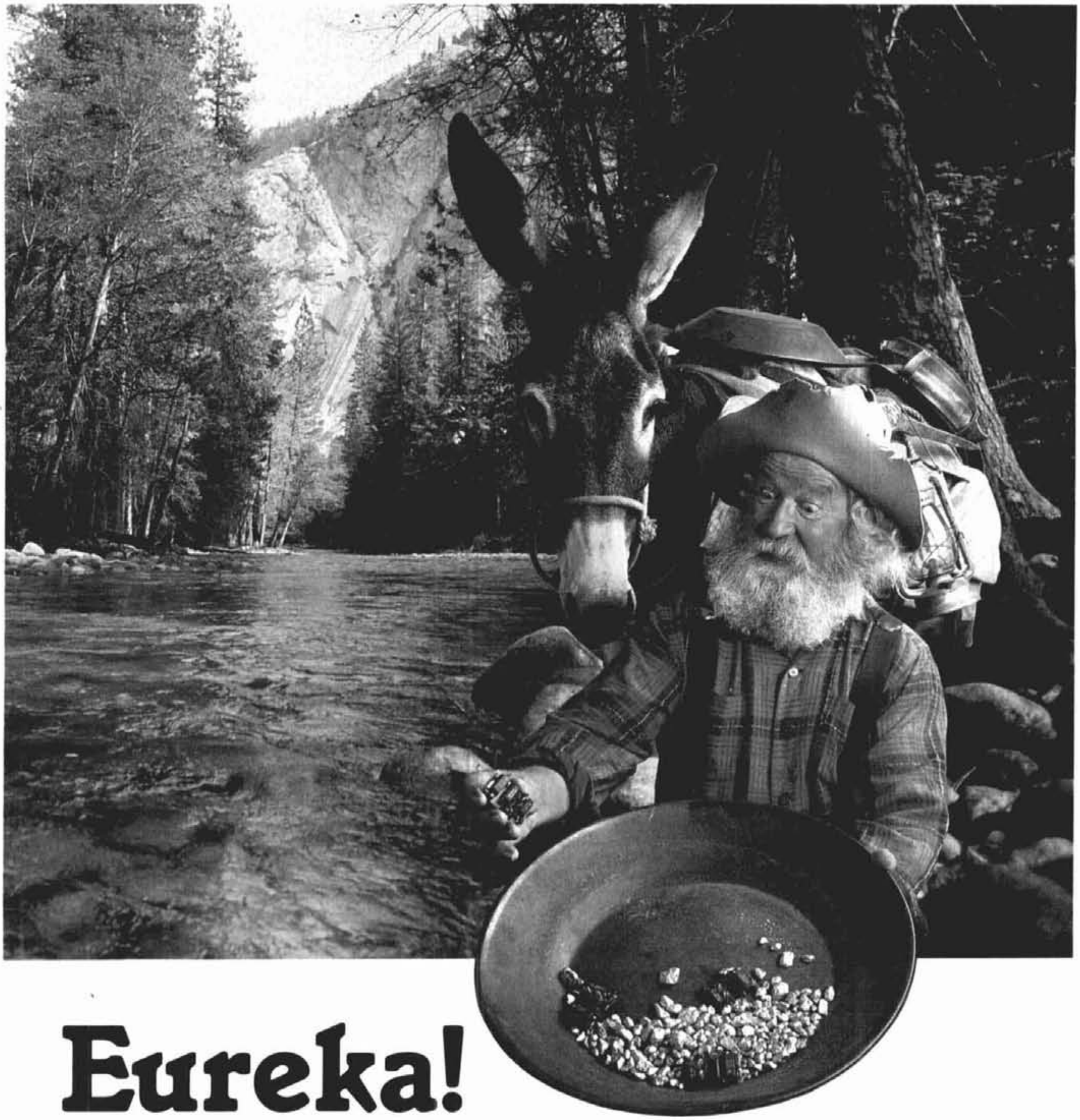

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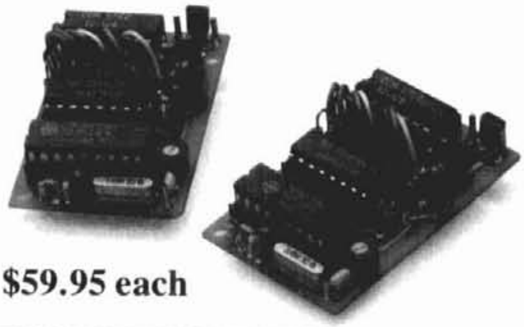

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- **Programmable scanning.**
- **Semi or full break-in (QSK) CW.**
- **Low distortion transmitter.** Kenwood's unique transmitter design delivers top "quality Kenwood" sound.
- **Keyboard entry frequency selection.** Operating frequencies may be directly entered into the TS-940S without using the VFO knob.
- **Graphic display of operating features.** Exclusive multi-function LCD sub-display panel shows CW VBT, SSB slope tuning, as well as frequency, time, and AT-940 antenna tuner status.
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Optional accessories:

• AT-940 full range (160-10 m) automatic antenna tuner • SP-940S external speaker with audio filtering • YG-455C-1 (500 Hz), YG-455CN-1 (250 Hz), YK-88C-1 (500 Hz) CW filters; YK-88A-1 (6 kHz) AM filter • VS-1 voice synthesizer • SO-1 temperature compensated crystal oscillator • MC-42S UP/DOWN hand mic.
• MC-60A, MC-80, MC-85 deluxe base station mics.
• PC-1A phone patch
• TL-922A linear amplifier
• SM-220 station monitor
• BS-8 pan display
• SW-200A and SW-2000 SWR and power meters.

- **Built-in FM, plus SSB, CW, AM, FSK.**
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- **General coverage receiver.** Tunes from 150 kHz to 30 MHz.

More TS-940S information is available from authorized Kenwood dealers.

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Complete service manuals are available for all Trio-Kenwood transceivers and most accessories.
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