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contents

REFLECTIONS

it used to be . . .

It used to be one of the major considerations in planning any antenna installation. After the wish list ("How many?" "What kind?" "How high?" "What bands?") was complete, reality entered the picture, raising such questions as "Can I really afford all this?" and "What kind of reception will I get?" This latter question often had less to do with performance and more to do with worrying about what the neighbors — and the zoning board — would say.

Radio Amateurs nationwide breathed (or should have breathed) a collective sigh of relief on February 12, 1987, when the courageous and persistent John Thernes, WM4T — who had taken on, at considerable personal expense, the city of Lakeside Park, Kentucky — won his case. In April, 1982, John had filed an application with the city zoning administrator for permission to erect a tower which was to include a triband beam at 70 feet and a two-element, 40-meter beam at 78 feet. (The specifics are important.) He was told, in effect, that the city's zoning regulations excluded *all* antenna towers. His application was rejected.

The details can be found in all the major Amateur Radio news reports (HR's *Presstop*, *The W5YI Report*, *The Westlink Report*, and *The ARRL Letter*) and in the other ham magazines, but basically what happened is that John took his struggle right on up to the Federal Appeals Court. And on February 12, the city of Lakeside Park agreed to sign a full consent judgment. What this meant to him was that he could now install his tower, his antennas, and his guy lines. There was a compromise — instead of a total height of 78 feet, he had to "settle" for 73 feet overall. (I believe I read that 73 feet would have been acceptable to John at the very beginning, before the city turned him down for any height at all.)

The significance of this case isn't that one Radio Amateur won his own personal antenna battle, but that *we all did*. . . because this was the first time that Memorandum Opinion and Order FCC 85-506, better known as PRB-1, was tested and supported in the higher courts. In its initial resolution, the Commission had declared that "local regulations which involve placement, screening or height of antennas based on health, safety or aesthetic considerations must reasonably accomodate amateur communications and represent the minimum practicable regulation to accomplish the purpose of the local authorities." In other words, it maintained that local and state governments cannot arbitrarily rule against the installation of Amateur Radio antennas.

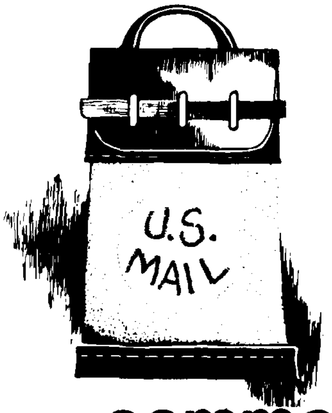
John's legal fees, I believe, exceeded $20,000. In deciding in his favor, the court ordered the city of Lakeside Park to pay all John's legal fees — almost $14,000 — incurred since the enactment of PRB-1. It now appears likely that any municipality that contests other proposed Amateur installations could very well lose and be held responsible for costs.

This is our annual antenna issue. Personally, I couldn't have asked for a more appropriate time to acknowledge and discuss WM4T's victory.

You can get a copy of the consent decree from the Northern Kentucky Tower Fund (P.O. Box 17721, Lakeside Park, Kentucky 41017; SASE appreciated). John, by the way, is reportedly still out approximately $7,000 of his own money; when you write for your copy of the decree, you may want to consider enclosing a donation to help minimize the impact.

Rich Rosen, K2RR
Editor-in-Chief

Amateurs interested in further developments in this and other cases may want to attend the Amateur Radio And The Law Forum conducted by attorney Jim O'Connell, W9WU, at 1 PM on Sunday, April 26, at this year's Dayton Hamvention.



comments

modifying the IC-02

Dear HR:

Readers may beinterested to know that the extended receive modification for the IC-02 described in my article, "Extending Receive Coverage for the IC-02 and IC-04" (July, 1986, page 77), will work for *all* IC-02 HTs, including those with serial numbers above 34,000.

Robert K. Morrow, Jr., WB6GTM
Flora, Indiana

Yagi design program

Dear HR:

Early in 1984, Jerry Haigwood, KY4Z, and I wrote a computer program, based on DL6WU's article in the March, 1982 issue of *VHF Communications*, for designing long Yagi antennas. We presented that program at the West Coast VHF Conference held in May of that year at Paso Robles, California. Therefore, it should be no surprise that I have looked very carefully at the program developed by VK4ZF and described in his article "Computer-Aided Design of Long VHF Yagi Antennas," which appeared in the May, 1986 issue of Ham Radio [page 28].

VK4ZF did an admirable job, but I believe that certain deficiencies should be pointed out. (The same could probably be done about the program Jerry and I wrote.)

First, the initial input requirement for the number of elements in the antenna is irrelevant. The initial criterion should be the desired gain or the available boom length. (Coincidentally, the irrelevance of the number of elements is covered by Joe Reisert in his column in the same issue [page 103]). Furthermore, in an earlier paper, DL6WU stated that the minimum boom length for an antenna of this type is about two wavelengths; a 2.2-wavelength boom will accommodate eight directors. There is no restriction as to the minimum number of elements in the program.

Second, the diameter of the elements is limited to the discrete values for which data files have been made. This makes it impossible to compare the program results directly with the example antennas described by DL6WU, although the differences are slight.

Third, the program is limited to 40 elements, which makes it impossible to compare the data for directors 39 through 47 of the 1296-MHz antenna described by DL6WU. There does not seem to be any valid reason for this limitation, since DL6WU states that his curves can be extrapolated almost indefinitely.

Fourth, the program limits the boom diameter to 0.05 wavelength, although this can be changed easily by modifying line 490. Without this change, it is impossible to use a boom diameter of 12.7 mm at 1296 MHz, which is the boom size used by DL6WU. Correspondence between DL6WU and KY4Z indicates that a minimum boom diameter of 0.075 wavelength is acceptable.

I have enclosed comparisons of the element lengths and spacings, showing DL6WU's figures, those obtained from VK4ZF's program, and those generated by the program written by KY4Z and me. A major discrepancy seems to be the length of the driven element in VK4ZF's program; it is far too short at 432 MHz, but slightly long at 1296 MHz.

None of the limitations described above exist in the program written by KY4Z and me, although the program does not include calculation of beam widths or stacking distances. Furthermore, it is a great deal easier to keyboard because the 16 data files are not required (which also conserves disk space).

Our program was written in Microsoft BASIC and will run under GWBASIC and BASICA. Minor editing may be required to convert it to other species of BASIC.

The program exists, under the filename DL6WU-1.BAS, on most of the RCPM bulletin boards in the San Francisco Bay Area, including KY4Z's AMPRO1 at 408-258-8128. I can also supply it in the following forms:

1. A listing, with a sample printout of results, for $1.00 (U.S.) plus a No. 10 (business-size) SASE. (Outside of the United States and Canada, send 10 IRCs.)

2. A 5.25-inch soft-sectored floppy disk for virtually any CPM computer (except Apple) or for any PC/MS-DOS computer. Be certain to specify the disk format desired (and an alternate, if possible) or the version of PC/MS-DOS that is used. The cost in the USA and Canada is $5.00 (U.S.), elsewhere, $7.00 (U.S.); this covers the cost of the disk, mailer, and postage. The same costs apply to either a disk or tape cassette for the Commodore 64.

Please address all requests to me.

Robert S. Stein, W6NBI
1849 Middleton Avenue
Los Altos, California 94022

any ideas?

Dear HR:

A friend installed a plastic owl on his beam to discourage birds. A real owl appeared and attempted to court the plastic owl. When the plastic owl failed to respond, it was attacked by the real owl, causing commotion and damage.

Any ideas, anyone?

Berand Kirschner
Oceanside, California 92056

two-element hf beams

Tune these medium-sized high performance antennas right from the shack

Physically small beam antennas that represent the least compromise in gain and directivity have been discussed in the literature.[1] Large antennas, for those for whom size is no problem, have received widespread coverage; the W2PV series of articles, for example, includes a wealth of material on large Yagis.[2] Yet the topic of medium-sized antennas — which includes the majority of Amateur beams — remains an area of uncertainty, about which many have sought without success for more information. The quad-versus-Yagi controversy continues unabated; conflicting claims are made for what might appear to be a bewildering variety of different beams, and an imperfect grasp of essentials has turned an inherently simple situation into one of needless complexity, with two-element beams deprived of their rightful status.

how small two-element beams work

In **fig. 1**, we have a bird's-eye view of two identical vertical elements carrying equal currents and spaced by a small fraction of a wavelength, with the plus and minus signs indicating that they are initially fed in opposite phase, thus tending to cancel each other.

At this point it's not important to know how the currents got there. Energy arriving at a specific point in space travels a different distance from each vertical element. This difference in path length and the opposite polarity of each vertical causes the maximum radiation from the array (two elements) to be along a line that goes through the elements. The two fields combine vectorially as shown in **fig. 1B**. For small angles, (ϕ_0) halving the angle halves the field. As one moves around the antenna, the difference is reduced; therefore the angle reduces, producing the directional pattern shown in **fig. 1C**, which is independent of spacing *as long as the angle remains small.* It follows that because energy remains similarly distributed throughout space, signal strengths must also be independent of spacing — provided there are no losses. Usually one introduces an electrical phase shift, ϕ. If this is equal to the spatial phase shift, ϕ_0, cancellation takes place in the reverse direction, producing the well-known cardioid pattern of **fig. 1D**. As the electrical phase shift, ϕ, is reduced, the null in the back direction splits into two. It gradually shifts around, with the back lobe increasing in strength until we arrive back at **fig. 1C**. However, for a given ratio of ϕ/ϕ_0, the pattern remains independent of spacing.

In the case of horizontal beams the directional pattern of the individual elements is superimposed on the beam patterns derived in accordance with **fig. 1**, but the principles are the same. Because no dimensions are mentioned, it follows that for two elements *the directive pattern — and therefore the gain — depend only upon the phase shift ratio, ϕ/ϕ_0, and are independent of the size, shape, or spacing of elements, provided the dimensions are not excessive.* This rule is reasonably accurate for element lengths up to about 0.7λ, and as shown in **fig. 2**, for spacings up to 0.2λ. It starts to break down if there are regions of high current that are separated by a substantial fraction of a wavelength, the λ/4 separation between top and bottom of a quad loop not being appreciable in this context. In this case, a directive pattern results through the addition of fields — a completely different mechanism that is the basic principle of large arrays. **Figure 2** shows the effect that element spacing has on gain and, from another source, a very similar curve for three elements.[3]

The basic statement emphasizing gain as primarily a function of the phase shift ratio rather than spacing — though it seems physically obvious — is in flat contradiction of widely published figures. These figures, derived mathematically for parasitic arrays, show gain and directivity to be *critically* dependent upon spacing and whether an element is tuned as a director or reflector. But although the calculations are indeed correct, they happen to be the wrong ones! More accurately stated, perhaps it's the designs to which they relate that are faulty, since I have assumed equal currents, whereas normally performance is sacrificed if the elements are straight.[5] As can be inferred from **fig. 3**, this is the worst possible shape because it minimizes coupling, consequently precluding the possibility of the presence of equal currents, except with very close

Les Moxon, G6XN, Gorse Hill, Tilford Road, Hindhead GU26 6SJ Surrey, England

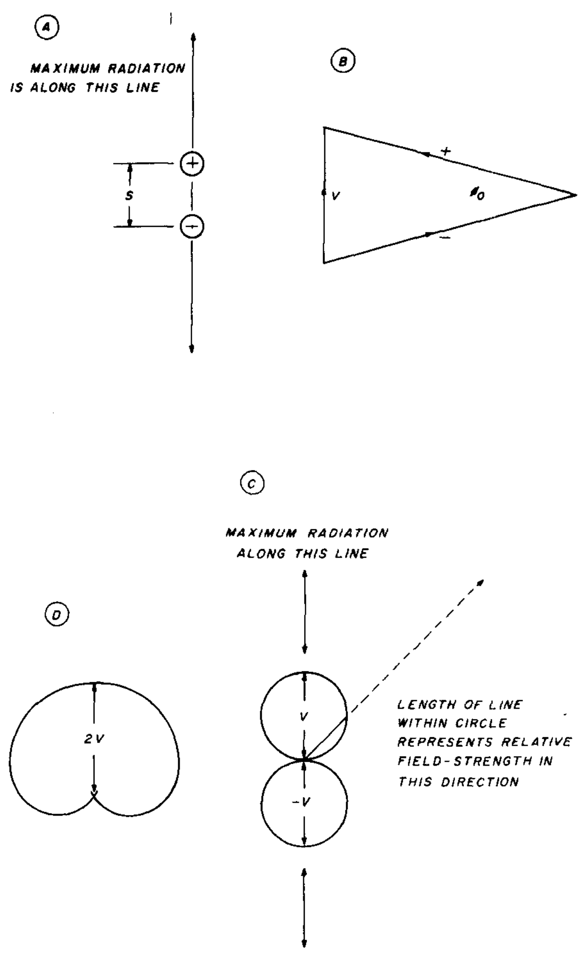


fig. 1. (A) Two closely-spaced sources separated by distance "S." (B) Vector addition results in voltage V that for small angles is proportional to ϕ_0. (C) Polar plot shows variation of field voltage as a function angle to observer. No additional (electrical) phase shift has been introduced — i.e., ϕ = 0. (D) Field pattern if electrical phase shift, ϕ equals physical phase shift (ϕ_0).

spacing (0.05λ). Nulls in the directional pattern are filled in and gain is also adversely affected.

Coupling between straight elements can be increased by moving them closer together. But for this to be effective, spacing has to be reduced to about 0.05λ, which is normally regarded as unacceptable because of reduction in bandwidth and efficiency. For this spacing, my calculations and those of W2PV are in close agreement. In my case, however, due to the assumption of equal current amplitudes, dependence on physical dimensions has been eliminated.

Inductive coupling (**fig. 3A**) isn't advised because of the reduction in radiation resistance. More often, natural coupling tends to be capacitive and needs only to be supplemented. One advantage of the quad is that loops couple more tightly than straight dipoles; this probably accounts for its popularity despite a poor reputation for survival in high winds. On the other hand, bent elements (see **figs. 3B** and **3C**) lend themselves to the design of more compact but equally efficient antennas with overcoupling rather than undercoupling as the more common fault. This is easy to correct either by an alteration of spacing or, if necessary, neutralization[1], as shown in **fig. 3C.**

mutual impedance

From the narrowing of the radiation pattern, it is evident that there must be gain relative to a dipole. But how, one might ask, can this be if the elements are tending to cancel each other? The answer lies in the fact that the element currents rise to whatever value may be necessary to account for the observed gain, and they can do so only by virtue of the *mutual resistance* between the elements which subtracts from the self-resistances when closely spaced elements are excited in antiphase. Without mutual resistance, there can be no power gain; these quantities are inseparable, so that given equal currents, one follows from the other. On the other hand, mutual resistance alone cannot achieve the degree of current equality necessary for obtaining deep nulls. This requires *mutual reactance*, which exists in most cases but may need to be increased or decreased, with reflector operation requiring negative reactance. Mutual resistance, R_m and reactance, X_m data appears to be available only for straight λ/2 elements (**fig. 4**), but the "size rule" implies that mutual resistance bears a constant relationship to the single-element radiation resistance (R), and so the mutual resistance can, if necessary, be inferred from it. Likewise, if the elements are self-resonant, mutual reactance can in principle be determined from

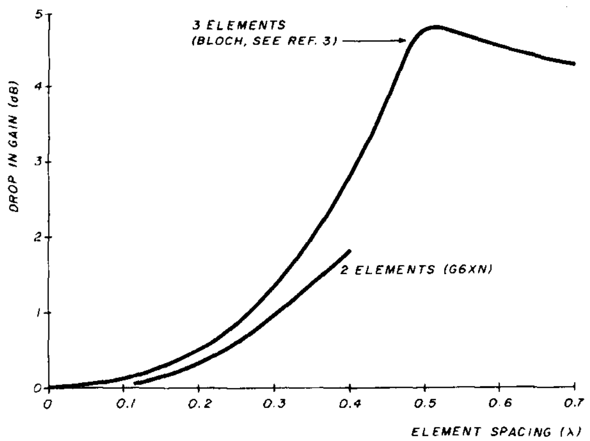


fig. 2. Decrease of gain with increase of spacing. Note that gain is a minimum for both two- and three-element beams as spacing diminishes though practical constraint impose a lower limit of about 0.1λ.

directions of minimum response by obtaining corresponding values of ϕ/ϕ_0 from **fig. 5**, since with no detuning the phase shift ϕ is determined solely by the phase angle of the mutual impedance — i.e. by X_m/R_m so that by knowing ϕ, ϕ_0 and R_m we can evaluate X_m. This method has not been evaluated in practice and its use is restricted by the fact that with large departures of X_m from its optimum value the nulls will not be deep enough for their direction to be determined. In general, however, with two elements there should be no need to know the actual value of X_m since constructions are available which allow it to be adjusted by trial and error. Additionally, by virtue of the "size rule" calculations or measurements for a set of dimensions for which X_m is known can be applied to any other, with due allowances for differences in R. Calculations, simplified by assuming equal currents,[5] have led to further results:

- Radiation resistance (R_B) for a parasitic array is given by

$$R_B = 2\,(R - R_M \cos \phi)$$

- For an array in which each element has its own feedline, the radiation resistances are:

$$R\ director = R - R_M \cos \phi + X_M \sin \phi$$

$$R\ reflector = R - R_M \cos \phi - X_M \sin \phi$$

With a resonant reflector and equal currents, the null directions are approximately 130 degrees relative to the beam heading in all cases. The total resistance is the same as before, but that of the reflector (or director if X_M is positive) can be zero or even negative, which bodes ill for the matching process. Until now, driven operation has been the usual method of trying to equalize currents, but the reason for some failures may now be apparent, particularly because the usual phasing lines must be matched for correct operation. Solutions to this problem have been discussed before.[1,5] Driven operation remains a possible solution to the problem of obtaining equal currents with straight elements, and a number of such antennas have been described. Most of these, intended to be reversible, specify λ/4 spacing, which is too wide, or λ/8 spacing, which is convenient and simplifies the mathematics to the extent that X_M disappears. Unfortunately, because of mutual reactances of opposite sign, which each element induces into the other, a very high VSWR exists in each of the individual feeders. This high VSWR may not be noticed because it doesn't appear in the common feed from the transmitter; if it were corrected, the beam couldn't be reversed because the correction would then be of the wrong sign and make matters worse. Open wire lines can be used, but result in excessively narrow bandwidth (though I've overcome this by using folded dipole elements).

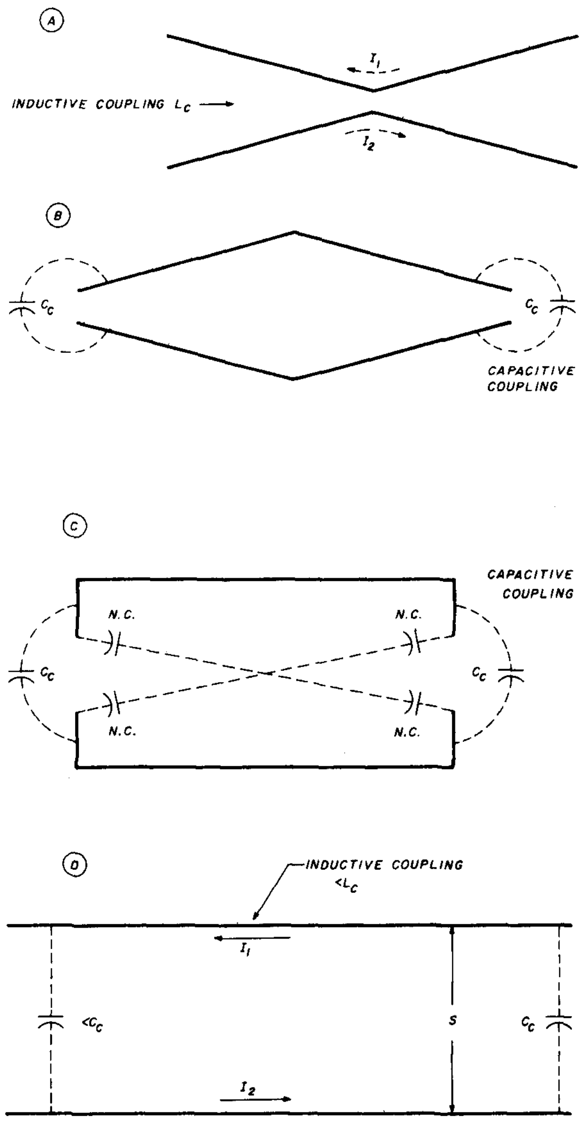


fig. 3. Inductive and capacitive coupling of two elements. (A) Elements bent inwards at their centers couple inductively. (B, C) Ends bent inwards couple capacitively. (D) Excessive coupling may be neutralized by capacitors as shown in (C). In (D), the two couplings cancel each other if S = λ/8, leaving only the resistive coupling, R. Straight elements minimize coupling.

Overcoupling is a problem likely to be experienced in the case of quads with less than 0.15λ spacing. The "Swiss Quad" (with 0.1λ spacing) gets around this by driven operation, but as we'll discuss later, there are many advantages to be derived from resonant feeders, including the possibility of increasing coupling or neutralizing excess coupling by means of capacitance between the lines. **Figure 5** shows the dependence of gain, radiation resistance, and null directions on the phase shift ratio.[1,5] If any one of these quantities is known, all the others except radiation resistance (R_B)

follow from it. For the last parameter, we also need to know the value for a single element (R); with a few exceptions, this can be obtained from **fig. 6**. The method of calculation is explained in reference 5. **Figure 7** is a further extension of **fig. 5** showing the direction and magnitude of the back lobes in the radiation pattern. They demonstrate the crucial importance of the ratio ϕ/ϕ_0 in determining all aspects of the performance of two-element beams (including bandwidth, since this is linked to radiation resistance, as discussed later).

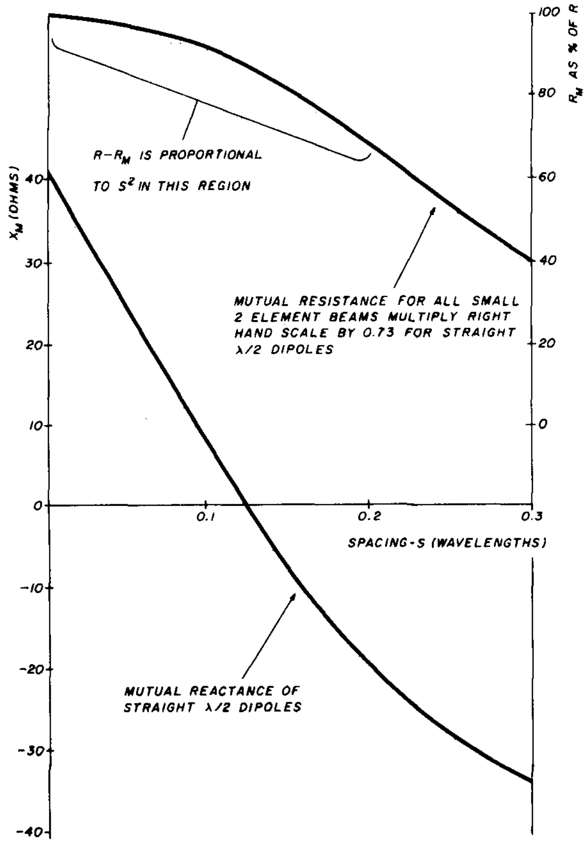


fig. 4. Mutual resistance R_m and mutual reactance X_m as a function of spacing for two-element beams.

directivity gain

So far we've assumed that there are no losses. Apart from feeder loss, other losses may occur because of proximity to nearby structures, use of very thin wire, or as the limiting factor when trying to make an antenna as small as possible. Besides radiation pattern distortion, currents induced in booms or supporting structures due to lack of symmetry may introduce additional losses. If equal currents and correct phasing are maintained, losses as such have no effect on directivity which, because of high external noise levels, is usually the sole requirement in the case of reception on the hf bands.

Losses can make it impossible to equalize currents by means of increased coupling, but there is then no longer any problem with driven operation since the mutual resistance, as a result of these losses, is no longer in control of the situation. Because of this, it's customary to distinguish between directivity gain and power gain, the two being equal when there are no losses.

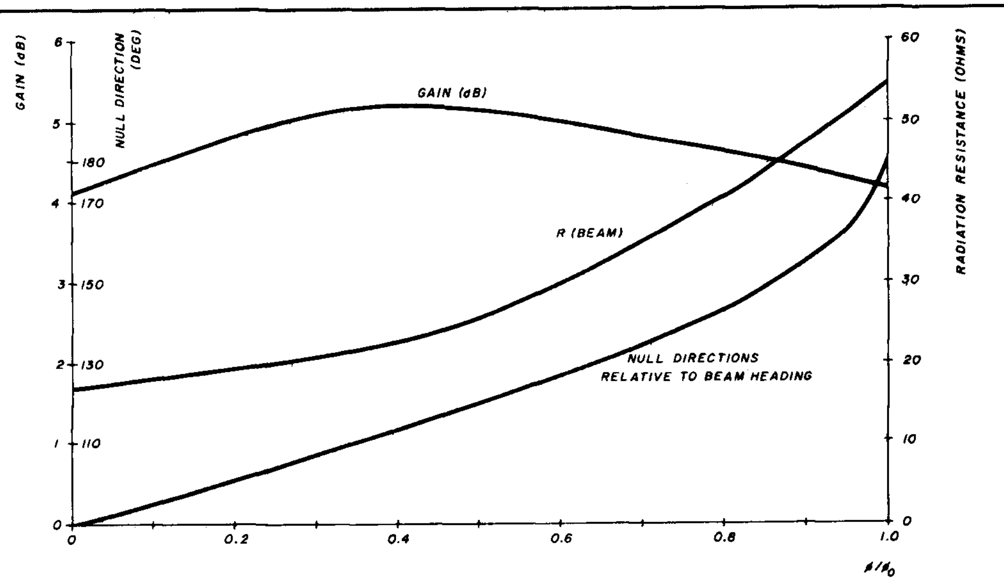


fig. 5. Relationship between phase angle, gain, null directions, and radiation resistance for all close-spaced, two-element beams with equal current drive. Note: losses not included; gain figures valid within 0.3 dB for null depths > 10 dB (approx.). Radiation resistance (in ohms) for half-wave elements spaced λ/8 (see text for other beams).

losses

Horizontal monoband hf beam losses rarely exceed a few ohms, and with radiation resistances of a few tens of ohms, can usually be neglected. In doubtful cases they can be roughly estimated from conductor sizes, assuming one has some idea of the current distribution.

Resistance data in graph form can be found in textbooks, but a handy figure to remember is one ohm per half-wavelength for 3-mm diameter copper wire (approximately No.10 AWG) at 14 MHz. The loss is inversely proportional to diameter and to the square root of frequency. However, divide by 2 for long conductors that have a sine wave current distribution, such as antenna wires or resonant feeders. This gives the resistance referred to a point of maximum current, which is standard practice also in the case of the radiation resistance with which it must be compared. For parallel wires, divide by the number of wires; for aluminum alloy, multiply by 1.6, and don't use iron or steel!

bandwidth

Bandwidth is roughly proportional to radiation resistance but also varies inversely with the length of the resonant system (which includes the antenna up to the point of matching). We are interested in two kinds of bandwidth:

• **SWR bandwidth** — i.e., the frequency range over which the SWR is less than 2.0. As might be expected by analogy with coupled circuits, bandwidth in this sense is improved by tighter coupling between elements. The better the SWR bandwidth, the less frequently the antenna tuner has to be readjusted, or the better the chance of being able to dispense with it. In general, SWR tends to rise steeply at the low frequency end of the tuning range, since tuning low is equivalent to tuning the reflector higher. This reduces ϕ, causing a shift to the left on the curves shown in **fig. 5**, with R_B dropping to a relatively low value.

• **Pattern bandwidth,** or the frequency range in which a specified null depth such as 10 dB is exceeded or the forward gain remains within 1 dB of maximum. Despite their relatively small size the antennas to be described here come close to meeting the above specifications on most bands without retuning the reflector. This is consistent with a reasonable degree of operating convenience, but to take advantage of very deep nulls it's essential for the reflector to be connected through its own feeder to a tuning device at the operating position. In this case, pattern bandwidth is less important but makes for added convenience. Use of two feeders provides an additional bonus: the ability to reverse beam direction.

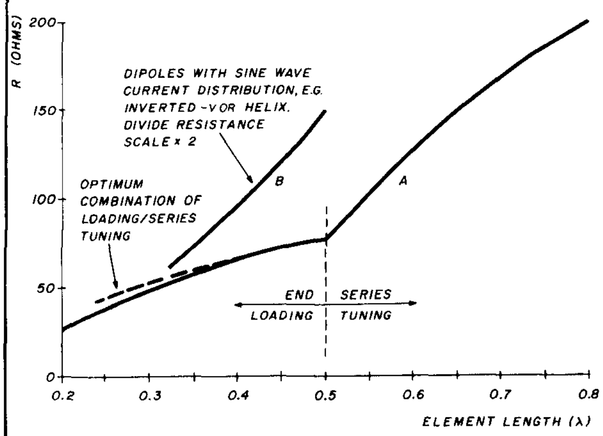


fig. 6. Radiation resistance of (A) "best possible" dipole elements (includes fig. 8C) and (B) resonant λ/2 dipoles fitting into restricted space (e.g., fig. 8D) — in this case, R is proportional to (1/length)².

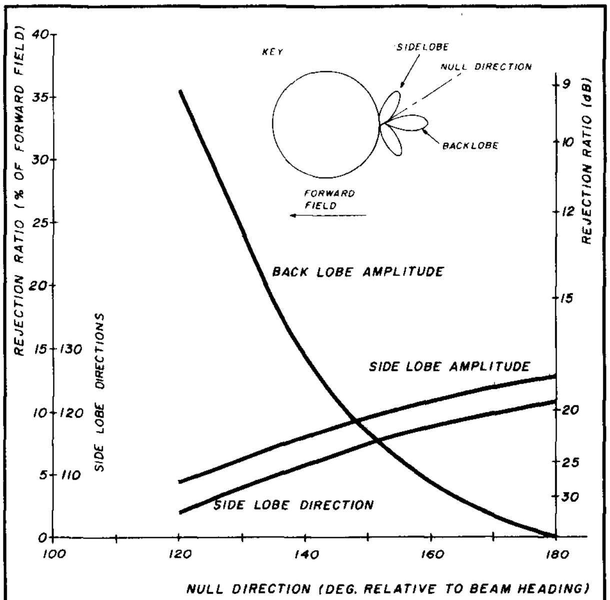


fig. 7. Size and direction of back lobes (see key, above). For corresponding gains, see *fig. 5*.

design of elements

Although elements don't have to be identical, it usually helps — and is essential if one wants to be able to reverse beam direction without having to retune. **Figure 6** shows that half-wave elements can be reduced by 30 percent in length for only a trivial reduction (17 percent) in radiation resistance, provided capacitive end-loading (or its equivalent) is used. **Figure 8** shows three practical ways of achieving this. In the case of **fig. 8C**, *AB* and *CD* act solely as end

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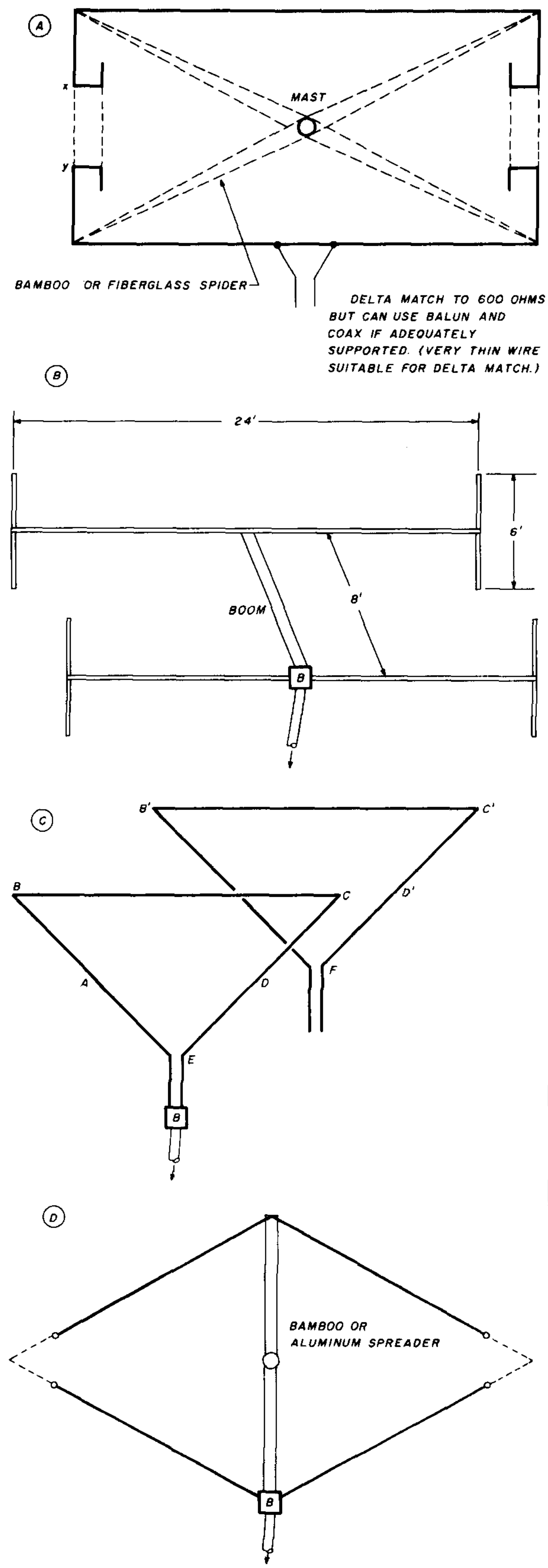

fig. 8. Two-element horizontal beams with reduced length and enhanced coupling. Reflector should preferably be a duplicate of the driven element (see text). Otherwise, if currents equal (i.e. if deep nulls are obtainable), tune reflector to the low edge of desired band. (A) Bent dipole elements (20 x 10 feet suggested, though dimensions are not critical) xy (nylon fishing line) ≈ 30 inches. (B) End-loading by vertical rods. Single elements have been used successfully with the dimensions shown. Coupling may need augmenting. (C) Small delta loops (ABCD) should be just over λ/2. Size can be reduced by small loading stubs. BB′ may be 0.12-0.2λ; EF<BB′/2. (D) Erect between posts or as inverted V. Spreader (or boom) may be 9-12 feet for 14 MHz.

loading because radiation from them is cancelled by that from *AE* and *DE*.

Most of the designs to be described are based on the small delta loop (**fig. 8C**), which can be suspended between the tips of fiberglass fishing rods angled upwards, thus achieving an effective height considerably in excess of the mast height, since there's little or no radiation from the sides of the loop. In this form it has become known as "The Claw" for reasons obvious from the photograph (**fig. 15**). In most cases there seems to be little point in exceeding an element span of about 35 percent of the longest wavelength to be used; further size reduction is governed by three main constraints: bandwidth, losses, and difficulty of folding enough loading wire into the space available. For a reasonable approximation to "full size" performance, the above length can be more than halved if some form of remote tuning is provided.[1] Practical difficulties escalate rapidly as the span length drops below 0.25λ.

The arrangement shown in **fig. 8D** can be erected as an inverted V and is important as an alternative option though the sinusoidal current distribution halves the radiation resistance for a given span.

coupling and null depth

All four arrangements shown in **fig. 8** provide increased coupling. In cases A and D, this is readily adjustable by altering the spacing between ends; 30 inches for a span of 20 to 24 feet at 14 MHz has been found suitable, but some experiments may be advisable. Ajustment of coupling isn't critical. I've found that "design by guesswork" frequently produces null depths in excess of 20 dB. It's best for errors to be corrected in the antenna itself, but for fine tuning, placing capacitors between convenient points on feeders has been found satisfactory. These can be connected either in phase to increase coupling or out of phase to neutralize excessive coupling. I then find it possible to get null depths usually in excess of 20 dB, and often much greater, for all back directions and in-band (14 MHz) frequencies with single-knob tuning of

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the reflector. "Deepest possible" nulls aren't thought to be worth additional effort, given the unstable nature of the ionosphere and sensitivity to local field disturbances — for example, trees blowing in the wind, the presence of other antennas, even aircraft reflections. Up to 30 dB can be useful, but deeper nulls require precise adjustments of phase and amplitude (two knobs). By the time these adjustments are made, the interference one is trying to remove has probably disappeared anyway! With deep nulls a tendency has been observed for non-reciprocity between transmission and reception, due probably to pickup on wiring in the shack. If a linear is used, this won't be identical for the two cases.

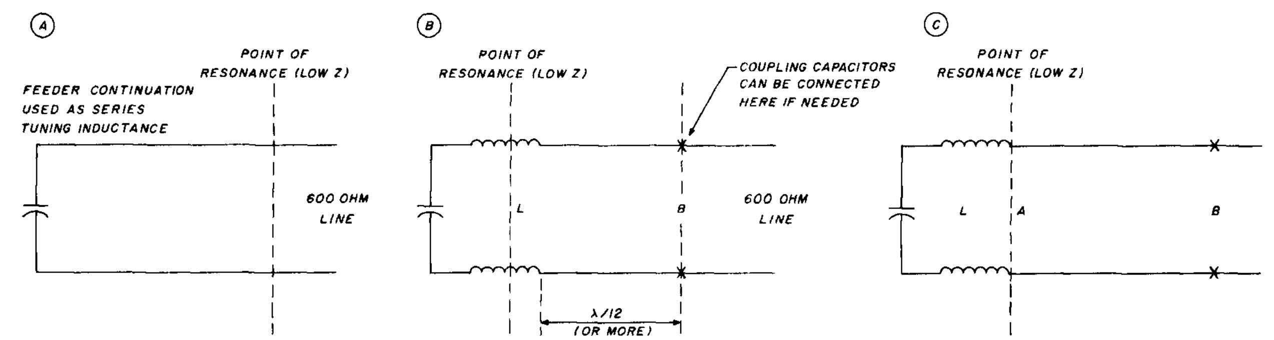

fig. 9. Reflector tuning of "Claw" antenna: (A) Long feedline; (B) short feedline; (C) resonant feedline. This method, especially as illustrated in (B), is convenient, since point B is more likely to be accessible. Total L = 3.5 μH. Terminations can be band-switched, but often cover two or three bands.

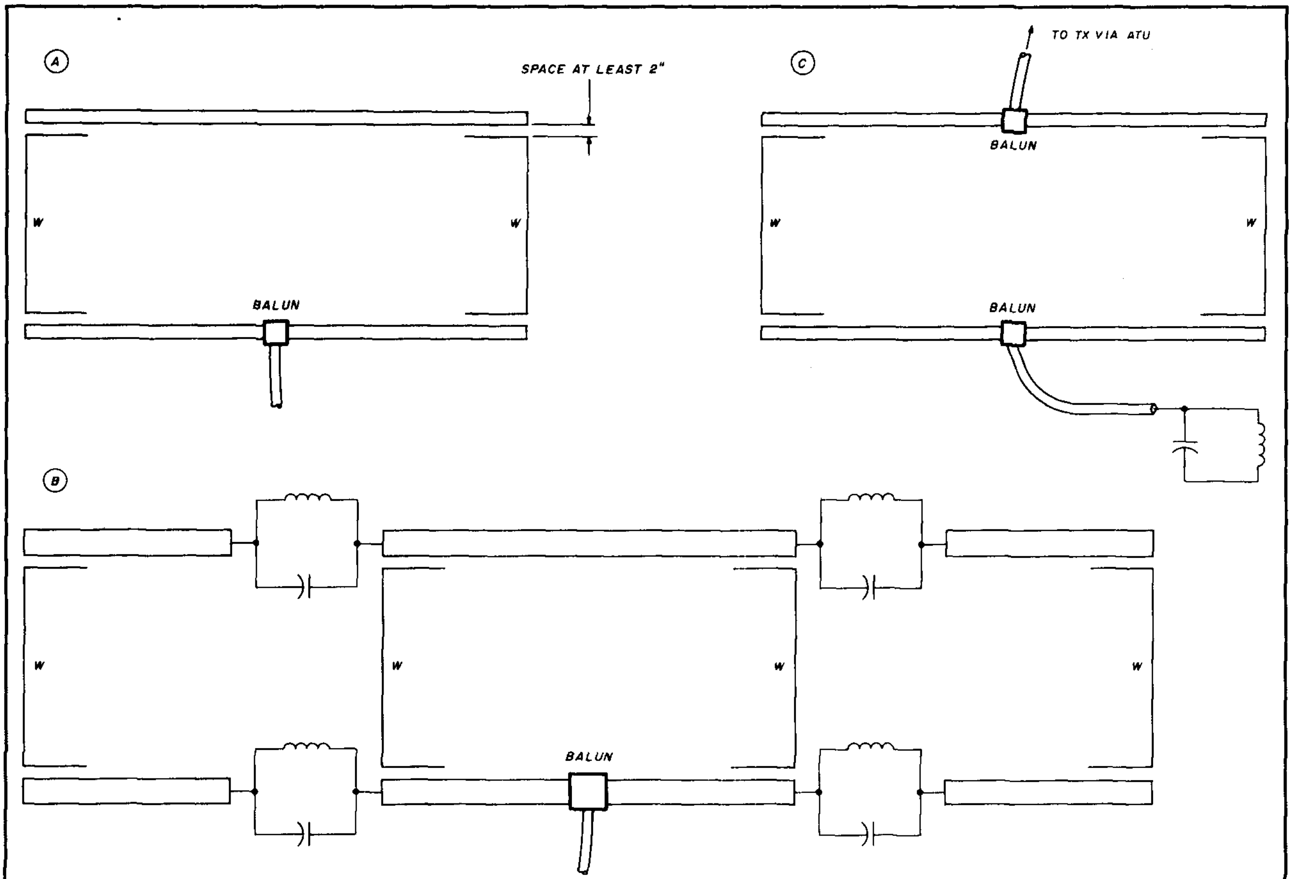

fig. 10. Application of enhanced coupling to conventional beams. (A) monobander — coupling wires (w) suggested as alternatives to bending the elements. (B) Beam with traps. (C) is similar to A, except in that the reflector is tuned via the feeder.

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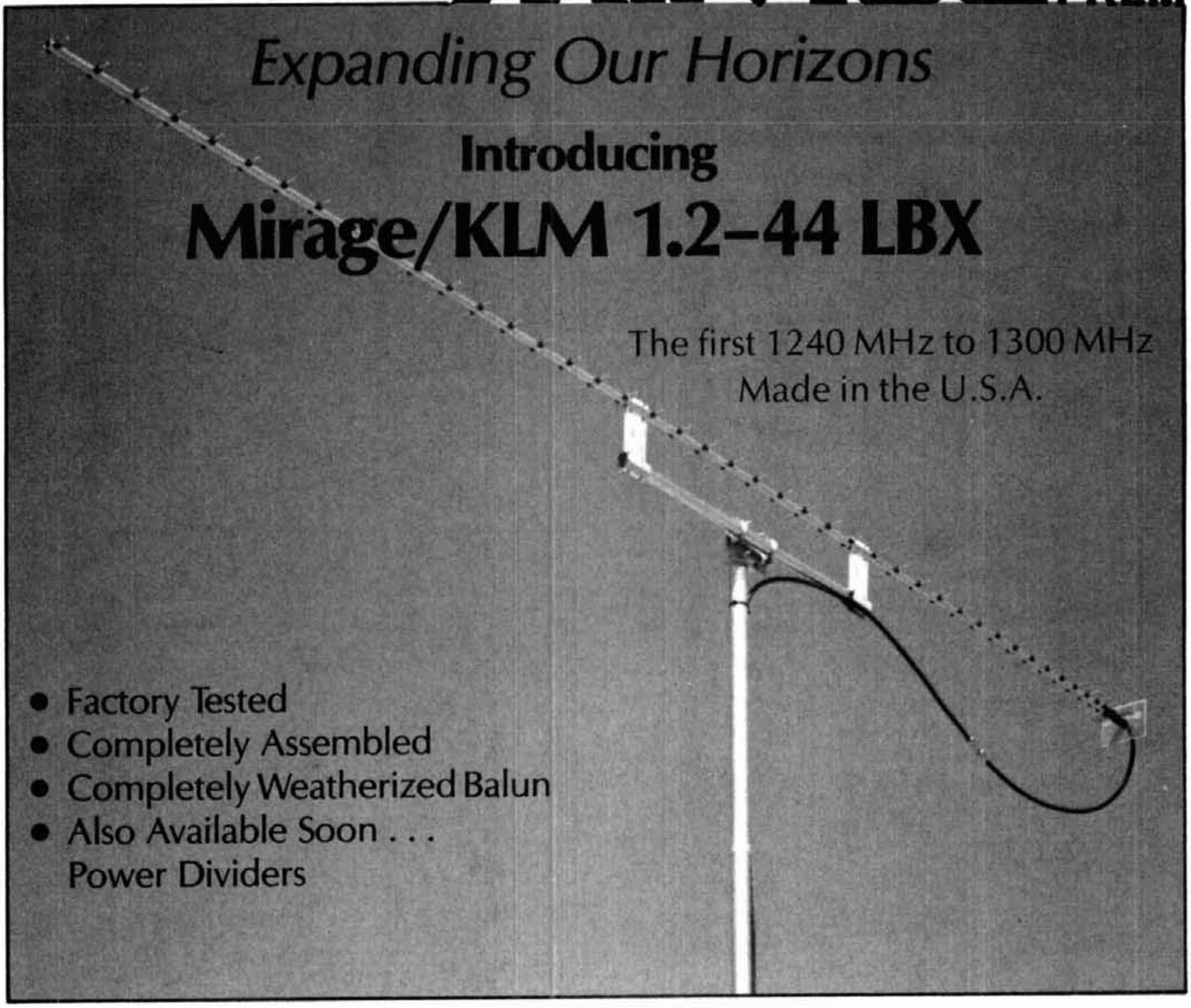


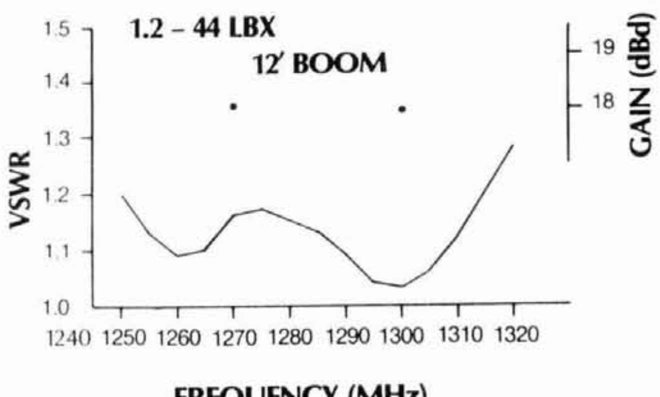
SPECIFICATIONS

Electrical

- Band Width .... 1240—1300 MHz
- Gain 18.2
- VSWR .... Better than 1.5 to 1
- Feed Imp...................... 50 Ohms
- Balun .... 4:1 Rigid Coax

Mechanical

- Beam Length .... 12′ 4″
- Element Length .... 4.5″
- Mast .... 2″ O.D.
- Windload .... 1 sq. ft.



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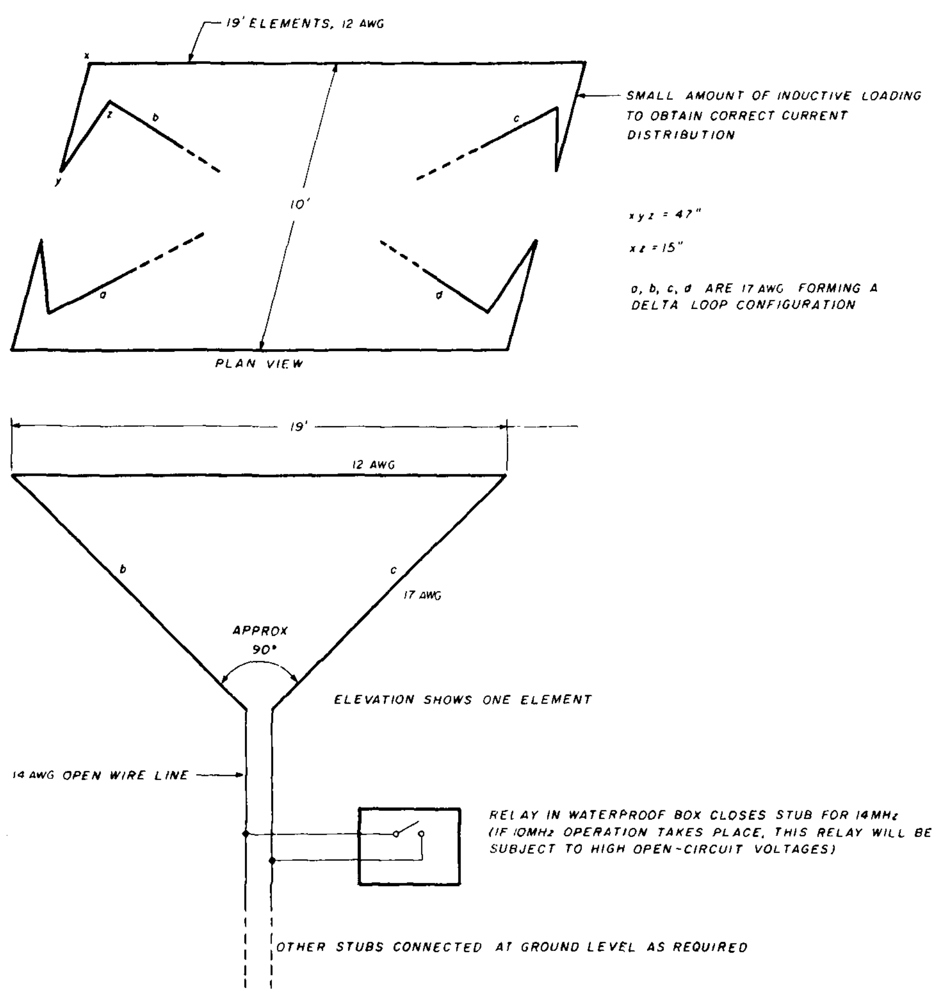

fig. 11. Wire beam based on the small delta loop. In plan view, this may be recognized also as a derivative of the VK2ABQ antenna. ***Wires should not be attached directly to bamboo supporting arms. Lengths of nylon fishing line should be used*** **as insulators. (Reproduced with permission from RSGB.)**

reflections from other antennas

These reflections can be large enough to seriously degrade forward gain at distances of over 30 meters at 14 MHz. (In one case I observed a loss of 2 S-units due to screening by another antenna at about 25 meters.) Their effect on front/back ratio is much greater. From mutual resistance data, it appears that another antenna 7 wavelengths away might be expected to degrade a 30-dB null by about 6 dB. Such effects depend, of course, on the extent to which the interfering antenna is in the beam path, so the effective radiation pattern varies with beam heading. The interfering antenna may be "removed" by detuning or rotating it to an end-on position, but any front/back ratio *it* may possess applies *only to its own* input terminals and does nothing to help. Unless such effects can be eliminated, the possibility for serious errors remains. This further emphasizes the importance of being able to make adjustments at the operating position to suit the needs of the moment. However good its f/b ratio, a large Yagi will still be wide open to reflected signals from other antennas in its beam path.

reflector tuners and t/r switching

Separate optimization of transmitting and receiving characteristics by switching between two different reflector tuners is a further important option. Tuning of the reflector to null out an interfering station can have a large effect on the SWR unless the antenna tuner is readjusted. Using an FS710H automatic in-line SWR meter, I haven't found this to be a problem, but without such a device and with modern solid-state amplifiers it can be an embarrassment. Because transmitting and receiving requirements aren't identical, it makes sense, in any case, to use separate tuners switched by a relay, not forgetting to use the "trans-

mit" (tuner) condition when checking for prior channel occupancy. While any feeder length can be used, it simplifies matters to choose one that allows series tuning as shown in **fig. 9**, preferably as shown in **fig. 9B**, which increases the chance that points such as *xx*, where the rf voltage is suitable for coupling adjustment, will still be available in the shack if required. With feeder impedances of both 50 and 600 ohms at 14 MHz, I have found a capacitance (C) of 40 to 250 pF and an inductance (L) of 3 to 4 μH to be suitable, but this would depend on feeder length. The trick is to pick a likely-looking capacitor out of the junk box and, with a grid dip oscillator, find an inductance that allows the reflector to be tuned through the band and down to about 2 percent lower.

beam reversal

This reduces the average time required for changing beam heading since rotation can be limited to about 140 degrees. Also, in many cases an Armstrong method of rotation can be employed, with two ropes substituted for the usual heavy, expensive, and sometimes unreliable beam rotator. It can be particularly useful in multi-way contacts, and if there's uncertainty about whether propagation is short or long path. It also provides confirmation that the antenna is working correctly. **Figure 10** includes suggestions for the addition of controlled coupling to conventional beams which, though as yet untried, may be useful to experimenters. In (A) and (C), it may be easier to pull the ends in toward each other with nylon fishing line. To permit beam reversal and null-steering, the reflector must be replaced by a replica of the driven element.

comparison between two and three elements

Two-element beams can be expected to produce deeper and more controllable nulls, but this may not help if more than one interference source is present. In this respect, three-element beams are superior, assuming fixed tuning of the reflector in both cases. With two elements, a rejection ratio better than 18 dB can be obtained for all back angles if the nulls are placed at 150 degrees to the beam heading; this is for a spot frequency, but can be obtained throughout the band if reflector tuning is synchronized with the main tuning. With three elements, W2PV[2] found null depths in excess of 20 dB over 2 percent bandwidth in the best case, but this was only for the 180 degree direction. It has also been shown that three elements can provide rejection in excess of 28 dB at all back angles simultaneously on a spot frequency.[4] From tuning data given in this reference, I estimate a minimum rejection of around 18 to 20 dB over a 2 percent band, which is little better than the two-element result and requires very precise adjustment of the kind difficult to obtain in practice because one is working with too many variables. The two-element beam, moreover, provides the option of deeper nulls in specific directions, though the rejection of QRM from several sources simultaneously may then be adversely affected. In practice, not more than 1 to 1-1/2 dB extra gain can be expected from the third element, and in terms of the low-angle radiation required for chordal-hop propagation (which is probably responsible for most long-haul DX[5]), this is equivalent to an antenna height increase of only 15 to 20 percent. The small size, light weight, and construction of antennas described in the next section should, in many cases, lead to height increases of this order. It is not suggested that these small beams can compete with a six-element monobander on a 100-foot tower, but they can hold their own in more ordinary circumstances, requiring only a modest means of support, indifferent results quoted by earlier authors being attributable entirely to the assumption of straight elements and the resulting current inequalities. Much of this ground has been covered in earlier publications; a complete bibliography can be found in reference 5.

multiband beams

Multiband beams have previously consisted mainly of tribanders involving some degree of compromise. Instead of using the whole of a 14-MHz $\lambda/2$ element on 28 MHz, it is cut down to size by traps, or 28-MHz loops are stacked inside 14-MHz loops which could be used to provide extra gain on 28 MHz. This sacrifices 2 to 4 dB of gain at 28 MHz[1], as well as incurring losses due to circulating currents in traps or "wrong way" currents induced in unused elements, which can reduce bandwidth and affect coupling.

Trapped beams rate highly in terms of convenience as well as off-the-shelf availability, and their popularity could no doubt be further enhanced by design improvements — for example, along lines suggested by W0JF.[11] At the same time, the fact that now we have, within 1-1/2 octaves, six bands instead of three, presents an exciting challenge unlikely to be met by traps or stacking without further compromises. The log periodic antenna, though simple in use, is large, heavy, expensive, and inferior in performance to a Yagi of the same size.

the "poor man's log periodic" (PMLP)

When short of new ideas, it often helps to take a fresh look at old ones, which is what I've been doing in the case of resonant feeders. Though these have been *blamed* for TVI, radiation from balanced lines is very small, and they've consequently also been *recommended* as cures for TVI. It's true that they can get themselves twisted around the mast or entangled in guy ropes, but there's no excuse for this if beams are reversible as previously recommended, since rotation can then be restricted to less than 180 degrees. A more serious objection is the restriction of bandwidth. But with remote tuning, this becomes an inconvenience rather than a basic limitation. Now, through a fortunate accident, a solution to the bandwidth problem has also emerged and with it a family of small, lightweight antennas that provide the performance and other characteristics of the antennas described earlier, yet are tunable over the frequency range from 10 to 30 MHz. This largely achieves the object of the log periodic antenna, though the principle at work is entirely different.

the ideal antenna?

To establish the respectability of resonant feeders and provide a useful perspective, the design of a "best possible" multiband beam will be attempted.

Consider three identical straight tubing elements 44 feet long, spaced 8 feet apart, fed with about 46 feet of open wire line, and tuned to 14 MHz. The radiation resistance of a single element is 150 ohms and the bandwidth of antenna plus feeder for an SWR of 2:1 is about 8 percent, differing only slightly from that of a normal half-wave element. This should provide gain and f/b ratio in line with the previous three-element example. The larger value of radiation resistance, however, makes it much easier to use resonant feeders for remote tuning and beam reversal; even if this is not required, it helps to ensure reasonable bandwidth. The main benefit occurs at other frequencies, since on 28 MHz the elements are "extended double Zepp," which was the reason for the choice of length. The boom length is nearly optimum,[2] bringing the total gain to about 10.5 dBd. The spacing is too wide for good f/b ratio on 28 MHz, but this could be improved by additional coupling. On 10 MHz, omitting the center element provides for satisfactory spacing and achievable gain is in accordance with numbers indicated in **fig. 5**. Losses are negligible. The lower end of the feeders is assumed to be accessible near the antenna and can be lengthened or matched into, if necessary, utilizing band switching, depending either on local requirements or bandwidth considerations. With two elements, the boom length would have to be reduced, with 0.1λ the minimum acceptable length at 10 MHz. The gain at 28 MHz is reduced to 7 dB, but remains high for two elements. For comparison, the gain of a log periodic will be in the region of 6 dBd, assuming a boom length of 50 feet, making the PMLP far superior except for the inconvenience of having to tune it. This can be done in the shack if the feeders aren't too long. Nevertheless even the PMLP in this ideal form is in the "monster" class, and much effort has been devoted to applying the same principles to smaller antennas.

the small delta loop

The antenna shown in **fig. 8C**, a fixed pair of loops supported by a tree, was selected for this purpose after being used initially as the quickest and easiest way of getting back on the air from a new location. Though it wasn't possible to make a direct comparison, the performance of a full-size quad — in the same tree at the same height — was later judged to be about the same. The first multiband version of this antenna[6], shown in **fig. 11**, was used initially without the switched stubs, with correct coupling established by capacitance between the corner stubs (which also provided a small amount of loading) and by bringing the lower corners in towards the mast. The electrical lengths from top center to a shorting bar at ground level were arranged to be λ on 14 MHz, 1-1/2λ on 21 MHz, and 2λ on 28 MHz, providing for 600-ohm feedline matching as well. Current nulls in the center of the sides on 14 MHz ensured that all the radiation was from the top of the system, while at higher frequencies the loops radiated as ordinary loops, with effective spacing reduced by bringing the lower corners together. The matched lines (120 feet) were taken respectively to an antenna tuner and a series-tuned circuit for reflector tuning via a beam-reversing switch which interchanged the feeders in the shack. The elements were supported by four 8-foot bamboo garden canes radiating outwards and upwards from an aluminum hub with four 4-foot spokes, for a total radial length of 12 feet. The SWR bandwidth for given settings of the antenna tuner and reflector tuning at 14 MHz was only 100 kHz which generated a tendency to stay in one part of the band. Differences in tuning between wet and dry weather were a nuisance. These were aggravated by short lengths of 300-ohm line initially used for bypassing the rotating joint. Checking the feasibility of operation on 10 MHz was difficult because it required the attachment of matching stubs at half the mast height, but it was achieved on one occasion, which resulted in an S8 report from VK with reasonable f/b ratio.

Despite the narrow bandwidth, such an arrangement may well be acceptable on the grounds that it is simple, cheap, versatile, and efficient, especially if the shack is located at the base of the mast. For me, however, it has one fatal flaw: the difficulty of living with the knowledge that identical performance could be obtained from a smaller antenna! To improve bandwidth on 14 MHz, the stubs were moved a half wavelength closer to the loops, with relays to disconnect them as shown in **figs. 11** and **12**. This enabled tuning for the 21- and 28-MHz band, where the radiation resistance is much higher, to be carried out at ground level as before.

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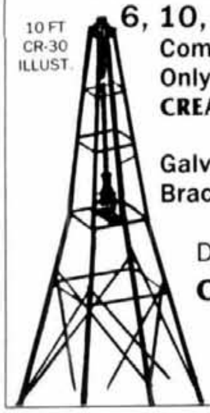

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center-fed bent dipole (**fig. 8A**), since the center of the element doesn't have to support the weight of the feeder. Other features include higher radiation resistance and reduced effective spacing on 21 and 28 MHz, but on 14 MHz an adverse impedance transformation takes place at the bottom corner of the loops so that an estimated radiation resistance of 45 ohms referred to the top center is stepped down to only 20 ohms in the feeder. Using the relay as shown, this isn't important, since only a short length of line is affected. But with no relay and No. 14 AWG feeders, there's an estimated loss of 1 dB, as well as the narrow bandwidth already noted. With tubing elements as shown in **fig. 12**, the situation is more favorable, with an estimated impedance reduction of only 30 percent. There's also more flexibility because the impedance discontinuity at the ends of the tubing tends to offset the step-down at the bottom corner and the boom can, if necessary, be used to support a heavier feeder system.

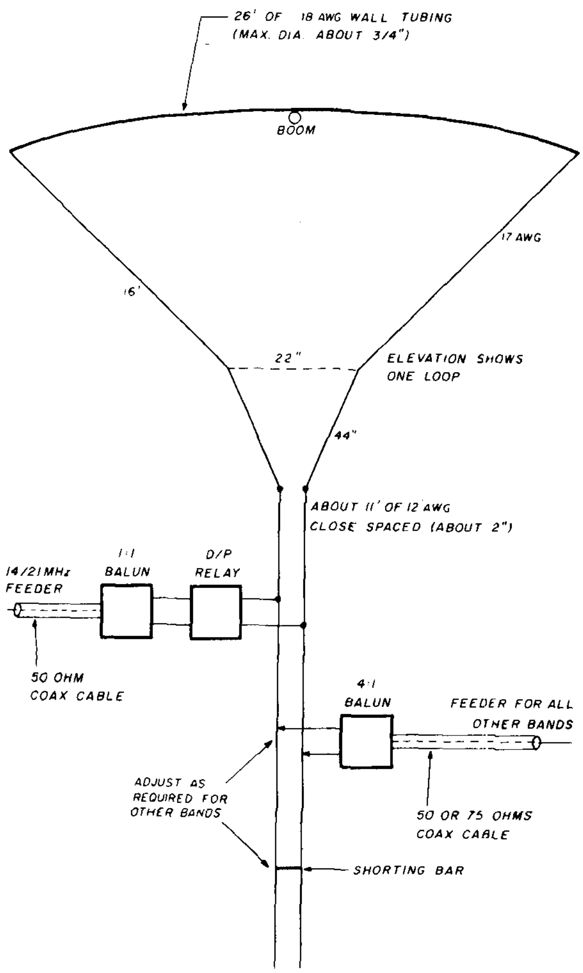


fig. 12. One element of small delta loop array using tubing end-fed with wires. These wires can be thin because current zeros occur at the crosspoints on 14 MHz, and on higher frequency bands Rg is relatively large. Element spacing is with the lower corners 4 feet apart. (Reproduced with permission of RSGB.)

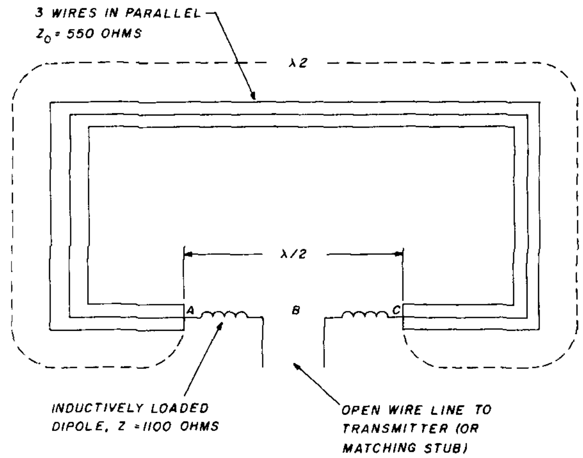


fig. 13A. Example of the impedance transforming loop showing principle of operation. (A) Loop acts as pair of λ/4 transformers so that a radiation resistance R appears (in this case) as 4R at the feedpoint.

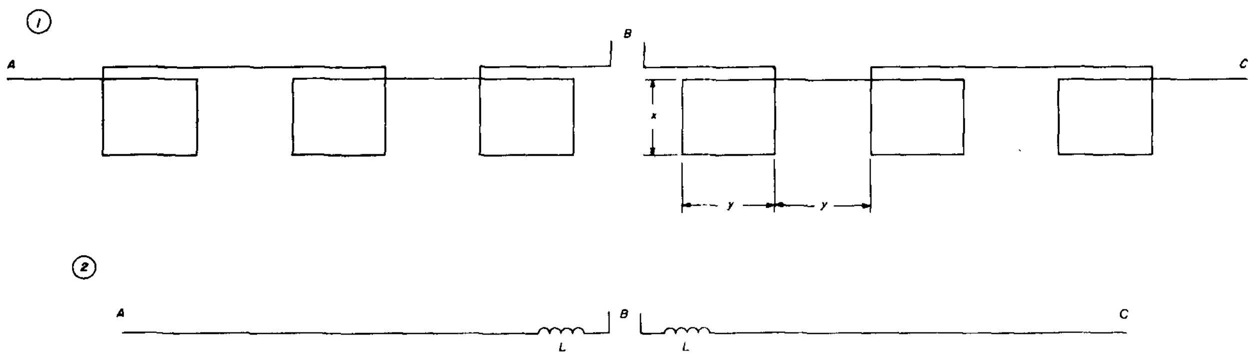
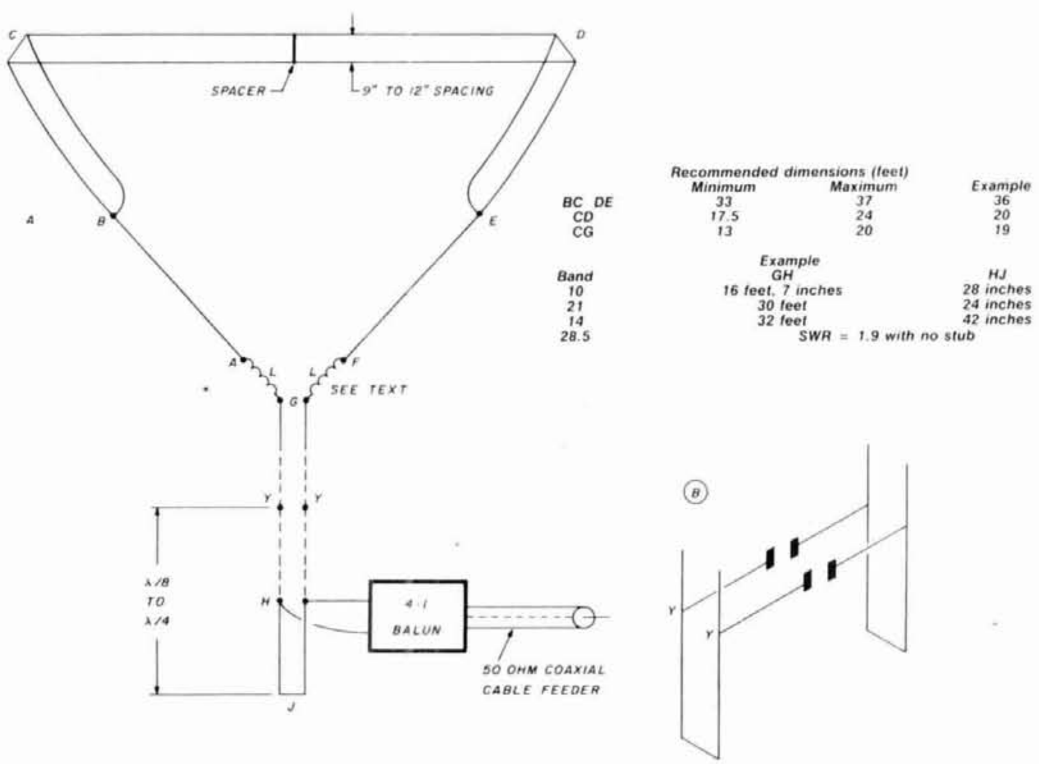


fig. 13B. Alternative forms of inductively loaded dipole. Note: in (1), x = 10 inches, y = 15 inches (at 14 MHz). In (2), AB = BC = 9 feet; each L is a 40-turn, 1-inch diameter, 20-inch coil.



	Recommended dimensions (feet) Minimum	Maximum	Example
BC DE	33	37	36
CD	17.5	24	20
CG	13	20	19

Band	Example GH	HJ
10	16 feet, 7 inches	28 inches
21	30 feet	24 inches
14	32 feet	42 inches
28.5	SWR = 1.9 with no stub	

fig. 14. Claw antenna design: (A) exact shape isn't critical (see fig. 15); (B) small capacitors are used to adjust coupling if necessary. (Reproduced with permission of RSGB.)

Figures 11 and **12** represent two extremes of design in which "anything goes." Typical observed SWR and f/b ratios are included in **table 1**. No additional coupling or neutralization was needed to obtain the results shown. In the case of the **fig. 12** configuration, it must be assumed that although on 14 MHz the radiation was coming from straight elements, the "quad loop effect" was operative with respect to coupling. In the antenna shown in **fig. 12**, it was found that for two-band operation (14 and 21 MHz), the relay could be omitted because of a chance combination of impedance transformations which caused the second harmonic resonance to occur at only 1-1/2 times the signal frequency. In general, I've not found it difficult to obtain efficient two-band operation of antennas without switching, but three bands are much more difficult.

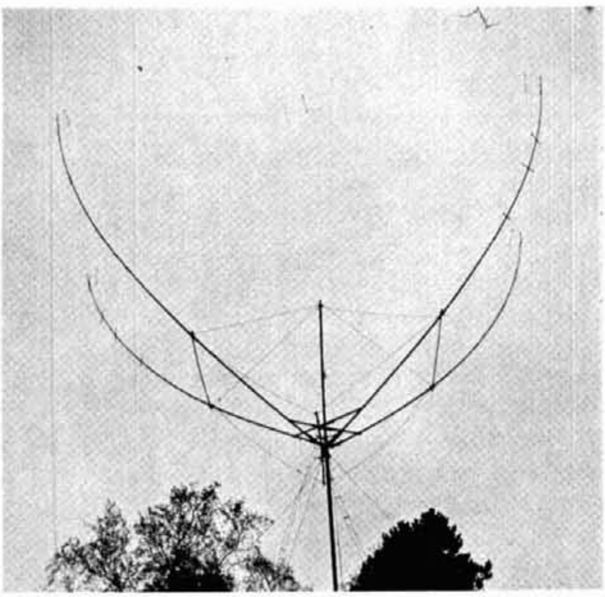


fig. 15. The Claw antenna.

the impedance transforming loop(ITL)

Disadvantages of the systems illustrated in **figs. 11** and **12** include the need for switches or relays in positions that are usually inaccessible. Even if this is acceptable, frequency coverage is restricted because as R decreases, switching devices have to meet increasingly stringent requirements with respect to capacitance and rf voltages.

Figures 13, 14, and **15** show a means of dispensing with relays and, to a large extent, the need for matching stubs. This was the outcome of an unsuccessful attempt to develop a small (i.e., 18-foot, 14 MHz) broadband folded dipole by slowing down the wave velocity.[8] The idea was to trick the wave into thinking

Table 1. Comparison of various antennas described in this article.

BAND (MHz)	Antenna	Bandwidth for F/B ratio >20dB	>15dB	>10dB	Bandwidth for SWR <1.25	<1.5	<2.0
14	S.D.L. (wire)		140	280	110	190	300
	S.D.L. (tube)	150	220	385	225	390	
	Claw No. 1	40	120	220	160		330
	Claw No. 2		145	300			230
	Folded Dipole			230	100	260	350
21	S.D.L. (wire)			320	110	205	370
	S.D.L. (tube)			550	360		
	Claw No. 1	85	210	350	330	420	
	Claw No. 2			400		320	380
	Folded Dipole			260			450
28	S.D.L. (wire)				190		500
	S.D.L. (tube)			800	550	800	
	Claw No. 1		240-300	600	180	370	680
	Claw No. 2	170	840	1000		1000	
	Folded Dipole					280	1000

the element was larger, but this was unsuccessful. Being difficult to draw and of limited practical interest, its somewhat fearsome appearance will not be inflicted on the reader, though some performance figures are included in **table 1**. The surprise came in the form of a chance discovery that long feeders could be connected without degrading the bandwidth; the explanation, though elusive, led eventually to the design of a number of antennas bearing little resemblance to the original dipoles.[7,9]

principles of operation

Figure 13A illustrates a small loop element which could be any shape. Two or more half-wave wires are used in parallel for the top part of the loop, resulting in a low value of characteristic impedance Z_{OT}.

The remainder of the loop consists of a second $\lambda/2$ dipole with a high value of characteristic impedance, Z_{OB}; this can be a helix as shown, or inductively loaded in other ways. Each dipole functions as a $\lambda/4$ transformer so that the radiation resistance, R, after being stepped up to the value

$$Z_{OT}^2 / R$$

at the ends of the top dipole, is then stepped down to

$$(Z_{OB} / Z_{OT})^2 \cdot R$$

at the feedpoint. As illustrated, a typical R value of 50 ohms is stepped up to 200 ohms at the feedpoint, which is high enough to ensure that bandwidth remains an intrinsic property of the antenna and is free from serious degradation due to the feeder. A selection of Z values is given in **table 2**. Depending on size and construction, the lower dipole may be a thin wire unloaded V or one of the alternatives shown in **fig. 13B**. All of these arrangements have been used successfully. The usual objections to inductive loading don't apply because the radiation is mainly from the top part of the loop. This comes about because the current is stepped down in the ratio of the impedances; because the lower dipole is shorter; and because the current distribution in it is sinusoidal or triangular, in contrast to the almost uniform current in the top dipole. This constitutes a major advantage over the quad loop, in which the mean height is dragged down by radiation from the lower side. On the other hand, there is some radiation from the sides; it can be cancelled

Table 2. Design data for ITL antennas.

Characteristic impedance for various wire sizes and combinations.

Number of conductors	Diameter (inches)	Spacing (inches)	Z_0(ohms)
1	0.04		1000
1	0.8		650
2	0.04	4	690
2	0.04	6	640
2	0.04	12	550
3	0.04	4	550
4	0.04	4	490

Equivalent Z_O of lower dipole (wire diameter, 0.04 inches) with inductive loading.

Physical length of dipole (wavelengths)	Equivalent Z_0 (ohms)
0.375	1200
0.3	1500
0.25	2000
0.2	29000

Note: Z_O values are calculated for 14 MHz. However, because of some length dependance, they will be slightly different for other bands. No data is available for helical windings.

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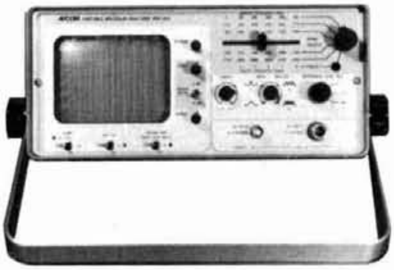

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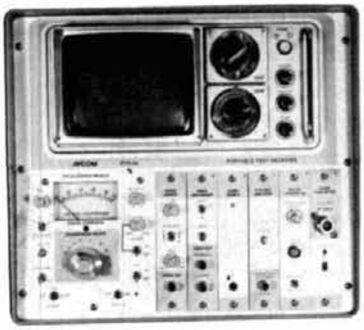

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MICROWAVE SWEEP GENERATOR **$1282**

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by reverting to a more or less triangular shape as shown in **fig. 14**. Assuming an ITL to be designed for 14 MHz, operation on the higher frequency bands differs little from that of the small delta loops described earlier; at 21 MHz there tends to be some "wrong-way" impedance transformation, suggesting the desirability of matching stubs at ground level in the case of long feeders. Concentrated loading, as shown

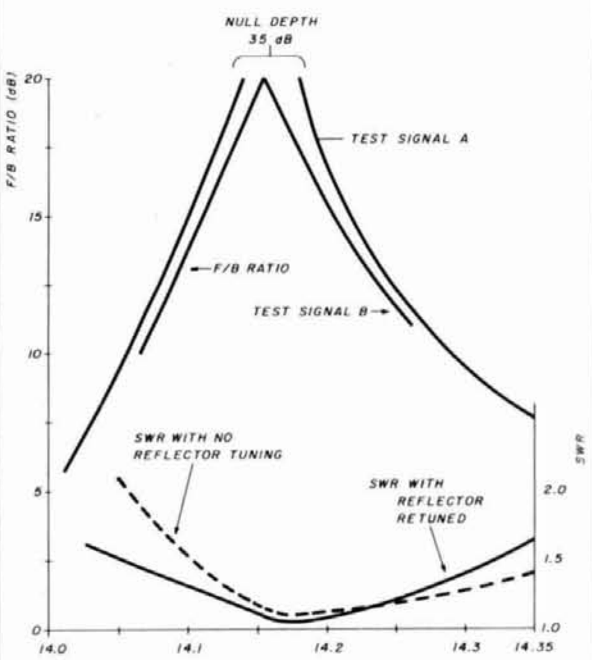

fig. 16. Typical performance of Claw No. 1 on 14 MHz. F/B ratio curves demonstrate null-filling due to any slight error in adjustment. In this case, one test signal was slightly too close. SWR rapidly increases as the π approaches zero. The reflector was adjusted for nulls at 140-150 degrees, but curves were roughly repeatable over a range of 110-180 inches without readjustment of coupling.

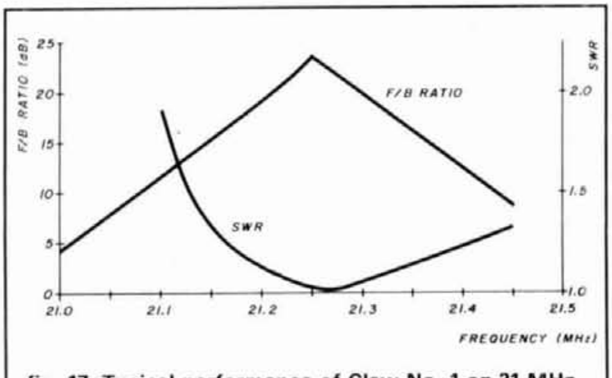

fig. 17. Typical performance of Claw No. 1 on 21 MHz. Note steep rise in SWR at low frequencies — i.e., as ϕ decreases.

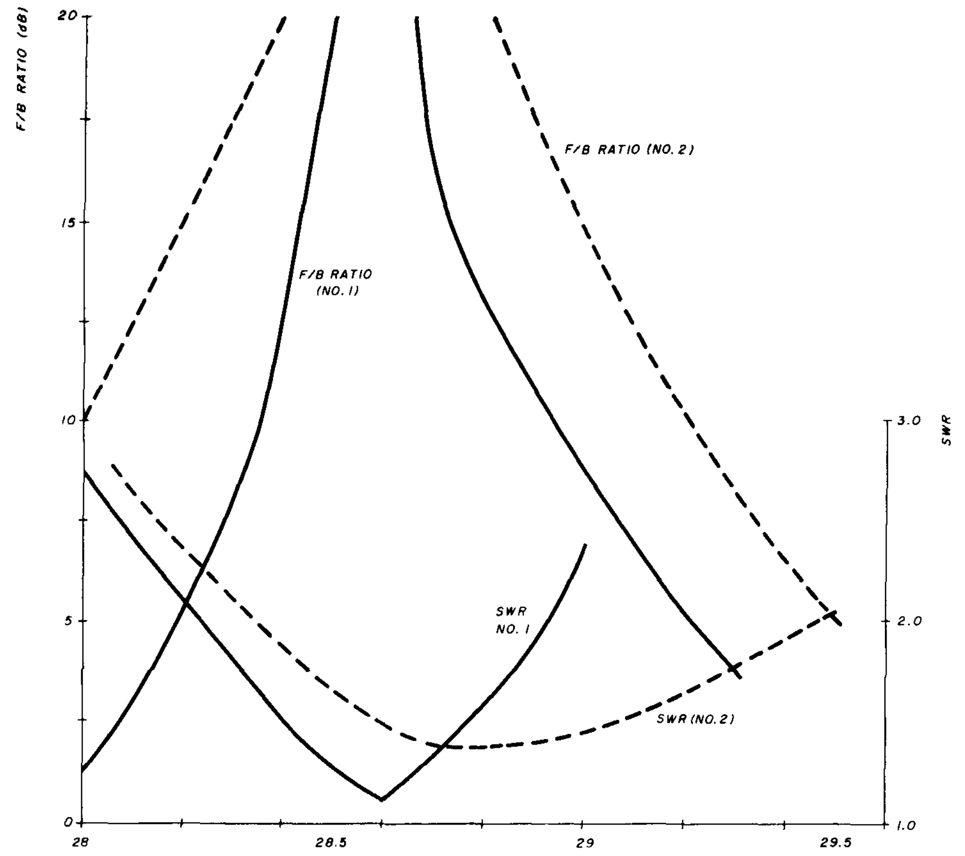

fig. 18. Typical performance of both Claws on 28 MHz. Curves demonstrate adverse effects on bandwidth of very long unmatched feeder.

in **fig. 13B2**, improves matters on 14 MHz by increasing Z_{OB} (see **table 2**), but reference to a Smith Chart suggests that at 21 MHz this could lead to an increase of SWR in the open-wire line of 2 or more. On the other hand, with long coils of small diameter (20 inches x 1 inch), as shown in **fig. 14**, much better agreement between theory and practice resulted from regarding them as a harmless continuation of the traveling wave system.

construction

Figures 14 and **15** illustrate the latest version of the Claw antenna, which uses two pairs of fiberglass fishing rods 13 feet long, extended at their lower ends by an additional 6 feet of 1-inch diameter fiberglass tubing. These are plugged into alloy sockets which radiate outwards from the top of the mast. They are braced back with further lengths of fiberglass tubing to a short mast extension. The elements are held apart by 6-foot spacing rods of 1/2-inch diameter alloy tubing. Plastic rod end-pieces are used to keep the rods a few inches clear of the elements; even so, these may be responsible for some of the coupling. The tips of the fishing rods are pulled in by nylon fishing line to give an element spacing of 12 feet. Points on the rods are guyed back to crosspieces at the top of the mast. The top wires are held 11 inches apart in the horizontal plane by fiberglass spacers cut from the discarded tips of the fishing rods. Additional spacers on the rods themselves (with fishing-line ties) are used to maintain even tension in the wires to avoid flexing and breakage. Earlier versions used three copper wires spaced 4 inches apart, but the benefit from the extra wire hardly justifies the added complication (see **table 2**). The latest version uses No. 16 AWG aluminum alloy wire, which reduces weight for a given rf resistance, but increases windage. Since the rf resistance is only half that of a single wire, mechanical considerations are more likely to be the deciding factor. Wires break if not kept under tension, but with two antennas over a period of three years — which has included periods of heavy winds — no fishing rods have broken, and there has been no other damage to the main structures.

The same wire gauge is used throughout. The loading helices are each wound with 40 turns over a total

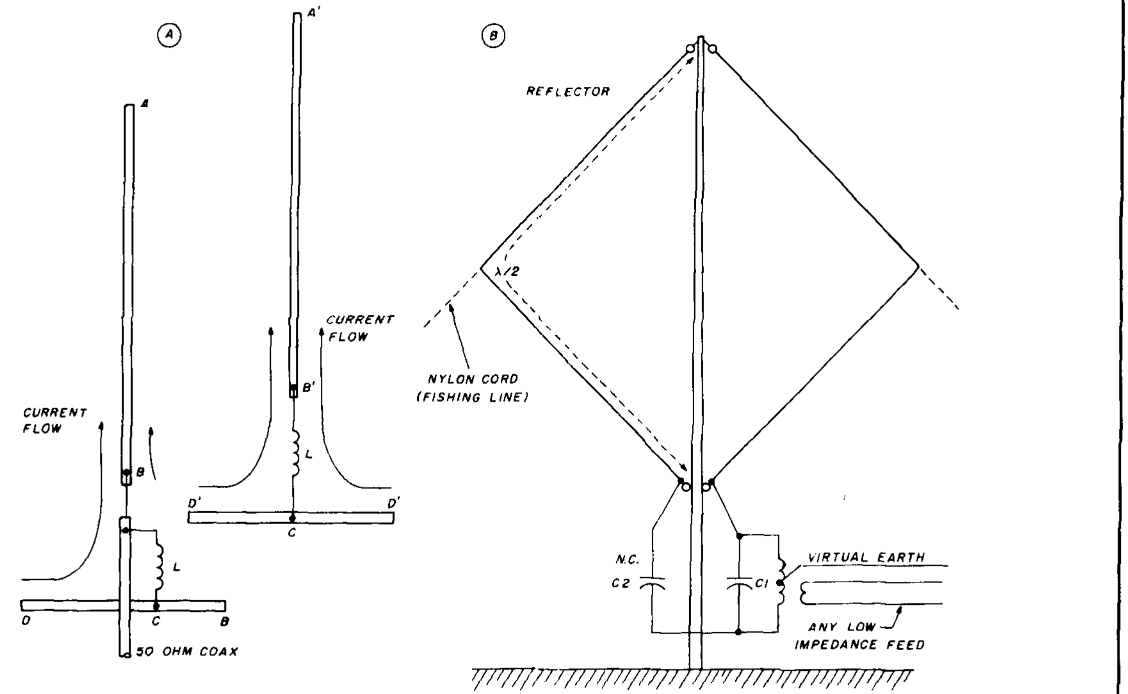

fig. 19. Vertical arrays. (A) Asymetrical dipolr array can be mounted on fence posts. To adjust coupling, swivel around to alter spacing DD'. (B) Maypole array.

length of 20 inches, partly near the lower end of the rod extensions and partly on the bracing struts. Because of the low radiation resistance on 10 MHz, it's advisable to provide matching as close as possible to the antenna. In one case, 28-inch stubs were placed 16 feet, 7 inches from the element. Later, for greater convenience I used a pair of series-connected 10-pF capacitors near ground level. The location could be determined by finding points of "zero" current and then moving 3 feet closer to the antenna. Matching on the other bands was used initially, but discarded because it made no difference in signal strengths, though **table 1** suggests the loss of some bandwidth. Even on 10 MHz, despite the additional 120 feet of open wire line (No. 19 AWG), the loss without matching was less than one S-unit. Measured performance data for both Claw antennas is included in **table 1**. The plots of f/b ratio and SWR shown in **figs. 16, 17** and **18** are typical of results obtained with Claw No. 1.

alternative designs

The loops can also be suspended from spreaders between two supports. In this case planar loading (an idea suggested to me by Steve Hart, VK5HA), as shown in **fig. 13B**, is suggested. The assembly can be supported by three lengths of nylon fishing line with small ring insulators cut from fiberglass tubing to keep adjacent edges apart. I find that nearly a 3:1 reduction in length can be achieved this way; because it uses less wire, its efficiency is greater than with helical loading. For this reason, it was used in the first two versions of the Claw,[7] but helical windings in this case are easier and neater, with losses insignificant. Similar loops can be suspended from their centers in inverted V fashion. I've also built a rotary version of such an antenna modelled after the one shown in **fig. 3B**. This used a lightweight mast extension surmounted by a 1/2-inch diameter aluminum boom. Two fiberglass radial arms were used to hold up the dipole ends. Apart from the neutralization problem mentioned earlier, this worked well on 14 MHz. A three-element version of the Claw was also constructed; since only triband operation was required, I was able to use a coaxial feeder for the center element and a relay to switch in an additional length of helix on 21 MHz. The third element was effective on 28 MHz and was indirectly useful for 10 MHz because, though not in use, it allowed wider spacing between the other two elements without degradation of performance on 28 MHz. On 14 and 21 MHz, there was no improvement compared to using any one of the three possible pairs on its own. SWR on 14 MHz could be varied between 1.0 and at least 5.0 by tuning the parasitic elements! The problem was basically one of "too many variables," and it was concluded that for three elements to be viable, they would need to be spread out along a boom; the "Claw" concept would then lose most of its attraction in return for a relatively small improvement in performance.

vertical arrays

Vertical beams can also be constructed using controlled coupling.[10] **Figure 19** shows two examples. The first is an "asymmetrical dipole" array that uses inductively-loaded counterpoises to form the lower half of the dipoles. The inductances can take the form of linear loading.[5] The elements are movable and can be plugged into sockets on fence posts. Coupling is varied by rotating the counterpoises towards each other and all adjustments are conveniently accessible. Each half of the dipole should be resonated separately against a $\lambda/4$ wire. The second can be regarded as a "vertical VK2ABQ" antenna. It's best to use four wires at right angles; adjacent pairs may be connected in parallel, though they can also be used in a three-element configuration. In the two-element case, which is recommended, overcoupling was experienced, requiring neutralization as shown. ("Zepp feed" can also be used, provided the open end of the feeder is closed with a $\lambda/4$ stub[5,10] as recommended by G6CJ.)

conclusion

My intention has been to provide guidelines, rather than blueprints, for the construction of antennas tailored to suit individual needs. The Claw designs will be useful even if the best mast available is only a garden post, and I hope that some who have decided regretfully that beams are "not for them" will have second thoughts. The null-steering and beam-reversal capabilities are particularly useful. In addition to coverage of six bands — with "monoband" performance on several — Claw elements are particularly suitable for use as top-loaded verticals for the lower-frequency bands.

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G6XN's book, *HF Antennas for All Locations* is available from Ham Radio's Bookstore for $11.95 plus $3.50 S&H.

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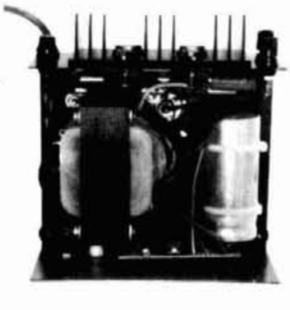

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RS-7B	5	7	4 x 7½ x 10¾	10
RS-10A	7.5	10	4 x 7½ x 10¾	11
RS-12A	9	12	4½ x 8 x 9	13
RS-20A	16	20	5 x 9 x 10½	18
RS-35A	25	35	5 x 11 x 11	27
RS-50A	37	50	6 x 13¾ x 11	46

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RS-12S	9	12	4½ x 8 x 9	13
RS-20S	16	20	5 x 9 x 10½	18

homebrew antenna mount

Hand tools and standard hardware are all you need for this project

A number of years ago I visited a ham friend who proudly showed me his new tribander. Sitting atop a rotatable mast secured to a ground-mounted fixture, the antenna could also be lowered so that one could work on it comfortably.

We lived in an apartment then, and the only antennas I could install were dipoles for 80 and 40 meters and a vertical for 20, 15, and 10. Later, when we finally bought a home, I found that despite a large back yard, power and telephone lines — as well as trees we'd planted — put an end to my plans for an antenna farm.

Though finding antennas for 80 and 40 meters was no great chore, finding room for a tower or mast was. It was then I realized I already had a platform for working on my antenna — namely, the gently sloping garage roof. I decided I might be able to put up something similar to the arrangement my friend had shown me years before.

My plan was to use a push-up mast, supported somehow at the bottom, and drive it, with the antenna on top, from ground level. I did some shopping for parts and spent some time at the work bench; using hand tools only (with the exception of an electric drill), the result was a mast which has been in use now for a dozen years or more, with no problems (**Photo 1**).

initial considerations

One of the first things to realize is that your antenna isn't going to rotate at 5000 rpm. It turns *very* slowly (my rotor takes a full minute to turn 360 degrees), and hence puts little strain on the bearing you'll use. Aside from the inevitable accumulation of dirt, which is easily removed with a stiff brush and some paint thinner, I've had no problems with the bearing at all.

The second thing to realize is that when you have everything done, extending the push-up mast with the antenna on top of it isn't easy unless you've made some advance preparations. Suppose you've acquired such a mast; it will probably have three or four sections, depending on the height you've chosen. Mine has four, and the outside diameter of the lowest section is 2-1/4 inches. The lifting problem isn't one of weight, but of having some way of knowing when you're reaching the point at which you should stop lifting and secure the section with the clamp provided, and maybe even drill to pass a 1/4-inch bolt through the two sections if you're a bit timid.

mast inspection

Lay the mast out on the ground, fully extended, and examine the point at which the smallest section emerges from the one below it.

Although the smaller section of my mast won't separate from the larger one, there's an illusion at work: when you're lifting the smallest section, with the antenna mounted on it, you become absolutely convinced that at some point the whole thing will pull out, leaving you on the roof with 10 feet of mast and an antenna in your hands and nothing else to hold them. To avoid this, use paint or some other marker to warn you when you're just a few inches from the clamp-off point. Do this with all of the sections. At this point, let me add a caution: whenever you're extending or collapsing the mast, wear heavy gloves! (I use a pair of leather gardening gloves.) The mast sections have a nasty habit of pinching your flesh between them. *Wear those gloves!*

mounting the mast

Decide where you'll mount the mast. For aesthetic reasons, an exterior garage wall is a good choice; you may prefer to attach hardware through to the exposed studs rather than to a finished interior or exterior wall of your house.

You'll also have to decide how far off the ground the lower end of the mast will be supported. This will

Howard A. Bowman, W6QIR, 5872 West 77th Place, Los Angeles, California 90045

Photo 1. Complete installation.

depend on the length of your rotor, which will hang below the "shelf" you'll build (see **photo 2**), and should clear the earth by a few inches. At this point, do one other thing as well: measure the inside diameter of the lowest section of your mast.

Before you head out to the plumbing supply shop, try to visualize what your array of mast, rotor, and connecting pieces of pipe will look like overall. A short length of pipe should fit snugly inside the lower end of the mast. (Though it doesn't have to be an exact fit, it should be fairly close.) It should be 5 or 6 inches long and threaded on both ends; you'll find it at your local plumbing supply house, described as a "nipple." You'll also need two lengths of pipe – one to run from the support you'll build to the upper clamp of your rotor, and the other to run from the lower clamp of the rotor to about a foot below the surface of the earth. One end of the upper piece must be threaded. Aside from this, it's probably simpler to get one long piece and cut it in half yourself.

You'll also need a reducing fitting. At its larger end, it should accept the threads on the nipple, and at its smaller end it should accept the threads on the longer piece of pipe. Caution: pipe sizes are guaranteed to confuse everyone in the world except plumbers. Pay no attention to the designated pipe sizes; use a tape or a scale and measure everything for yourself. Try the mating pieces to be sure they do what they're supposed to do. That way you won't encounter unwelcome surprises.

The next step takes place in your own workshop. Screw the nipple tightly into the reducing fitting, securing it by drilling and tapping for a machine screw of some convenient size. (The screw won't bear any load, but will keep the two parts from coming apart.) Then slide the nipple into the lowest section of the mast until the lower edge of the mast section rests on the reducing fitting.

At this point I drilled and tapped for 1/4 inch x 20 machine screws and used hex-head screws about 1/2 inch long. This was overkill, but, to some extent, the number of screws you use will depend on the snugness of the fit between the lowest mast section and the pipe inside it. The idea is to square things up as well as you can. If you need four screws 90 degrees apart, use them.

You'll need a bearing with an inside diameter large enough to accept the smaller end of the reducing fitting. The tapered shoulder of the fitting will ride on the inner race of the bearing. I've used two bearings – one a standard ball bearing and the other a tapered roller bearing. Either does fine. The inside diameter of each is 1-5/8 inches, and the outside diameter is just a bit over 3 inches. It's important that the slanted portion of the reducing fitting fit inside the bearing, so take careful measurements or take the fitting with you when you shop for the bearing at an establishment that stocks new and used machinery. In a pinch, you may find one at an automobile junkyard.

mast and rotor support

Having come this far, you've done all but the drudgery of making some kind of a support for the mast and rotor. Mine is made of ordinary 1-1/4 inch angle iron, which you can find at any iron fabricating shop or even at some large hardware stores. If you get it at a hardware store, it will most likely be sold in 6-foot lengths; you'll need three of them. If you get it from a shop, be careful. Be sure of your measurements, since the cutter may distort the metal where the cuts are made, making part of it unusable for your purpose.

In planning your shelf, be sure to consider its height above ground and its depth. The shelf must be high enough so that your rotor can hang below it with a few inches clearance above ground. Its depth depends upon the distance your mast will be positioned from the wall. In my case, eaves extend 7 inches from the wall, meaning that my shelf had to be about 15 inches deep to allow the mast to clear the eaves and still provide adequate support. If you have no eaves to contend with, you may be able to make the shelf only 8 or 10 inches deep. (Keep in mind that this dimension will have some effect on the amount of angle iron you'll need.)

triangular supports

The next step is to make two right-angled triangles out of angle iron. They should be made so that they're mirror images of each other; that is, each should have the open sides of the angle iron pieces facing the other. One leg of the triangle will extend outward from the wall, another will fit vertically against the wall, and the third will complete the triangle by extending from some point near the outer edge of the horizontal piece to some point toward the lower end of the vertical piece.

Start by drilling both the vertical and horizontal pieces where they overlap and bolt them together. I used 1/4-inch bolts on mine. Use a square to make certain that the angles form a 90-degree angle. Measure carefully for the third leg, cut it to size, and, once again, drill for bolts. Do the same with the other three pieces of angle iron, making sure that the open sides of the triangles face each other.

Now, try to mount these triangles — at least temporarily — to the wall to which they'll be bolted. Once you've decided how far your shelf is to be above ground, locate a point on a stud adjacent to where you want to mount the antenna. (That point should be 2 or 3 inches below the intended level of the shelf.) Drill a small hole through from the inside, keeping it as close to the center of the stud as you can. Now move to the stud on the other side of the intended location and drill a similar hole. These holes should go all the way through the studs and the outside covering of the wall.

Locate one of the triangles over the small hole, have someone hold it there, go back inside with your drill, and, using the hole through the stud as a pilot, drill into the metal of the triangle at least far enough to make a mark. Now both holes can be enlarged to accept a 5/16-inch diameter bolt. You can also drill another hole in the triangle vertical leg toward its lower end. Align things carefully so that the leg is vertical, then drill through the wall and the stud for a second bolt.

Studs are sometimes not exactly vertical, so this hole may be a bit off center. Don't worry. If the triangle is vertical and your bolt has a good bite on the wood of the stud, you'll be all right. Use a washer under the head of the bolt, and a fender washer (one that is larger in diameter), a lock washer, and a nut on the inside.

Locating the second triangle is a bit tricky because you want its top and the top of the first triangle to

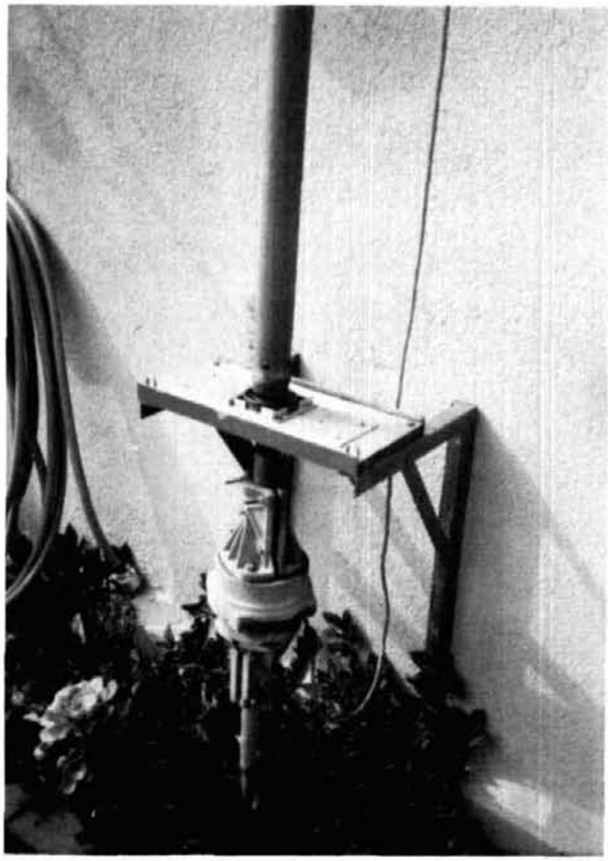

Photo 2. Lower support: the shelf.

be as level as possible. The easiest way to do this is to have someone hold the second triangle against the wall so that one edge of the vertical leg is beside the hole you've drilled through the wall, and so that a spirit level across from the first triangle to the second shows that both are at the same height. Carefully mark the angle iron beside the point at which you've drilled, then drill the angle iron for the bolt. Locate the position of the second bolt just as you did for the other triangle.

joining the triangles

At this point you have two triangles bolted to the outside wall of your garage. The next step is to join them, using two pieces of the same angle iron. One piece should join the outer ends of the triangles, and the other will be several inches closer to the wall, depending on just where the mast will come. It should be midway between these two crosspieces. Having located both pieces, and drilled them and the upper leg of the triangle to accept 1/4-inch bolts, secure them in place.

shelf assembly

You'll note that these two cross-pieces and the triangle legs to which they are bolted form a rectangle. Find a piece of wood about 3/4 or 1 inch thick and

Photo 3. Lower support viewed from different angle.

cut it to lie inside this rectangle. Then find a piece of aluminum about 1/8 inch thick to go on top of it. (I used marine plywood for the wood, but a solid piece would do just as well.) This assembly — the pieces of aluminum and wood — will form the actual shelf. Drill them for mounting with 1/4-inch bolts, but don't assemble them yet. With the two pieces clamped or bolted together, mark the center by drawing cross lines from the corners. This is where the bearing will rest. You'll need to drill a hole through both pieces that's large enough to clear the inner race of the bearing, and any ham who has had to make a hole for a meter can cope with this. One precaution: make a small pilot hole through both pieces first. You may find that a large socket-hole punch will do for the aluminum, and an expansion bit for the wood.

bearing placement

Once you've made this hole, you can mount everything but the bearing. Center the bearing over the hole and mark around the circumference of the bearing with a pencil. You'll need to devise something to make a "fence" around the bearing to hold it in place. I used some 1/2 x 1/2-inch aluminum angle stock I happened to have. Almost anything will do, so use your imagination. You can use small machine screws to fasten this fence to the shelf; there's little strain on it. When it's complete, the bearing should drop neatly into the hole.

When the bearing is in place, lean over and sight down through it to the earth beneath and mark the spot with a chip of wood or some other marker. You may want to drop a plumb bob down to mark this spot; it's where the lower pipe on your rotor will enter the earth.

Your next job is to dig a square hole about a foot deep with this point at the center. You can also prepare the length of pipe by drilling holes through it at a point which will be well below the surface of the earth. Run some long bolts through it, leaving them so they extend a couple of inches on either side of the pipe. Two or three of these should do nicely.

What will happen, you ask, when you get the mast, the various pieces of pipe, the bearing, the rotor, and everything else set up on the shelf? Answer: *it will all fall over*. To prevent this, you'll need an upper support, located directly above the shelf and as high on the wall as you can get it. Perhaps "support" is the wrong word, since it doesn't bear any load. All it does is hold the mast in a vertical position and allow it to rotate within a loose collar.

wall-to-mast structure

Install a piece of the angle iron horizontally on the wall, bolted between the same pair of studs as the shelf. Then put the mast up temporarily and make sure it's in a vertical position (use a spirit level). You'll probably need a helper to make sure the mast stays in this position while you measure the distance from the wall to the nearest edge of the mast.

Now, using the leftover pieces of angle iron, you'll need to assemble a rectangular structure as deep as the distance from the wall to the mast. It needn't be as wide as the distance between the studs; mine is only 8 inches wide. It must be wide enough, however, to accept either a band bent to go around the mast, or perhaps a large U-bolt. It should be braced corner-to-corner so that it retains its shape, and further braced by two supports running from the rectangle down to a point on the wall. These last two supports may be pieces of the 1-inch strap iron, suitably bent in your vise, and bolted to the wall. These bolts needn't go through the studs, but remember to put those large fender washers on the inside.

erecting the mast

Now put the mast up on the fittings you've made. Clamp the rotor to the pipe extending below the bearing. Clamp the other piece of pipe to the lower part of the rotor. Mix up some cement and pour it into the hole below the rotor. Go inside, wash your hands, and find yourself a good book that will take you a couple of days to read while the cement cures.

guying

When the curing process is complete, you may want to shovel some dirt back over the top of the cement block. You'll then be ready to install the antenna on the topmost section of the mast. At this point, you'll probably recall that your mast was supplied with a set of guy rings — one to fit atop each of the larger sections. In large part, whether you'll use any at all

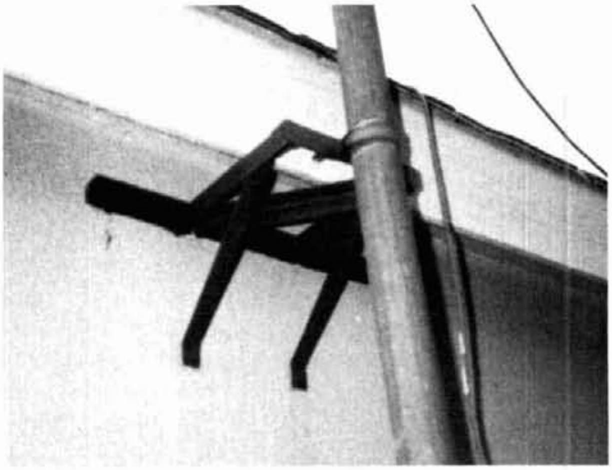

Photo 4. Upper support.

will depend on how high your mast is, how much support you can give it at the bottom, and whether experience has told you if you're likely to have a wind problem.

Consider the matter of support at the bottom. My lower installation is on a planter, but yours may be at ground level. Although I had eaves to contend with, you may have none. If your installation allows positioning your lower shelf close to the ground and your upper support near the top of the wall, you may have 7 feet or so between the bearing and upper support. (I have 4.) If there are no eaves to force you to extend your structures away from the wall, they'll be more rigid; you may be able to avoid guys entirely.

In my case I thought it best to have a set of guys at the bottom of the topmost section of the mast. Hams traditionally have followed the practice of using three guys spaced 120 degrees apart. However, the guy rings supplied, for reasons known only to the manufacturer, have four holes spaced 90 degrees apart, and a fifth hole midway between two of the others. It appears not to matter. Just use what you can, and don't tighten the guy wires as if they were violin strings. Remember, the mast is going to rotate inside that guy ring, so leave a bit of slack in the wires.

installing the antenna

At last you're ready to install the antenna atop the mast. I certainly wouldn't advocate installing a monster with a 30-foot boom, but I used to have a tribander on the mast, and all went well. My present antenna is a 10-meter monobander. Just raise that upper section to about eye level, mount the antenna on it when you get it clamped off, and do whatever final work is necessary while standing in reasonable safety and comfort on your roof.

Once the antenna is mounted, you'll have the task of extending the mast. Let me repeat my warning —

wear heavy gloves! As you push the mast up, you'll find that by pushing the section to one side a bit, it will bind enough so that you'll have a momentary respite and will be able to change the position of your hands.

Remember those marks you made on the mast sections for later reference? Now they'll prove their value. When you get the top section fully extended, clamp it off securely. If you're using the guy ring at this position, be sure to attach the wires to it before you raise it out of reach. If you have doubts about the efficacy of your clamp, you may even want to drill through the overlap between the two mast sections and secure them with a 1/4-inch bolt, flat washers, and a lock washer.

The higher you raise the mast, the less secure it will seem. *Don't worry.* Even though what you're lifting does indeed get heavier (because there's an extra section of mast each time, and the lower sections are larger and therefore heavier than the upper ones), you'll find that the load is well within your capacity. Of course, if you want to be doubly sure, ask a friend to hold the mast while you take a breather, search around for the pliers or wrench you've dropped, or just stand back and admire what you've wrought.

final precautions

One last thought: if you live in an area where the climate is less benign than it is here in Southern California, you may want to consider some sort of protection for the bearing assembly *before* you mount the mast to the nipple. The protective device will likely need to be attached, in some fashion, to the lowest section of the mast. Some sort of clamp or machine screws, with holes suitably drilled and tapped, can be used to secure it to the mast.

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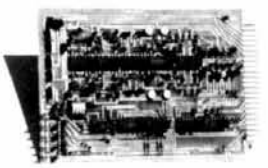

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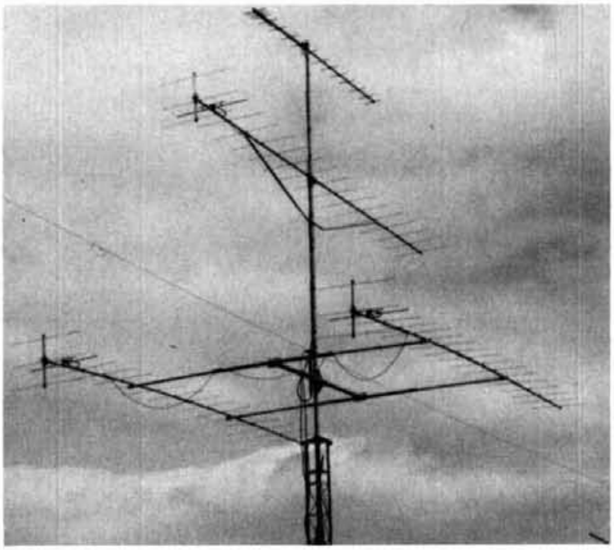
Yagi triangular array

Somewhat unconventional stack performs well mechanically and electrically



Inspired by recent articles on stacking Yagis, I decided to improve my 2-meter antenna system, which consisted of a single 19-element, horizontally polarized Yagi. Before long, I had installed another 19-element antenna above it — and with great anticipation, began making comparative checks with the new system.

Because my primary interest is in terrestrial communications, the 2.5- to 3-dB increase in gain didn't overly impress me. With a 2 x 2 array in mind, I bought two more antennas and started designing an H-frame structure. Very quickly, however, I realized how large and heavy the completed array would be. I weighed the possibilities: a tilt-over tower, with block and tackle, would allow access to the array, but would probably be unfeasible because of the antennas' size and weight. After much soul searching, I decided that a stack of four antennas, with the required H-frame, would be out of the question.

alternate stacking methods

I have, from time to time, heard mention of the diamond stacking configuration and claims of improved performance when compared with conventional rectangular stacking. Assuming reports on the diamond's performance to be correct, and seeing a triangle as half of a diamond, I concluded that a triangle would be likely to offer better performance than an inline stacked array.

Unfortunately, oddball stacking geometry such as the triangle or diamond has received little or no publicity; I've yet to find informative literature on anything but the inline stacking methods. (It would almost seem that the numeral 3 simply doesn't exist in the world of antennas. Instead, the philosophy of "double or nothing" seems to prevail.) Nevertheless, after due consideration of weight distribution on the mast and tower, I concluded that a triangle stack configuration — with two horizontally stacked antennas located at the lower level of the mast and a third Yagi mounted at the top of the mast — would best suit my needs.

Theoretically, three Yagis would provide an additional 1.75-dB gain over a pair. Subtracting the phasing harness loss from the theoretical value, a realistic gain of 4.5 dB over a single antenna should be possible. What was more important to me at this time, however, was what the plotted antenna pattern would be. How would it differ from a rectangular stack of four antennas?[2] The only way to find out would be to build the triangular array and compare the results with published articles on a four-antenna array.

optimum stacking distances

The first problem was to determine the optimum spacing required between antennas. Available stacking data apply only to a pair of antennas stacked in either of two unique locations with respect to each other. Both antennas must be located on the axis of either the E or H plane. Polarization and phasing of both must also be the same.[1,2] With triangular stacking, the two lower antennas would satisfy the above con-

John C. Cichowski, W2IKP, 167 Emeline Drive, Hawthorne, New Jersey 07506

ditions. However, the upper antenna is offset, and its H plane axis does not fall upon that of either of the two below. Consequently, the spacing from it to either of the two below will differ from dimensions found in previous studies.[1,2] After a little head scratching, it became apparent that non-standard H plane stacking dimensions were still useful.

Visualize, as in **fig.1**, a pair of vertically stacked Yagis evolving through positions into a horizontal stack. For example, by keeping the lower antenna location and polarization fixed, and swinging the upper one through an arc (which defines a locus), while maintaining the same polarization as the lower one, one ends up with a horizontal stack. Each and every point along the locus will locate the movable antenna at an *optimal* distance from the fixed antenna. Also, at some point along the locus, the antenna will be equidistant to either of the two lower antenna positions (see **fig. 1**).

E and H optimum spacing differs

If optimum spacing for E and H plane were identical, the locus would be a 90-degree arc of a circle, with its radius equal to the optimum spacing dimension. However, the E and H plane optimum values are *not* equal, and studies have shown that optimum spacing, in a particular plane, depends on beamwidth in that plane. The greater the beamwidth, the closer the

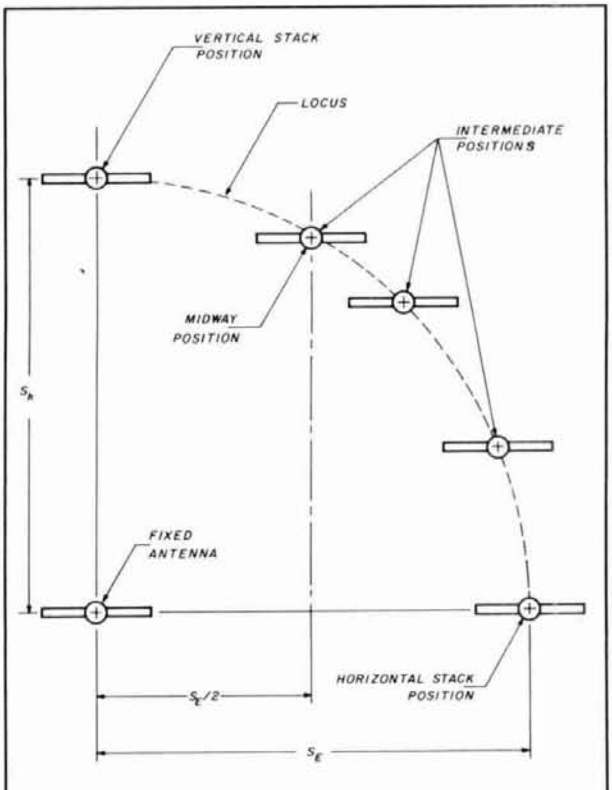


fig. 1. Vertical-to-horizontal stack orientation.

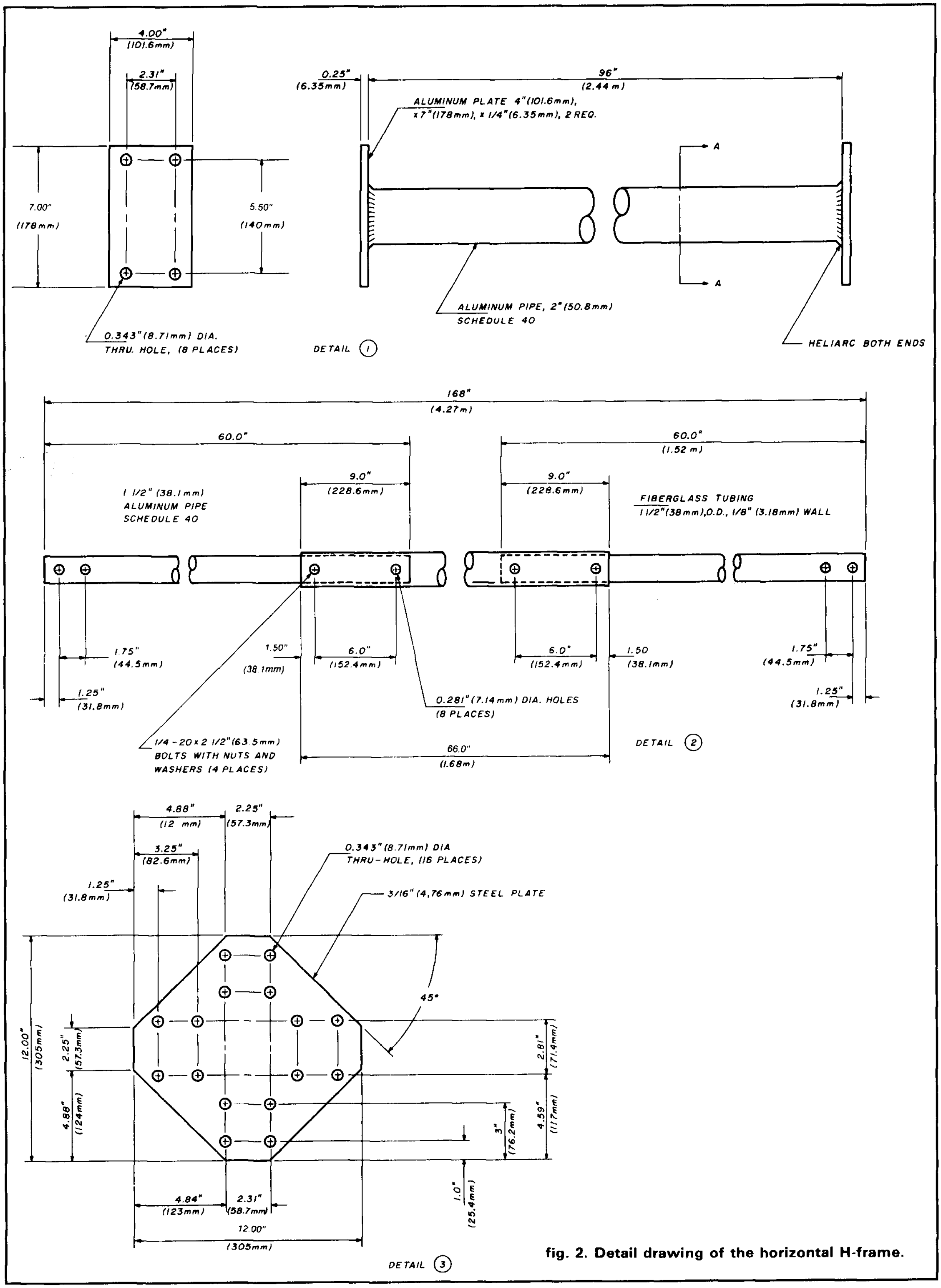


fig. 2. Detail drawing of the horizontal H-frame.

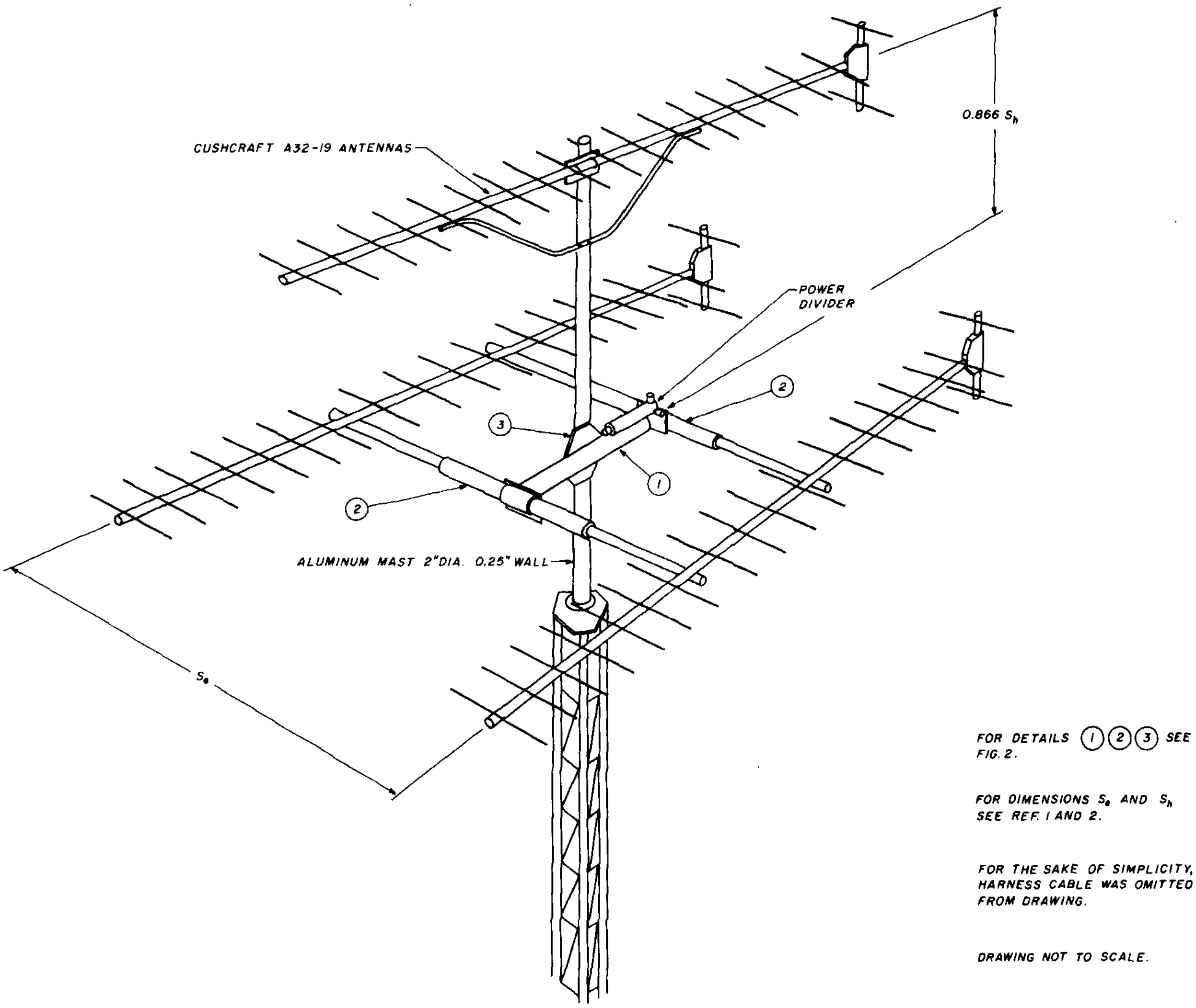


fig. 3. The Yagi triangle.

spacing.[1] The one feature all Yagis seem to have in common is greater beamwidth in the H plane than in the E plane. Consequently, H plane spacing will be less than the E plane's. The locus in this case is an arc of an ellipse. (*To visualize an ellipse, picture a hoop rotated about its diameter and viewed at an angle.*) Put into usable terms, E plane spacing is the value recommended by Joe Reisert, W1JR[1] and Steve Powlishen, K1FO.[2] Their tabulated data includes the most popular antennas in use today. The vertical stacking dimension is 86.6 percent of the optimum H plane dimension or $S = 0.866\ S_H$ where S_H is the optimum H plane stacking dimension recommended for inline stacking.[1,2]

horizontal H-frame construction

Horizontal stacking of horizontally polarized antennas requires the use of dielectric material in the immediate vicinity of the Yagi elements. A minimum distance of 1/2 wavelength of metal-free structure is recommended, or 1/4 wavelength beyond the active element tips.[3] Detail drawings for the structural parts used to assemble the H-frame are shown in **fig. 2**. The Cushcraft A32-19 antennas used in the Yagi triangle normally require boom supports supplied by the manufacturer; these are not necessary when mounted on this horizontal H-frame. The upper antenna, however, must be mounted in accordance with the manufacturer's recommendations (see **fig. 3**). Within reasonable limits, variations in frame design are certainly permissible.

If antennas other than those shown are used, changes in the overall length of items 1 and 2 might be required. Should it be necessary to make such adjustments, remember that the fiberglass support arms of the H-frame must be located midway between

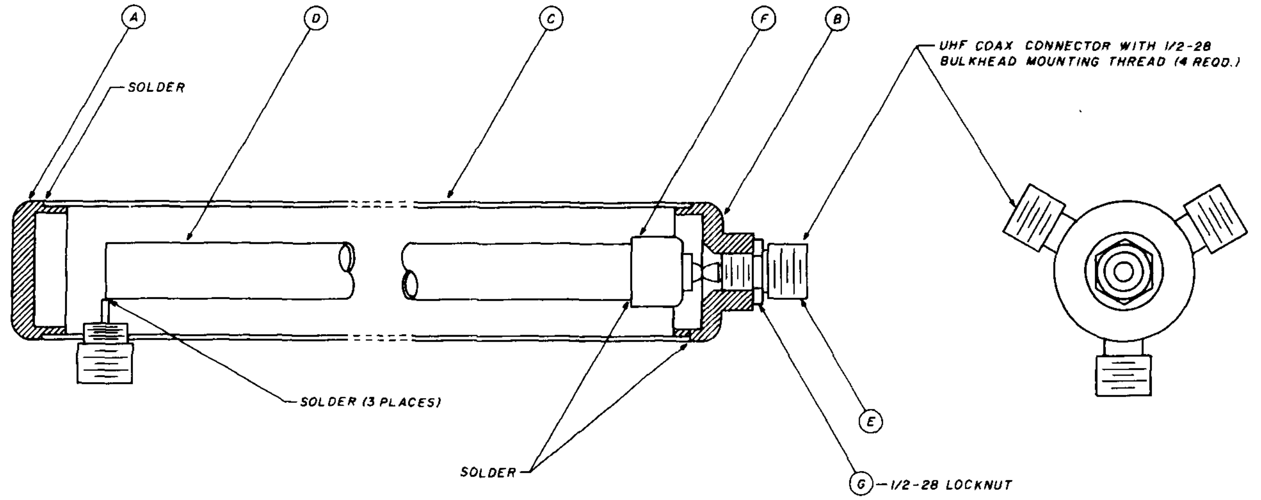


fig. 4A. Sectional view, 144-MHz three-way power divider.

the director elements of the antennas as shown in **fig. 3**.

material sources

I made use of readily available material. A local metal fence supply dealer stocked aluminum pipe and was also equipped with Heliarc welding facilities, which became very useful while constructing the H-frame. The 1-1/2 inch diameter fiberglass tubing, available in 5-foot lengths and used for satellite antenna work, was purchased from my local Amateur Radio dealer.

Because the inside diameter of the 1-1/2 inch aluminum pipe measures slightly more than 1-1/2 inches, it was necessary to shim the fiberglass tubing with glass filament tape to achieve a tight fit. The assembled frame and the three Yagis mounted on top of the tower are shown in **fig. 3**. All that remained at this point was choosing a feedline and deciding on a power divider method. A 50-ohm impedance, 7/8-inch hardline had already been installed with the previous array. The phasing harness and feedline around the rotator used more flexible RG-8U.

Use good quality cable for the harness. Each leg must be cut to equal electrical lengths, preferably from the same run of cable. Each antenna must be parallel to the others — elements as well as booms — and the most forward director element of all three Yagis must be located within the same vertical plane. Otherwise, the wavefront launched by any one individual antenna will be out of phase with the others, resulting in lower gain, greater sidelobes, and possible multipath propagation. Phasing lines, besides being equal in length, should be kept as short as possible, especially at higher frequencies. Mounting the power divider as shown in **fig. 3** allows shorter harness leads.

three-way power divider

Obtaining a three-way power divider meant building one from scratch, because I couldn't locate any commerical units. So I went back to the books and set off on a thorough search of local supply houses* for appropriate hardware.

To my knowledge, two methods for power splitting are commonly used. Most popular is the transformation of impedance by the use of a single 1/4 wavelength of coaxial transmission line. A common input port is located at one end and the required number of output ports at the other end. The characteristic surge impedance is determined as the mean value between transmitter output impedance and the parallel combined load impedance presented by the three antennas. Manufacturers of communications equipment have standardized their products for use with 50-ohm coaxial line. This simplifies the mathematics to determine power divider impedance when using more than one Yagi. Reduced to its simplest form, the equation for characteristic surge impedance for the above power divider becomes:[4-8]

$$Z = \frac{Z_O}{\sqrt{n}} = \frac{50}{\sqrt{n}} \quad (1)$$

where n = number of antennas in array, Z_O = impedance of each antenna and equals the transmitter output impedance of 50 ohms.

Using **eqn. 1**, the characteristic impedance is:

$$Z = \frac{50}{\sqrt{3}} = 28.9 \text{ ohms}$$

To determine the proper diameter ratio for coaxial line

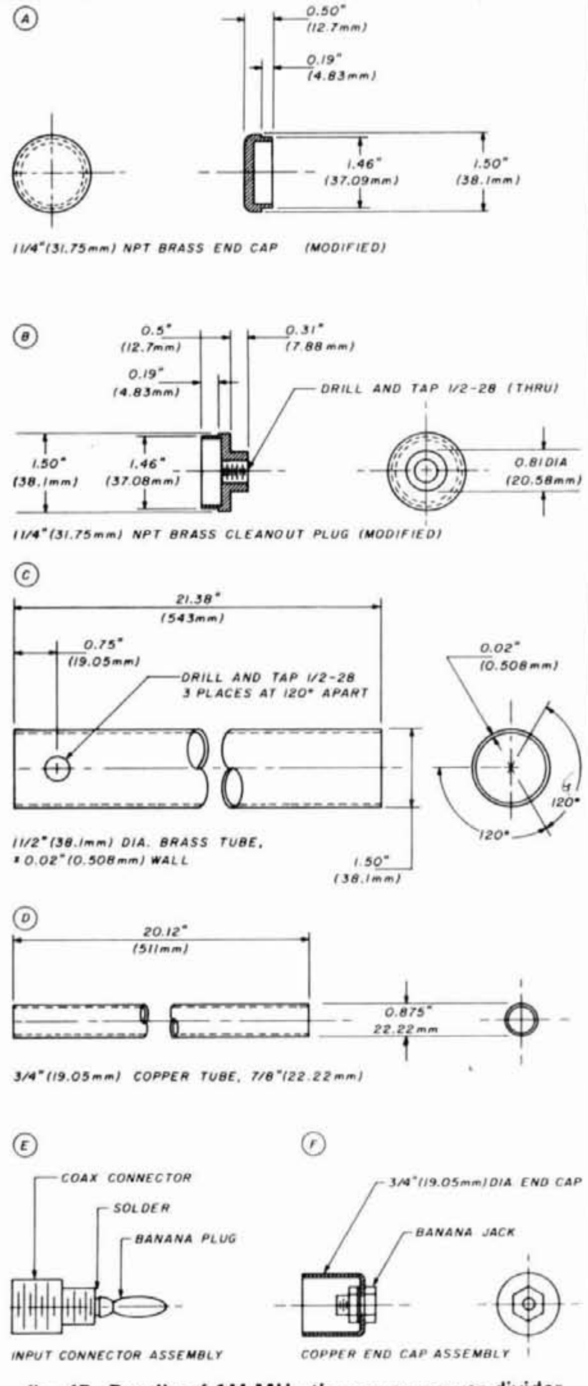


fig. 4B. Details of 144-MHz three-way power divider.

with the above impedance, the following relationship is used:

$$a/b = antilog \frac{Z}{138} = 1.62 \qquad \textbf{(2)}$$

a = Inside diameter of outer conductor
b = Outside diameter of inner conductor
Z = Characteristic surge impedance of coaxial line in the power divider.

The above diameter ratio (a/b) can be closely satisfied by using standard 3/4-inch diameter copper plumbing tubing (which actually measures 7/8 inch diameter) and 1-1/2 inch diameter brass tubing with 0.02-inch wall, normally used for kitchen sink drains. It can be purchased without the usual nickel plating at most plumbing supply stores.

To cap each end of the 1/4-wavelength line, it's necessary to machine 1-1/4 inch NPT brass cleanout plugs and end caps to the dimensions shown in the detail and assembly drawing for the three-way power divider (**fig. 4**).

Suitable connectors for this application are the familiar UHF type with 1/2-28 thread mounting capability. Amphenol 83-875 or equivalent can be used. By removing the snap ring, the connector can be dismantled and soldered to the body of the divider. Otherwise, excessive heat will destroy the insulator insert. To simplify assembly, it was necessary to include what at first would seem to be two unnecessary steps: first, the addition of a banana plug and jack at the input end of the line, to allow for adjusting the position of the inner conductor when you're soldering to output ports; and second, the drilling of three tapped holes (1/2-28) at the output end to hold coax connectors in place while you solder them to the 1-1/2 inch diameter brass tubing.

The power divider shown in **figs. 5** and **6** is the 432 MHz version of the above. Also, a scaled-down H-frame for a 432-MHz Yagi triangle is shown in **fig. 7**. (Although the antennas shown aren't representative of 144-MHz proportions, the reader may find the photos helpful nevertheless.) For further harness detail, see **fig. 8A**. The alternate power divider method (**fig. 8B**) requires 86.7-ohm impedance transformation sections of coaxial line in each leg of harness to the antennas.

$$Z = Z_0\sqrt{n} \qquad (3)$$

A 1/4 wavelength of RG-62/U cable whose impedance is 93 ohms should work well. However, transmitter power must be limited to a couple of hundred watts. With higher power, use of RG-63/U is recommended. The velocity factor for both cables is 86 percent, which makes the overall length (including connectors) of the 1/4-wavelength sections 17 inches.

A three-way "T" junction must be used at the feed point. A weathertight metal junction box with closely spaced coaxial connectors will easily satisfy the short junction lead lengths required at the distribution point. A variation of the above division method is shown in **fig. 8C**. The three 1/4-wavelength sections as well as the three 50-ohm harness cables are replaced with equal lengths of RG-62/U. The three lengths, however, must be odd multiples of 1/4 wavelength each.

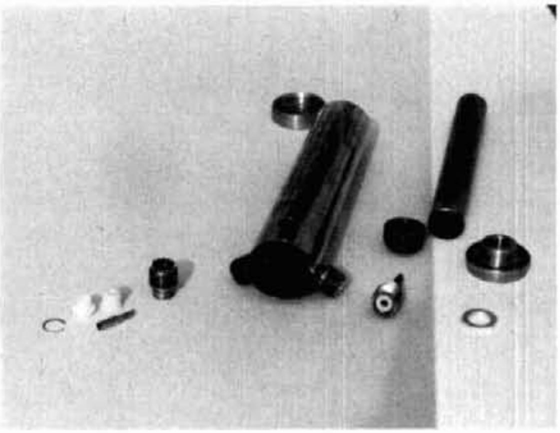


fig. 5A. Three-way power divider before assembly.

fig. 5B. Three-way power divider output ports.

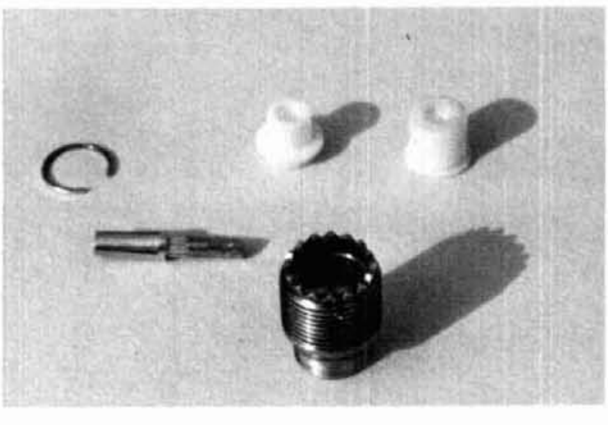


fig. 5C. Dismantled Amphenol coax connector.

Before connecting the harness to the power divider, best results will be obtained if each antenna is separately adjusted for best SWR using that leg (i.e, the same length) of feedline intended for the harness.

After adjustments have been made, connect the power divider to the antennas and feedline. Measure the SWR of the assembled array. In some cases, the

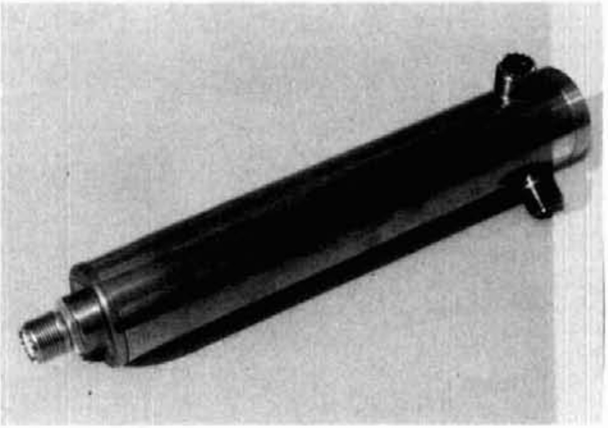


fig. 6. Assembled three-way power divider.

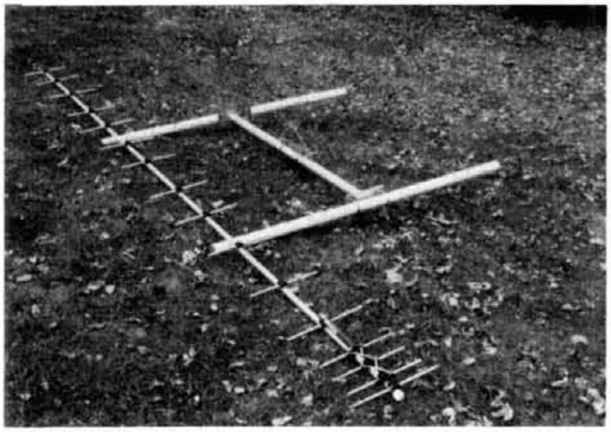


fig. 7. Horizontal H-frame for 432-MHz Yagi triangle.

final SWR measurement will appear to be better than that of the individual Yagis. Offhand this would seem to indicate an improvement to the system; however, this may not necessarily be so since the SWR measurements, other than 1:1, simply indicate the presence of a reactive load. The reactance, which can be either inductive or capacitive, depends upon how far the operating frequency is from the center frequency of the antenna and on the adjustment of the matching device at the individual antennas.[4] The inductive reactance of one antenna can cancel out, in part or completely, the capacitive reactance of another so that the resulting sum can be less than that of the individual antenna. Other than becoming more broadband (i.e., having lower *Q*), this does not imply that gain performance of the stacked array will be enhanced in any way. The SWR, as previously measured at the *individual* antennas, still exists and should be adjusted for the lowest ratio attainable or the maximum forward gain will be degraded accordingly. Once assured that the individual as well as the overall system SWR measurements are satisfactory, the Yagi triangle is ready for use.

E plane plot

The E plane plot shown in **fig. 9** indicates a half-power, 15-degree beamwidth. This was determined by the 48.5-percent method described by Gunther Hoch, DL6WU.[2] A comparison of the E plane plot of four stacked NBS-17 antennas with that of the Yagi triangle shows very little variation.[2] In fact, the front-to-back response seems to be better with the triangle. This might be attributed to the trigon reflectors on the Cushcraft A32-19 antennas used in the Yagi triangle.

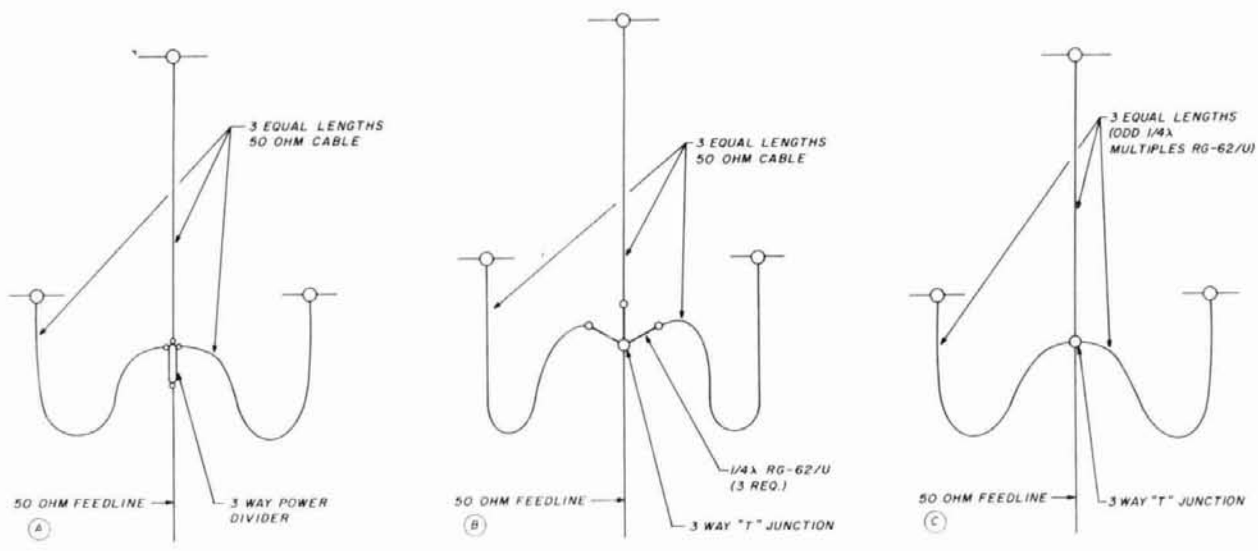
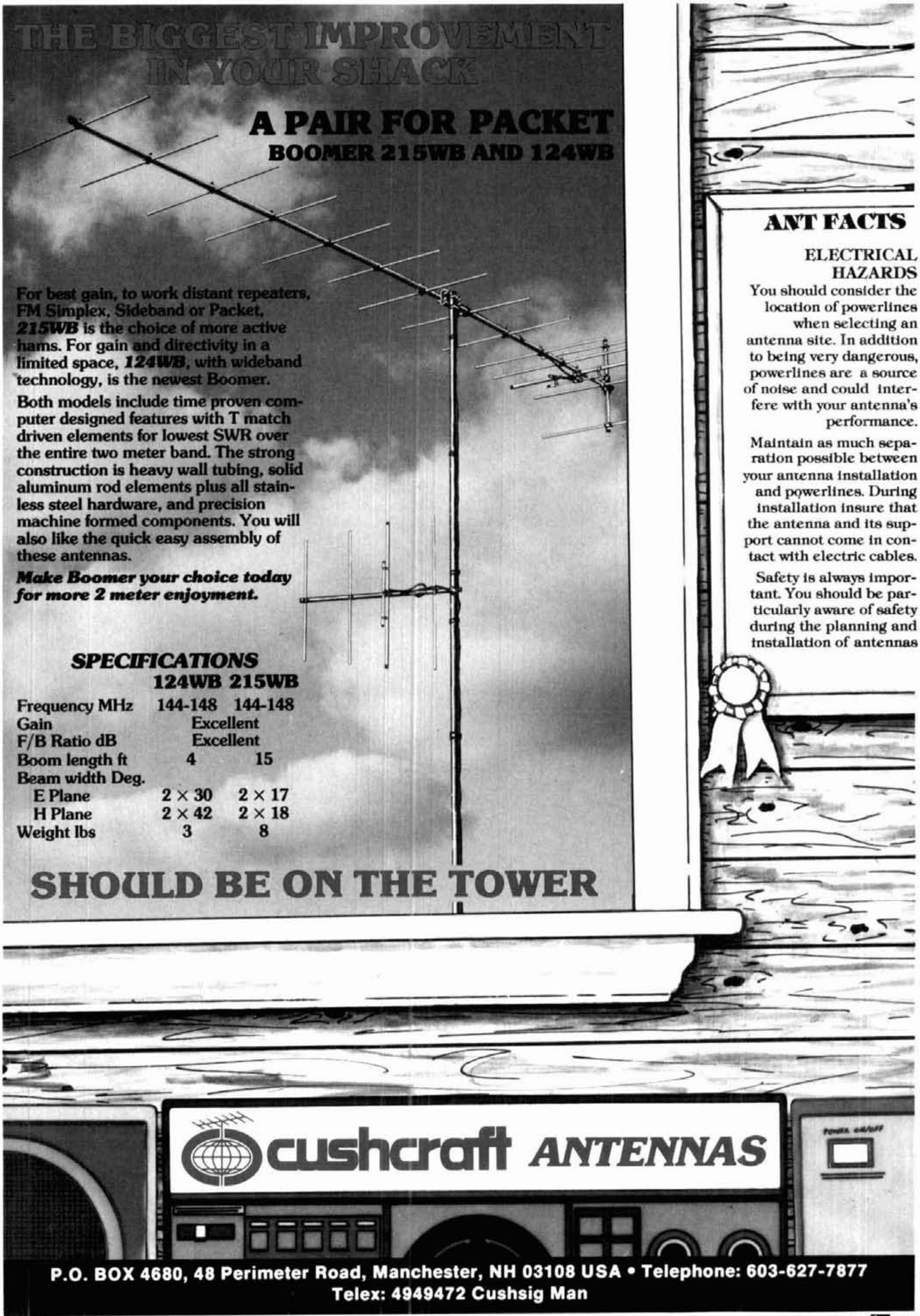


fig. 8. Alternate power divider and harness methods.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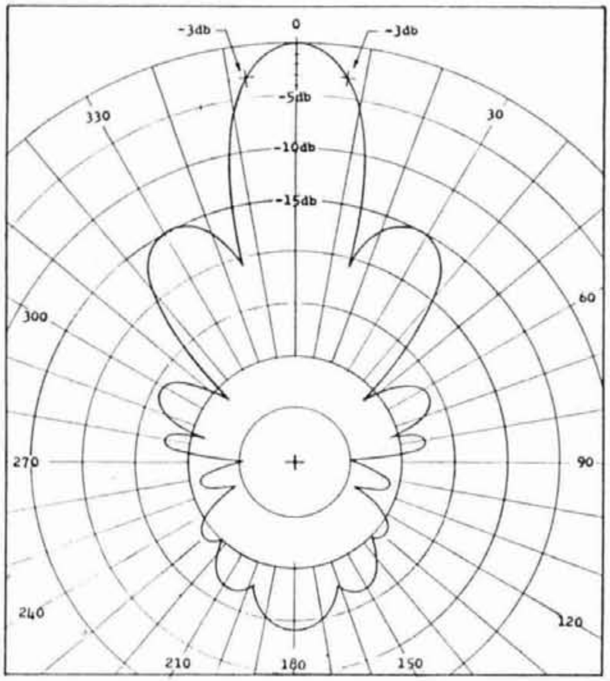

fig. 9. E plane plot.

No attempt was made to plot the H plane pattern, since no facilities to do so were available. It's my guess that the pattern would very much resemble that of two vertically stacked A32-19 antennas. Since I expect to duplicate the Yagi triangle at higher frequencies in the near future, a smaller array will be more manageable for the setup required to make H plane measurements.

antenna rotators and resolution

As the gain of a beam antenna system is increased, the beamwidth gets smaller until the point at which the resolving capability of the rotating system reaches a practical limit.

Most rotators available for Amateur use are geared to rotate at 1 rpm. The indicator on the control unit is graduated in divisions of 5 degrees. This means that rotation occurs at a rate of 6 degrees per second, or to put it in more dramatic terms, *less than one second per division*. A 15-degree segment (three divisions) will be scanned in 2.5 seconds.

To fix a beam heading, the antenna rotation between first nulls on either side of the main lobe shouldn't take less than 5 to 6 seconds. A main lobe with 15-degree beamwidth will have approximately 30 degrees between first nulls. Therefore, 1-rpm rotators will perform at the limit of their resolution capability. Antennas with beamwidths less than 15 degrees should be rotated with slower-speed devices. Aircraft prop-pitch motors are often used for this purpose. Manufacturers of one or two commercial rotators available for Amateur use claim dual speed, but the load capability of these units isn't sufficient for the size of the 144-MHz antenna array that would require the lower speed.

Used with 1-rpm rotators, antennas with less than 15-degree beamwidth require rocking the rotation back and forth several times to attain true beam heading. The problem is further compounded because of play (backlash) inherent in all such devices.

Still another resolution gremlin is the inertia that builds up during antenna rotation, causing long-boom Yagis to whip laterally when rotation is suddenly stopped. Many of these antennas have boom braces to keep them from sagging. However, the brace does little or nothing for the side motion. Heavy gusts of wind will also cause lateral flexing with these antennas. Though the two lower antennas of the Yagi triangle aren't prone to this problem because of the H-frame construction, the upper antenna does occasionally do a little dancing. Polypropylene guys from the upper antenna to the H-frame should remedy this problem.

Rotation at 1 rpm seems like a long enough period of time for a complete 360-degree turn of the antenna, and many of us — myself included — wouldn't relish the thought of extending the time. Therefore, antenna arrays with beamwidths of 15 degrees, or perhaps by stretching a point or two, even 14 degrees, should satisfy the resolution capability limits of 1-rpm rotators. This Yagi triangle is such an antenna.

performance

The triangle-stacked Cushcraft A32-19 antennas certainly perform better than the original dual stack. The theoretical 1.75-dB increase in signal seems to mock the theoretical 3 dB originally obtained while using the dual stack. QRP signals, unheard before, are now Q5 copy. Reports on my signal are almost always complimentary.

Raising or lowering the tower with the triangle stack is a one-man operation. Repeated inquiries about the triangle stack seem to indicate that others would like to give it a try. Anyone interested in a totally different approach for stacking Yagis will find building the Yagi triangle a worthy and rewarding effort.

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ham radio

ham radio TECHNIQUES

ham radio techniques

In the northern areas, winter is almost over and signs of spring are in the air. It's a good time to think about antenna systems. A lot of interesting antenna concepts have just been waiting for some good weather to set in! Here are some interesting projects for you to consider . . . .

inexpensive base station antenna for 2 meters

I think Fred Dietrich, NM6J, has come up with a winning 144-MHz antenna that has decent gain and a low SWR, and costs very little to construct. Shown in **fig. 1**, this vertical, omnidirectional array is only about 6 feet tall. The antenna structure is made of a length of 3/4-inch Schedule 40 (thick wall) PVC water pipe. The overall pipe length is long enough so that the antenna can be supported by clamps at the base end. For this particular installation, an 8-foot length of PVC was selected. The top of the pipe is closed with a PVC cap cemented in place using the liquid sealer that applies to such material.

The radiating portion of the antenna is a No. 12 copper wire 51.75 inches long. Enough extra wire is added to this length to allow it to be attached to the cap with PVC cement and to form a solder connection to the coax line at the base of the antenna.

Two phasing sleeves are used. They're made of galvanized hardware cloth folded around the PVC pipe and wrapped with wire to hold them in place. Each sleeve is 17.25 inches long. The retaining wires are soldered to the hardware cloth at several points around the circumference.*

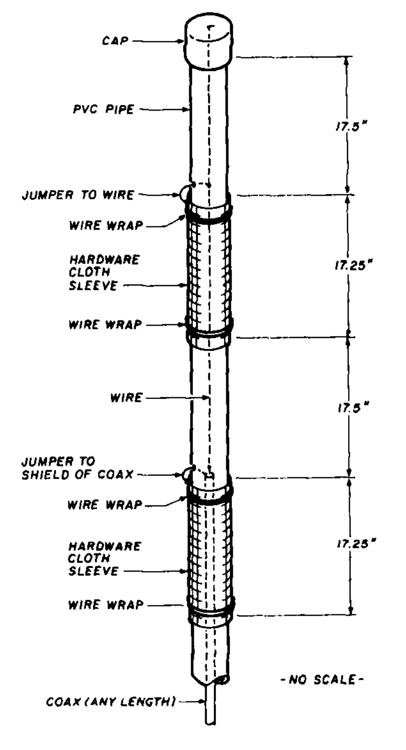


fig. 1. Two-meter PVC base station antenna.

A short jumper wire joins the top of the upper screen to the antenna wire running inside the PVC tubing. It is suggested that this wire be soldered to the antenna wire and then fished out through a small hole drilled in the PVC wall. If this and the following step are done before the top PVC cap is fastened in place, the assembly will proceed smoothly.

A second phasing sleeve is affixed to the structure below the first, as shown in **fig. 1**. This sleeve is connected to the outer shield of the coax line by means of a short length of wire inserted through a second hole after the antenna wire has been passed within the PVC pipe. After assembly, the holes are filled with cement to make the assembly waterproof.

The antenna is mounted in a vertical position and the coax line is brought down directly below the antenna. A VSWR plot representative of the antenna's performance is shown in **fig. 2**.

a "rubber duckie" for 160 meters

The ham who lives on a small, treeless lot faces a real problem when contemplating 160-meter operation. One solution to this problem is a vertical antenna. But a quarter-wave vertical antenna on "top band" is over 130 feet high. Joe Moraski, KY3F, has a solution to the problem. He recommends a helix antenna operating in the normal mode — that is, a coil with a small diameter compared to the operating wavelength. Maximum radiation is *normal* to the axis, hence the name. This is the same mode of operation as that of the 2-meter "rubber duckie" antennas used on handhelds.

*Though more expensive copper-based hardware cloth would maintain its electrical properties longer. — Ed.

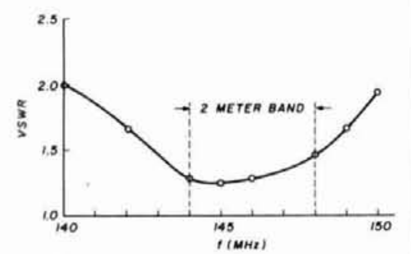


fig. 2. Measured performance of PVC antenna on 2 meters.

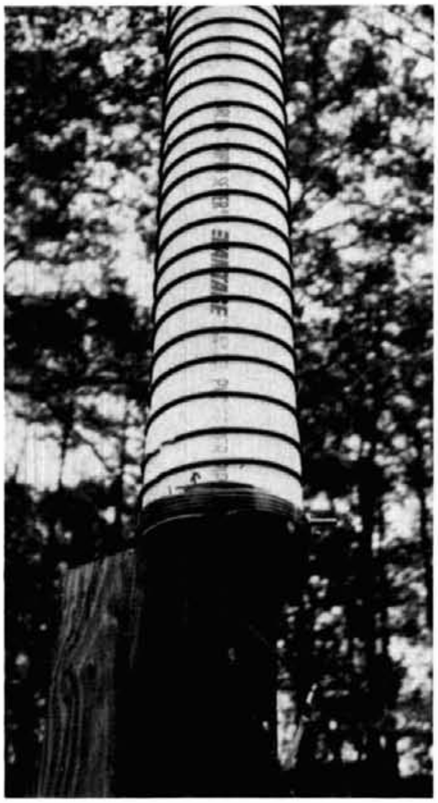


Photo 1. Base assembly of the KY3F vertical antenna for 160 meters. Final frequency adjustment is made by varying number of turns at the bottom of the helix.

There are no hard and fast rules about the length or diameter of the helix. The rule of thumb is that about a half-wavelength of wire is used to make the helix.

Antenna size is a matter of tradeoffs. The shorter and thinner the helix, the narrower the bandwidth. The longer and thicker it is, the harder it is to build and keep up in the air! A shorter helix is less efficient – consequently, the longer the better.

Since the helix bandwidth is narrow, a top hat is added to reduce antenna Q and add capacitance at the high voltage point. The resulting reduction in circuit Q causes the feedpoint impedance at the antenna base to vary less rapidly with frequency change than the unloaded antenna. This means that the antenna can be used over a larger portion of the band than would otherwise be possible.

By experiment Joe found that a 20-foot antenna was a good operating compromise. Accordingly, he used two 12-foot sections of 4-inch diameter PVC water pipe cemented together to make a 24-foot mast. He wound No. 18 insulated hookup wire on it at ten turns-per-inch spacing. This helix, in combination with a screen wire capacitance hat on top, resonated in the 160-meter band when operated against a ground rod and quarter-wave counterpoise wire run around the backyard. Four 30-foot radials were added. A sketch of the antenna is shown in **fig. 3.**

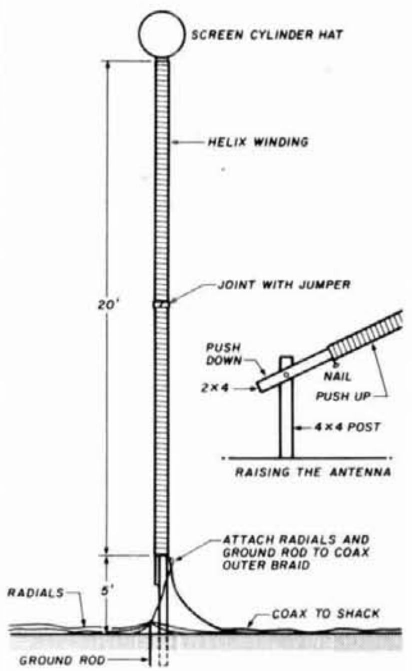


fig. 3. KY3F's 160-meter "Rubber Duckie."

The construction is simple if done in the proper sequence. The first step is to drill holes for the end tie bolts that terminate the winding. The holes are 10 feet apart. Galvanized bolts are used, with washers on each side of the PVC pipe. With a tape measure and felt-tip pen, make small marks at 1-inch intervals between the bolts.

Next, fasten an eye-lug to one end of a 140-foot length of No. 18 insulated wire. Fasten the lug to one bolt and wind the coil on the PVC pipe, using the pen marks as a guide – one turn per mark. Use tape to hold the coil in place as you progress along the form.

Wind the wire as tightly as you can and when you reach the second terminating bolt, cut the wire and place an eye-lug on the end that will fit over the bolt.

With the winding properly spaced, run a bead of RTV along the length of

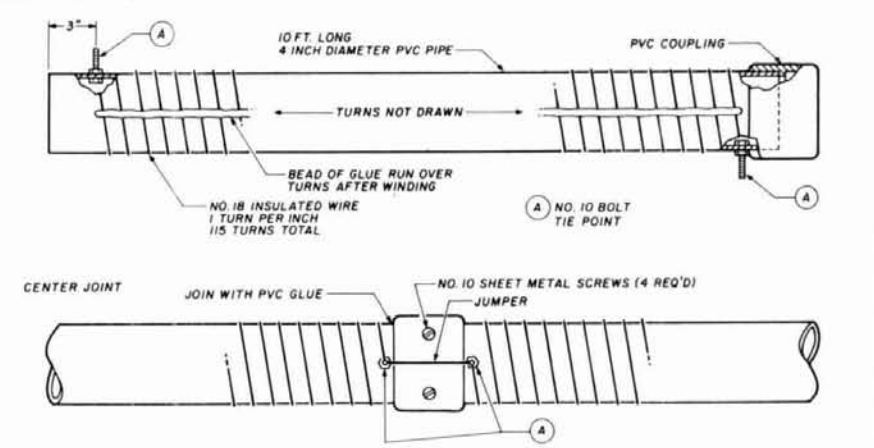
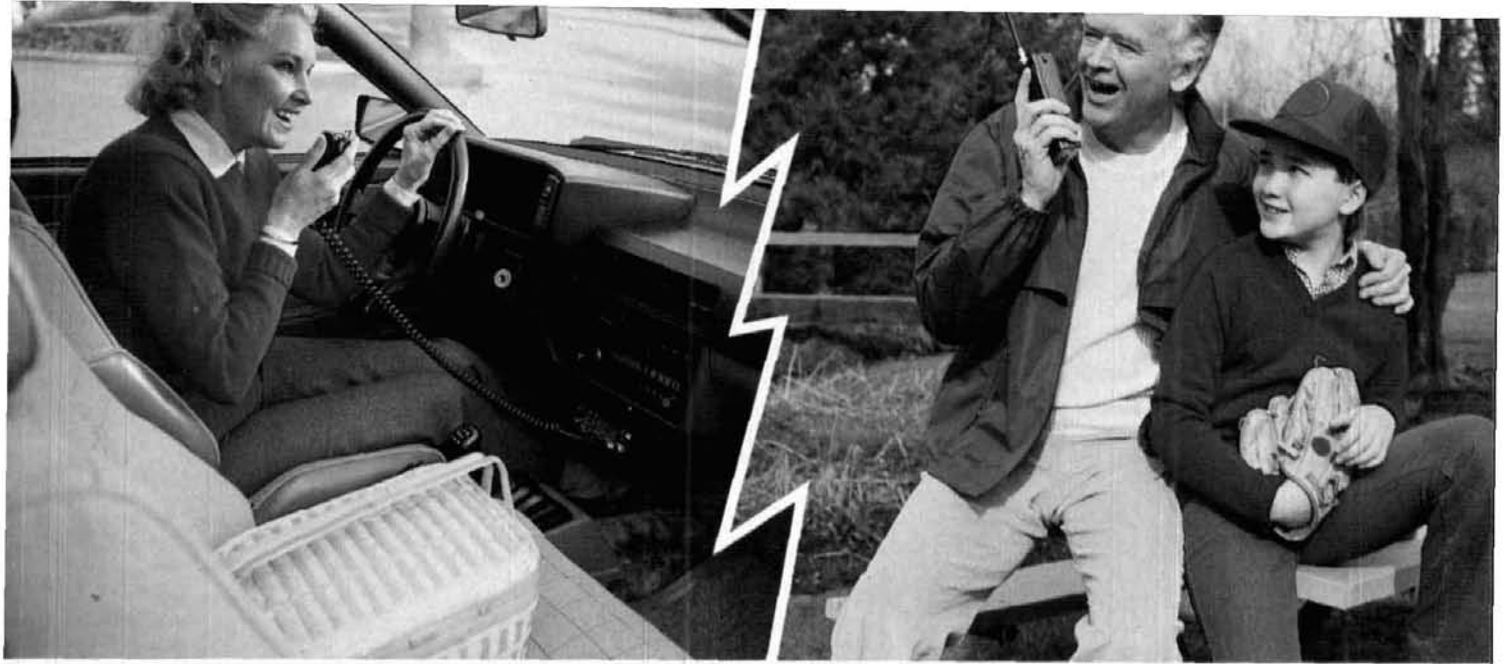


fig. 4. Mechanical details of the coil sections.



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pipe over the coil turns to lock them in place.

You have now completed half the antenna. Now, wind a second similar coil on the second section of PVC pipe, making sure that both coils are wound in the same direction (left- or right-hand turns, but be sure they're both the same).

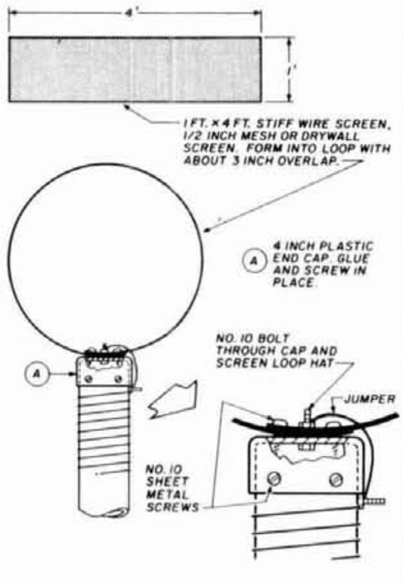


fig. 5. Top Hat assembly.

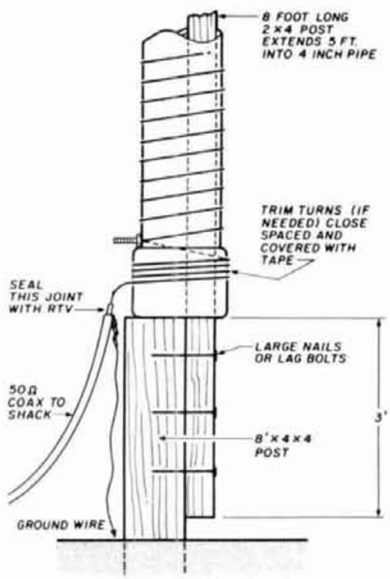


fig. 6. Mounting arrangement of antenna to post.

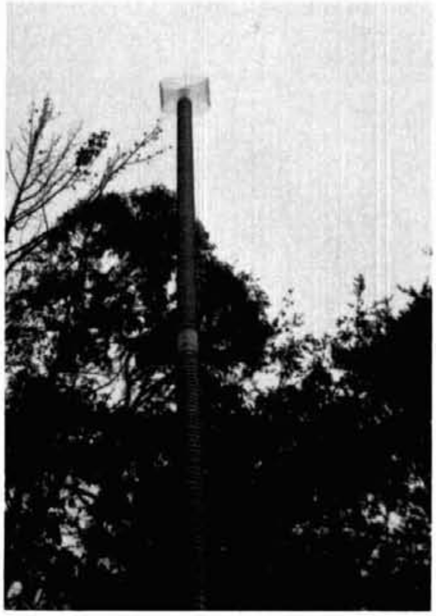


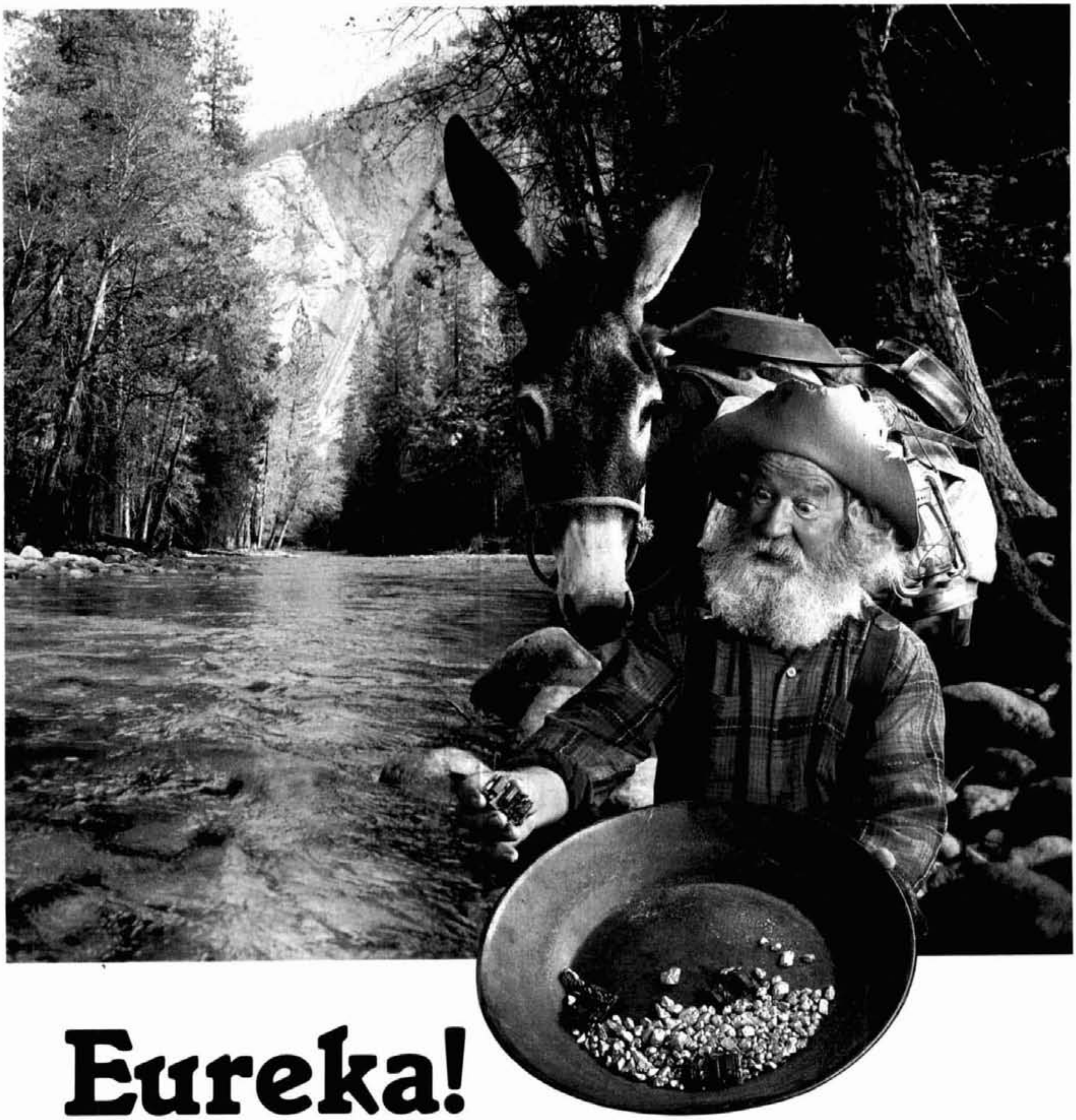
Photo 2. View of winding and capacitance hat on KY3F helix antenna.

The two pipe sections are now joined with a plastic pipe splice section and PVC cement. Align them quickly and let the joint dry (**fig. 4**). Some PVC pipes have a built-in coupling joint — nice if you can locate one. For added strength, run four No. 10 self-tapping sheet metal screws through the joints where the PVC pipes and splice section overlap. Finally, connect a wire jumper between the two coils to form one 20-foot coil.

The next step is to make the "top hat." A section of 1/2-inch mesh chicken wire or drywall screen can be used. Wrap it into a cylinder about 1 foot in diameter and 4 feet long. Solder the overlapping wires. Drill the cap piece of the antenna for a No. 10 bolt, which is bolted through the overlap portion of the top hat. Use large washers on each side of the screen to enhance stability. Then run four No. 18 sheet metal screws through the screen and cap to keep the screen from turning or buffeting in the wind (see **fig. 5**).

The final step is to attach the top hat to the top of the helix with a jumper wire. Glue the top hat in place and pass four sheet metal screws through the hat to hold it securely to the PVC pipe.

↵ 143



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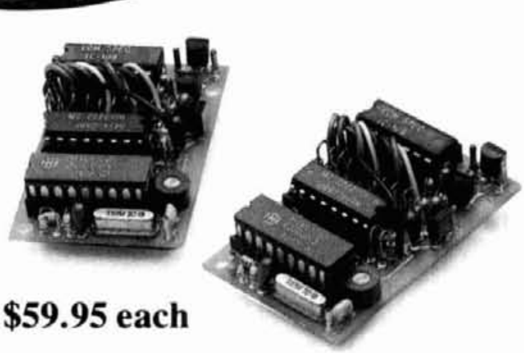

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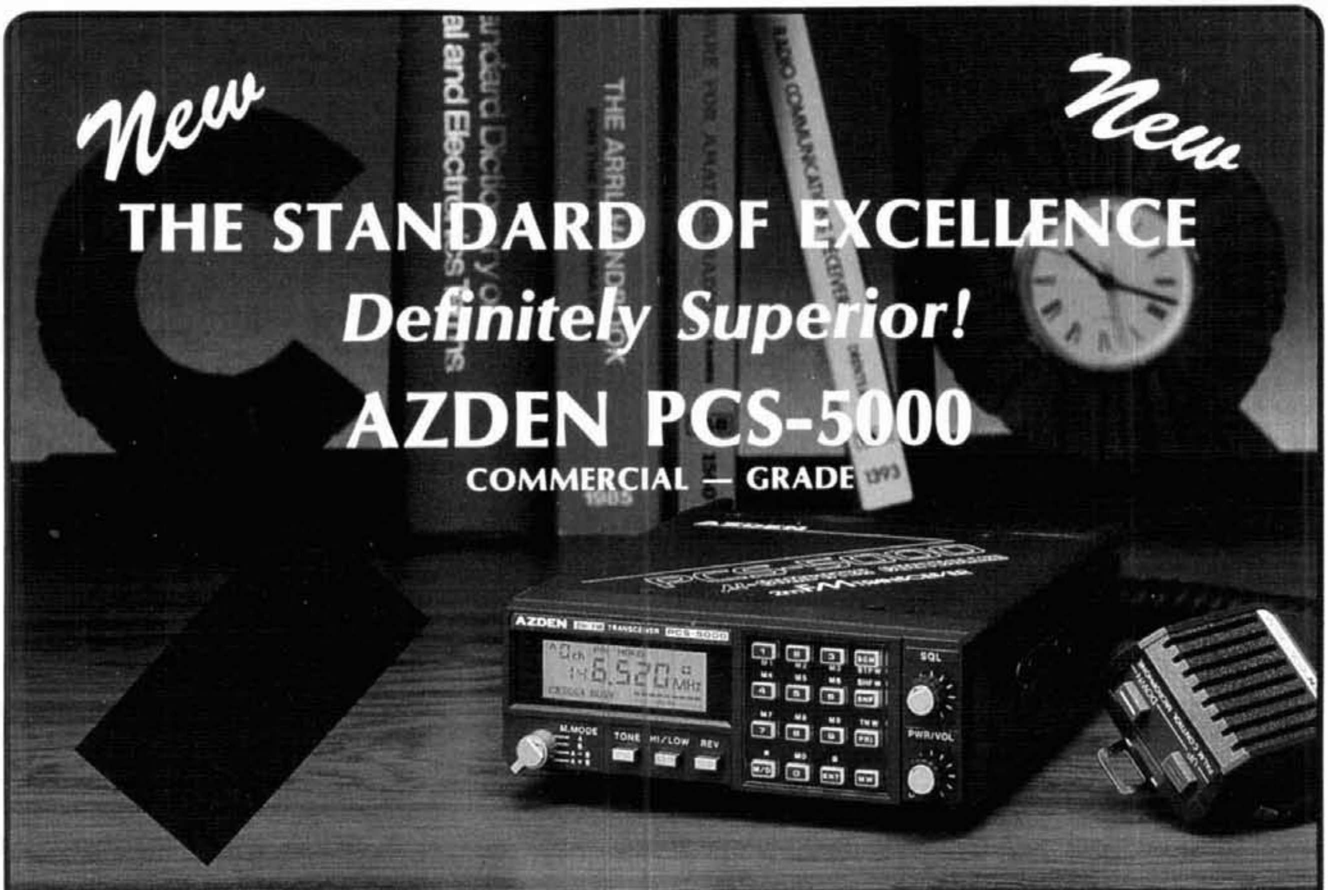

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Photo 3. Joe, KY3F, standing beside his 160-meter "Rubber Duckie."

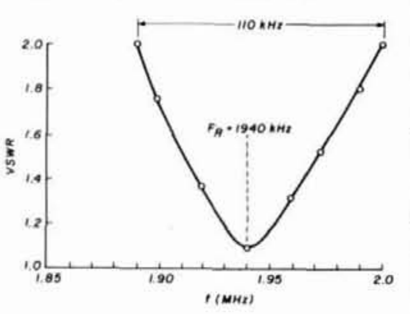

fig. 7. "Rubber Duckie" for 160 meters has 2:1 bandwidth SWR over 110 kHz. Antenna was adjusted for 1940 Hz.

Dig a 3-foot hole for the mounting post. Wrap the portion of the post that will be beneath the surface of the ground with heavy kitchen-type aluminum foil. A double wrapping held in place with plastic tape will protect the post from ground water. After the sides and bottom of the post have been wrapped, place the antenna in the hole and drive a ground rod into a corner of the hole, as far down as possible. Fill the hole with concrete, using a level to make sure the post is vertical.

To make the pivot joint, insert a section of 2x4 lumber within the PVC tubing. Fasten this extension to the 4x4 ground post with one lag bolt, used as a pivot. (See **fig. 6** for details.) Bolt the 2x4 and 4x4 together, with the 2x4 in a vertical position. Then raise the antenna to a vertical position and drop it down over the 2x4 section. When the antenna is in the final position, it will sit atop the 4x4 post with the 2x4 section acting as a positioning guide. Various views of the installation are shown in the accompanying photographs.

When completed, the radials and outer shield of the coax line are connected together and the inner conductor is connected to the helix by a short length of wire. The open end of the coax is taped and covered with RTV to keep water out.

As shown, the antenna is resonant at the top end of the 160-meter band. Four close-spaced turns were added at the bottom of the antenna to bring the resonant frequency down to 1.94 MHz. By picking the part of the band you wish to use most and adjusting the extra turns at the antenna base, you can resonate the antenna at any spot in the band you wish. SWR plots of Joe's antenna are shown in **fig. 7**.

Joe says the helix seems stable without any guy ropes, but recommends that ropes be added if the antenna is in an exposed, windy location. Light nylon guys would do the job.

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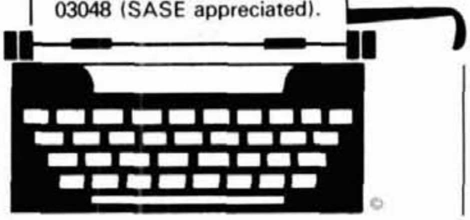

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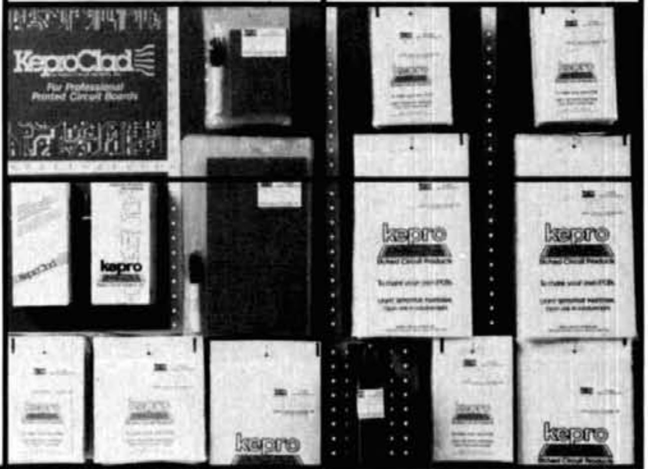

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Requires 1 Coaxial Cable for Hook-up

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Gain: Horizontal - 5.25 DB, Vertical - 4.75 DB
Multiplication Factors: Horizontal - 17 Times, Vertical - 15 Times
Horz. to Vert. Separation: 20-25 DB
Power Rating: 2000 CW, 4000 PEP
Height: 11 Feet
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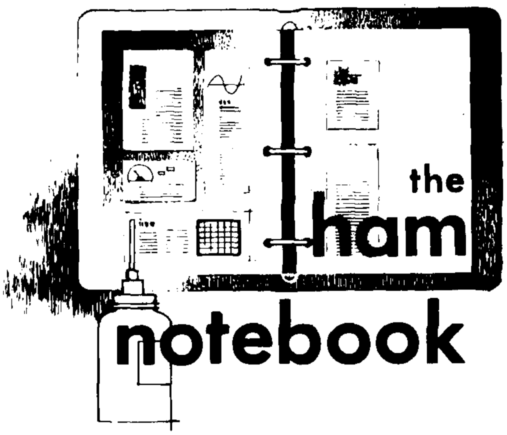

a 2-meter halo antenna

After obtaining a 2-meter multimode radio and operating it mobile for a short time, I came to a conclusion: 2-1/2 watts output and a 5/8-wave vertical wasn't good enough.

I decided to improve the antenna first; I could install my small 80-watt amplifier later for long trips. I decided to build a 2-meter halo since I'd worked several mobile stations who were using them, and they seemed to do a good job.

construction

The halo is a half-wave dipole bent into a circle (**fig. 1**). To make the insulator mounting block (**fig 2**), cut a piece of 1/2-inch thick plastic into a 2-1/2 by 3-inch rectangle. Cut a slot and drill the holes as shown in **fig. 2**.

The driven element or dipole is made from a 38-inch long, 3/8-inch diameter piece of copper tubing. Mark the center of the piece of tubing and bend it into a hoop measuring 12 inches in diameter. Drill a 9/64-inch hole at the top of the center mark on the dipole element. Secure the dipole element to the mounting block by inserting a screw through the dipole element and mounting block. Fasten with a lockwasher and nut. Insert a small piece of 5/16-inch diameter wood dowel into the ends of the halo element, leaving a 1-1/2 inch gap between the tubing ends. This completes the main element of the halo (see **fig. 1**).

To assemble the rest of the halo, refer to **fig. 3**. Mount the small plastic (*not metal!*) box under the insulator mounting block.

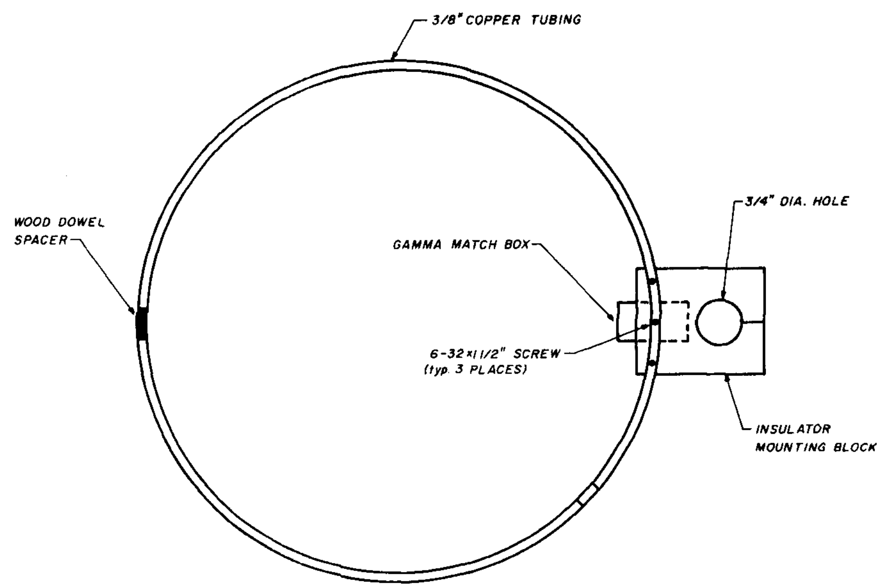

fig. 1. Top view of 2-meter halo.

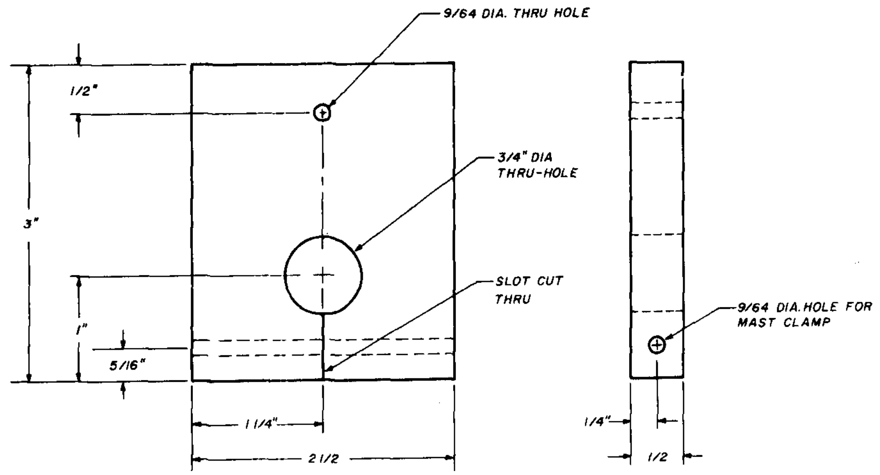

fig. 2. Insulator block details.

Following the details shown in **fig. 3**, drill the holes in the box and install the coax connector and gamma match capacitor. A variable capacitor of about 35 pF will work fine.

A 6-inch length of 3/8-inch diameter copper tubing is used for the gamma rod. Bend it around the halo's element to form it into a slight circle. Make a shorting bar now so you can secure the gamma rod to the halo antenna. (Any kind of easily bendable metal will work.) Be careful to keep the spacing between the gamma rod and dipole element to about 1-3/4 inch.

Insert one end of the gamma rod into the gamma match box and install the shorting bar on the other end.

Lay the halo on its side, with the open end of the gamma box facing up. Apply some 5-minute epoxy around the gamma rod and let it dry. Your halo is now finished and needs only to be tuned.

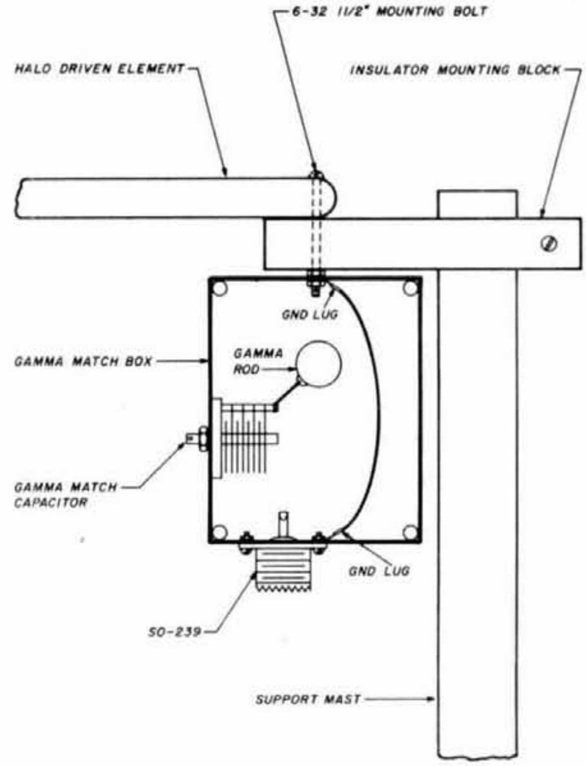

fig. 3. Matchbox details.

tuning

Mount the halo 5 to 6 feet above the ground or temporarily attach it to your car. Adjust the spacing on the driven element for minimum reflected-power indication. (Mine was lowest at an 11/16-inch spacing.) Do the same for the shorting bar, sliding it back and forth along the gamma rod. (My lowest SWR was 1 inch from the end of the gamma rod.) The final adjustment is made by tuning the gamma-match capacitor for minimum reflected power. My final SWR is 1.2:1 on the halo.

Remove the halo and seal the gamma match box. Plug the end of the gamma rod with RTV or epoxy. Coat the wood dowel spacer on the driven element with epoxy; this will waterproof it and keep it from slipping. The final step is to spray paint the assembly with a nonlead-based paint.

The 2-meter halo has increased my range significantly. While on vacation in Oklahoma, I worked West Virginia, New Jersey, and Maryland during an E opening. (My normal range is 50 to 100 miles with only 2-1/2 watts.)

One final word of caution: if you build and mount the halo, be prepared for lots of stange stares and questions. You'll get plenty of them.

Jerry Felts, NR5A
ham radio

short circuit

MMIC multiplier chains

In **fig. 5** of N6JH's article, "MMIC Multiplier Chains for the 902-MHz Band" (February, 1987, page 72), all values indicated as "μF" should be corrected to read "pF." Note too that coil L1, which can be seen just to the left of the crystal and directly above the partially meshed plates of the variable capacitor (**fig. 7**), is not the same as the coils in the multiplier. L1, which is five turns of No. 24 (AWG), is air-wound with an interior diameter of about 0.2 inches — this dimension is not critical because only broad resonance is needed to select the correct crystal overtone.

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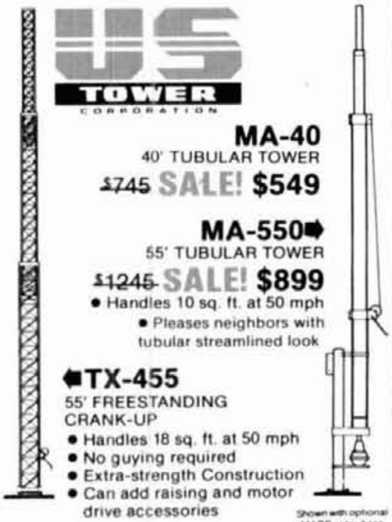

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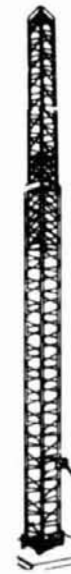

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The use of capacitors at the midpoint of the dipole allows the resonance currents in the dipole to reach larger amplitudes than are possible when the 50-ohm cable impedance is present as a series resistance. Apart from the copper loss, the principal limitation of resonant currents is the radiation loss. For this reason the capacitor dipole is highly efficient and has a very wide bandwidth.

Before studying the details, one should review the problems associated with the traditional half-wave dipole (see **fig. 1**), which are chiefly:

- an unbalance that causes an undesirable current on the outside of the shield results in higher levels of electrical noise from local sources on receive, and on transmit provokes annoying rf voltages at the transceiver (i.e., microphone feedback or finger burns); and
- matching problems between free-space impedance (377 ohms), a typical traveling wave on a wire dipole (800 ohms), and the feedpoint impedance of a half-wave dipole, said to be 73 + j 42 ohms.[4]

The first problem experienced with the conventional dipole has traditionally been solved by using a balanced feedline or a transformer balun. Unfortunately, use of a transformer brings its own problems: increased weight; the possibility of saturation and harmonic generation; or introduction of even more inductive reactance, from its leakage reactance, which necessitates shortening the antenna more than the customary 5 percent to achieve resonance.

The next step involves replacing the dipole with its equivalent (resonant) circuit as seen at its center where the voltage is least and the current is maximum. See **figs. 1, 2,** and **3.**

The magnitude of the various components are:

$$Z_o = \sqrt{\frac{L}{C}}$$

where Z_0 = traveling wave impedance
where L = inductance per meter
and C = capacitance per meter
traveling wave velocity

$$v = \frac{1}{\sqrt{LC}}$$

Rearranging terms, the impedance exhibited by a wire can be expressed in terms of velocity and capacitance as:

$$Z_o = \frac{1}{vC}$$

Because the velocity of a traveling wave on a wire in air is almost equal to its free-space velocity (3×10^8 m/s) and the capacitance per meter of a 2-mm (0.08 inch) diameter wire is approximately 4.17 pF, then this same 2-mm diameter wire impedance is:

$$Z_o = \frac{1}{3 \times 10^8 \times 4.17 \times 10^{-12}} = 800 \text{ ohms}$$

The circuit can be considered to consist of two equal and opposite sign reactances (800 ohms) that correspond to two oppositely traveling waves, and a shunt

Maurice C. Hately, GM3HAT, 1 Kenfield Place, Aberdeen AB1 7UW, Scotland, UK.

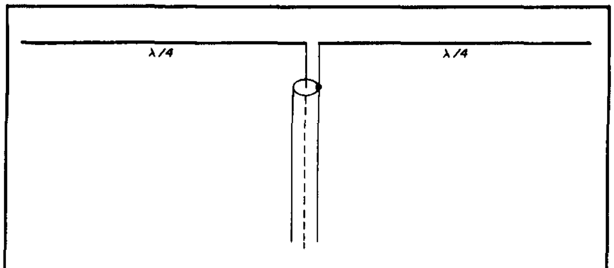

fig. 1. Traditional coax-fed half-wave dipole.

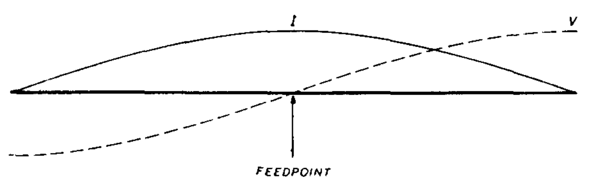

fig. 2. Symmetry of field conditions around basic dipole.

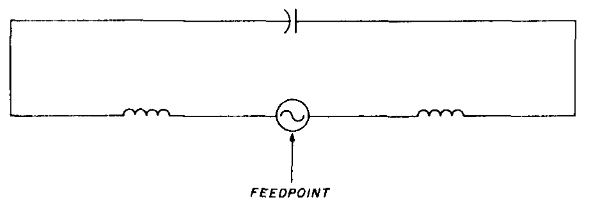

fig. 3. Equivalent resonant circuit of basic dipole.

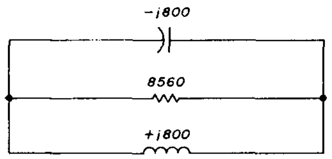

fig. 4. Parallel resonant circuit equivalent to practical dipole.

resistance that represents total losses (mainly attributable, one would hope, to radiation into space). The half-power bandwidth of a half-wave dipole is 9.3 percent of the nominal resonance frequency.[5] *Q* is the reciprocal of the percentage bandwidth or equal to 1/0.093 = 10.7 (for a length-to-diameter (L/D) ratio of 10,000 and a height above ground of λ/4). The shunt loss resistance value (i.e., radiated power) in parallel resonance is reactance times *Q* or 800 x 10.7 = 8.56 k. On the other hand, the series equivalent "loss" resistance (series resonance) is 800/10.7, or approximately 73 ohms. **Figure 4** shows the complete parallel equivalent circuit. **Figure 5** shows the next progression, developed by splitting all three terms, which enables one to place at this location a virtual ground or balance point. Next, **fig. 6** shows the actual induction field couplings which exist from end to end. M shows the magnetic field and E shows the antiphase electric field coupling. (The electric field has two 180-degree out-of-phase components that are at the same time out of phase with the current maxima and magnetic field. In other words, the energy stored in the resonant system of the antenna has either most of its energy in the electric field, or a quarter of a cycle later in time, in the magnetic field.) These are not small effects — in fact. they are considerable and must therefore always be taken into account.

If Kraus had drawn the half-wave dipole in this way, he would have shown it as it appears in **fig. 7**.[4] The extra -j42 ohms required for resonance, and the necessity for some balun in order to properly feed the coaxial cable, led me to decide to put in series two equal-value capacitors of -j21 ohms reactance and to feed the power across one of them as shown in **fig. 8**. The coaxial shield is now connected to the *electric field* center of the antenna. When first tried, this arrangement immediately showed promise in the removal of most of the local hash from machines, TV sets, and computers. But the VSWR on the feeder could not be reduced below 2:1 no matter what value capacitors were tried, or at which length or frequency the antenna was operated. Some of the problems must have been attributable to the unwarranted connection

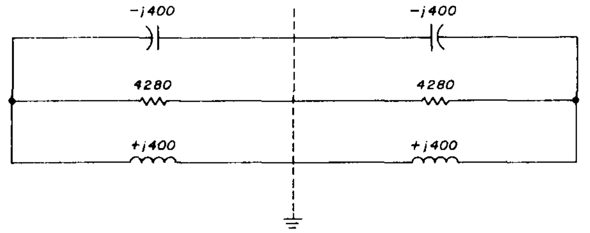

fig. 5. Equivalent circuit symmetrically splitting all three terms.

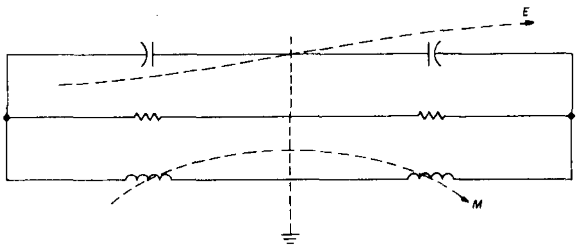

fig. 6. Equivalent circuit with accompanying symmetrical field.

of a capacitor of only 21 ohms across a 50-ohm feeder. It turns out that there are two solutions to this problem: you can install a series inductor before the capacitor (see **fig. 9**) or use a second resonant circuit, thereby making the antenna a dual-band radiator (see **fig. 10**). This approach extended its operating on two, three, four, or even five bands with low SWR, while still providing a balanced structure — hence the name, "Dipole of Delight," under which these capacitor dipoles are sold.

The additional reactance needed in the capacitive balun of the monoband dipole helped match the transmission line (50 ohms) to 800-ohm characteristic impedance of the antenna wires. It turns out that the optimum capacitive reactance is -j50 ohms (see **fig. 11**). If this is redrawn as a single-ended equivalent, all the components must be scaled down by a factor of $1/\sqrt{2}$ (This is due to the sharing of the load in the two halves and the doubling of the impedance on return to a dual, or balanced form (**fig. 12**). After slight rearrangement (**fig. 13**), the two capacitors are seen

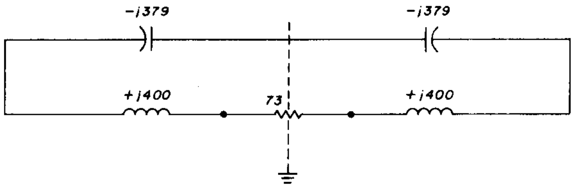

fig. 7. Symmetrical equivalent circuit with losses transformed to feed point.

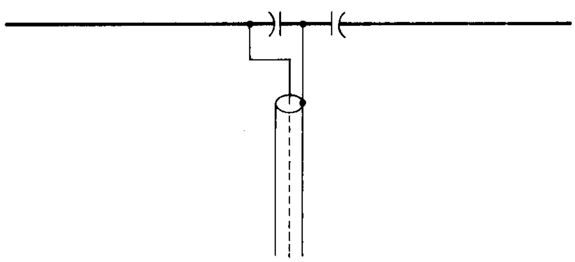

fig. 8. Basic capacitive balun system.

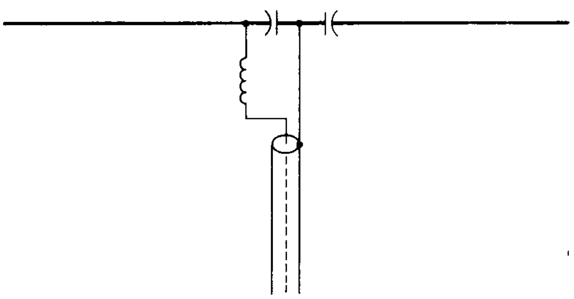

fig. 9. Additional inductor to correct feedpoint impedance; monoband antenna.

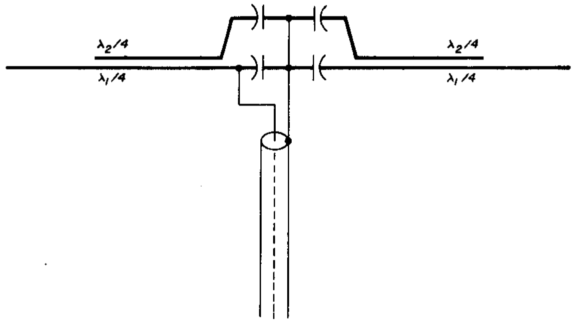

fig. 10. Alternative correction technique; multiband antenna.

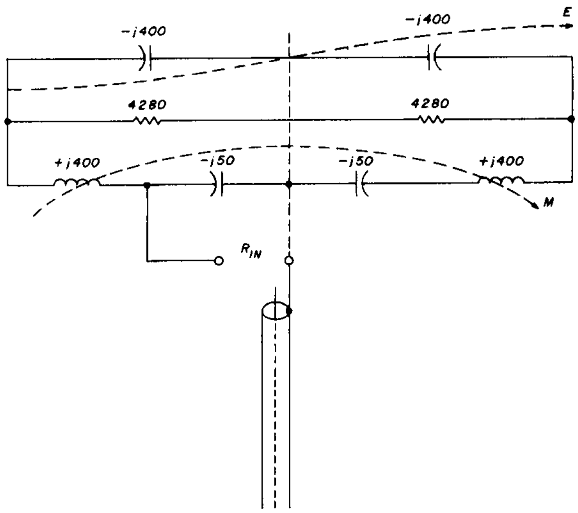

fig. 11. Optimum reactance values in parallel equivalent circuit of dipole.

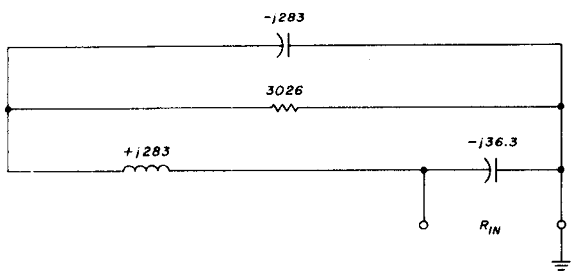

fig. 12. Rearrangement to show all losses transferred to one side of ground point.

as a capacitive autotransformer that works efficiently because of the considerable circulating current **I**. The equivalent inductive autotransformer is shown in **fig. 14**. The input resistance seen by the source is

$$3026 \times \left(\frac{36.3}{283}\right)^2 = 49.7 \text{ ohms}$$

Figure 15 shows a series inductive reactance of almost j50 ohms. This is needed to cancel out the equal

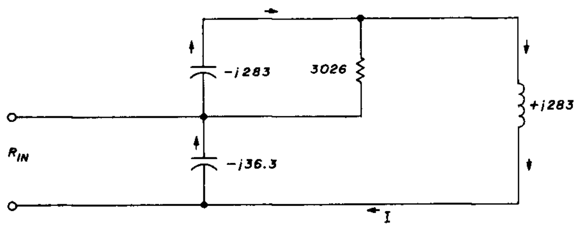

fig. 13. Circuit redrawn to show capacitive autotransformer.

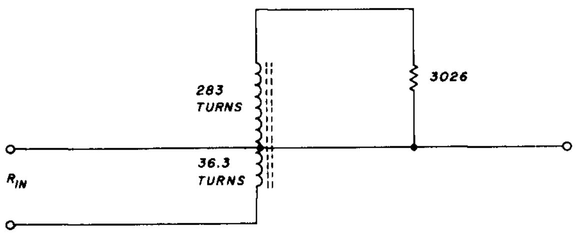

fig. 14. Analogous inductive autotransformer.

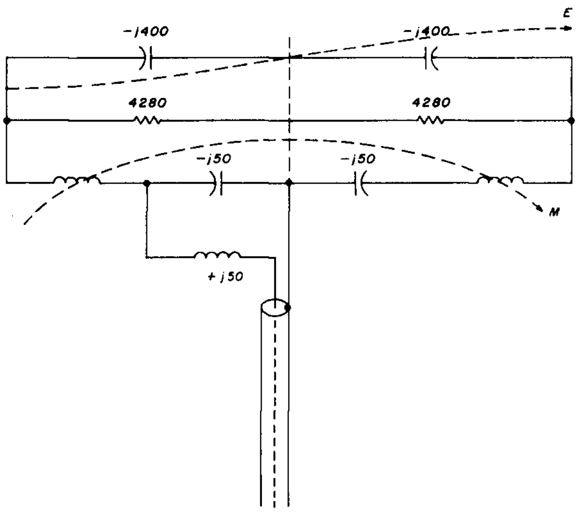

fig. 15. Full equivalent circuit; inductor-corrected capacitive balun monoband antenna.

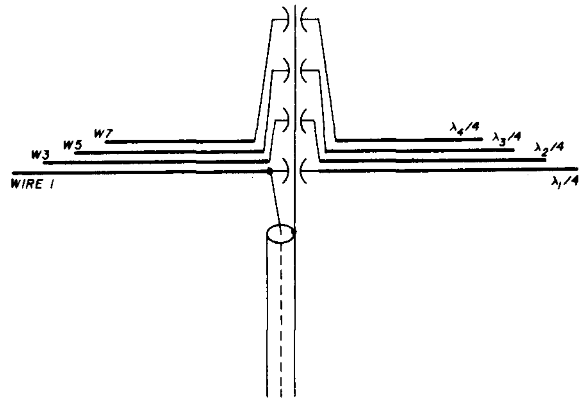

fig. 16. Four-band antenna.

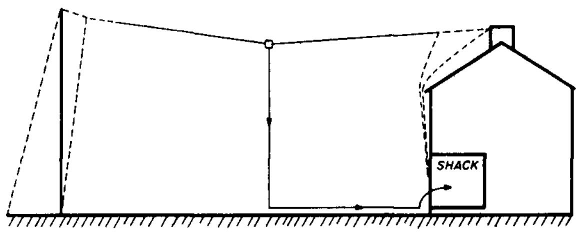

fig. 17. Preferred route of coax feeder.

Table 1. Input impedance is a genuine 50 ohms for a considerable bandwidth.

Frequency (MHz)	VSWR
13.7	1.45
13.8	1.25
13.9	1.14
14.0	1.08
14.1	1.03
14.2	1.02
14.3	1.07
14.4	1.13
14.5	1.22
14.6	1.30
14.7	1.40
14.8	1.50

and opposite capacitive reactance of 50 ohms, leaving a pure resistive termination of approximately 50 ohms. The *Q* of this resonant circuit is 1, and consequently does not affect the overall bandwidth of the system. The antenna bandwidth is determined by the *Q* of the dipole (10.7). As **table 1** shows, the input impedance is a genuine 50 ohms over a considerable bandwidth.

This second solution — i.e., the addition of a second, third, or fourth resonant system with voltage dividing capacitors, as shown in **figs. 10** and **16** — works by inducing current in the resistive components by inductive coupling from left-hand-traveling current in wire 1 to right-hand-traveling current in wire 2 into capacitor 2, and so on. **Table 2** gives the measured SWR values for a four-band antenna for the older hf Amateur bands. The system is not harmonic-dependent however, as can be seen in **table 3**, which lists data for a production version for the WARC Amateur bands.

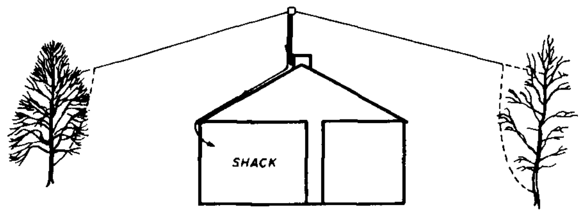

fig. 18. Route of chimney-supported inverted V.

Figure 19 shows the Smith chart display of the input impedance of a four-band Dipole of Delight when fed through approximately 50 feet of transmission line. The dot at the exact center of the chart represents exactly 50 ohms. Notice how closely the curve approaches this point for the 40, 20, 15, and 10-meter Amateur bands. **Figure 20** illustrates the effect with the feeder length canceled out. The equipment used for these experiments was a Hewlett-Packard Network Analyzer Model 8407A sweeping from 1 to 33 MHz.

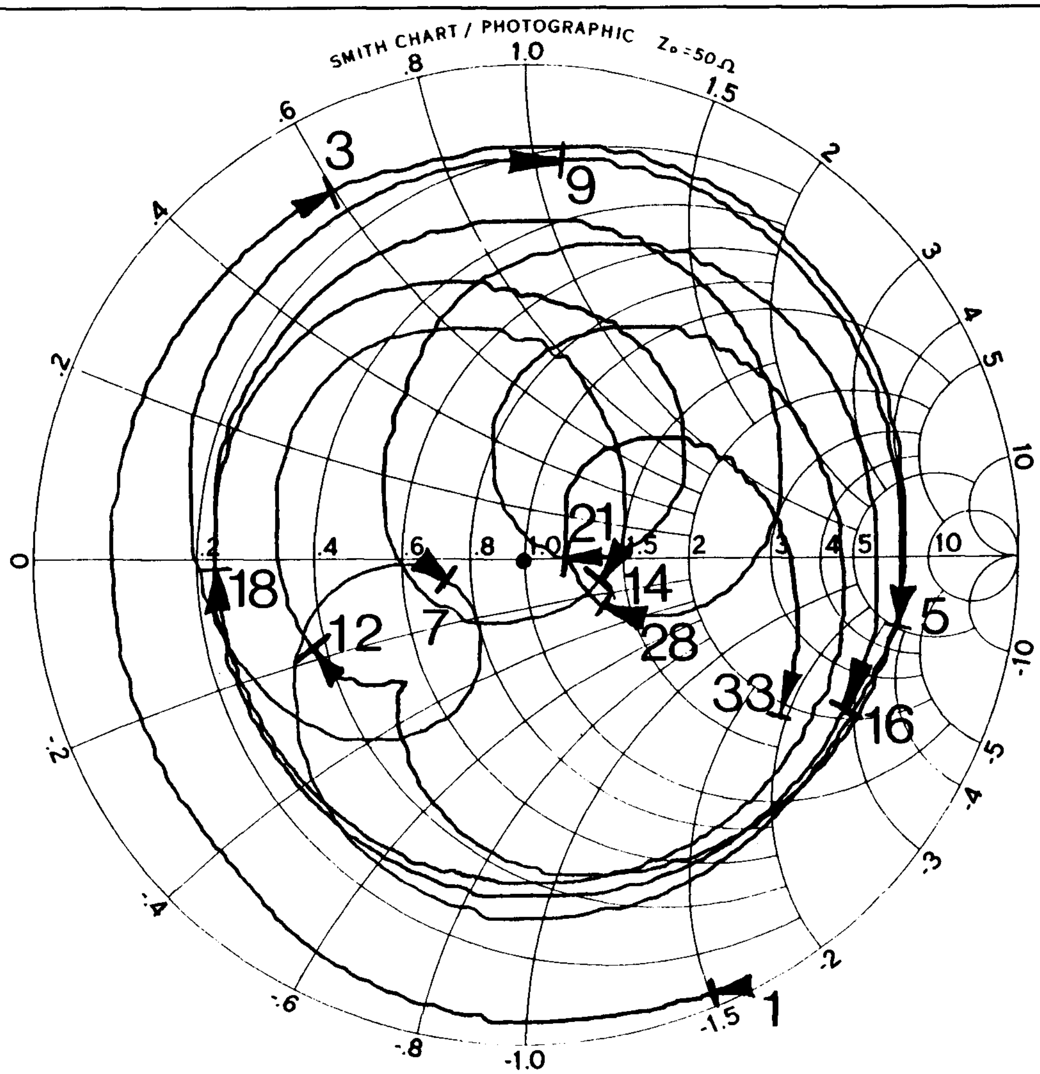

fig. 19. Input impedance of a four-band antenna at height of 8 meters (approx. 27 feet), fed by coax 15 meters (approx. 49 feet) long.

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Table 2. Measured SWR values for a four-band antenna for the older hf Amateur bands.

Frequency (MHz)	VSWR
7.00	1.3
7.05	1.2
7.10	1.3
7.15	1.4
7.20	1.6
14.0	1.32
14.1	1.15
14.2	1.20
14.3	1.30
14.35	1.45
21.0	1.3
21.1	1.15
21.2	1.15
21.3	1.25
21.4	1.37
28.0	1.62
28.2	1.45
28.4	1.22
28.6	1.05
28.8	1.35
29.0	1.55

Table 3. Measured SWR values for a production version for the WARC Amateur bands.

Frequency (MHz)	VSWR
9.9	1.45
10.0	1.3
10.1	1.18
10.2	1.25
18.0	1.25
18.1	1.15
18.2	1.20
18.3	1.32
24.8	1.38
24.9	1.12
25.0	1.08
25.1	1.22

capacitor construction

The capacitors consist of etched double-sided epoxy-glass-fiber circuit board. One side is not etched at all and is connected to the coaxial cable shield. The other side is etched, leaving copper patches (in pairs) of sufficient size to provide the needed capacitance for each wire. The glass fiber acts as the dielectric of the capacitor. In this way a lightweight capacitor balun without too much wind-catching area and usable at a kilowatt PEP level can be made from single-layer pc board. The only reported failures have been thought to be due to lightning flashover across the unconnected right-side wires to the shield. A solution to this problem is presently being investigated. For medium powers — up to 100 watts of rf power output — lumped silver mica capacitors are used. These are easily concealed in a small center connector assembly which presents a negligible wind load. **Photo A** shows the center card and UHF connector and cable hanging from the water-shedding cowl.

ATU not needed

Since the VSWR is so close to 1:1 on 40 through 10, there's no need for an ATU between the transmitter and the antenna. This feature provides the freedom to QSY rapidly in a competitive situation without wasting time retuning. For blind or handicapped operators, it offers considerably simplified operation. For

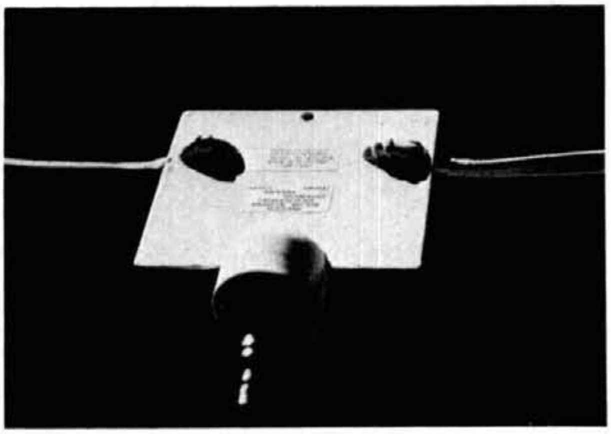

Photo A. Capacitor card of a three-band Dipole of Delight for 14, 21, and 26 MHz.

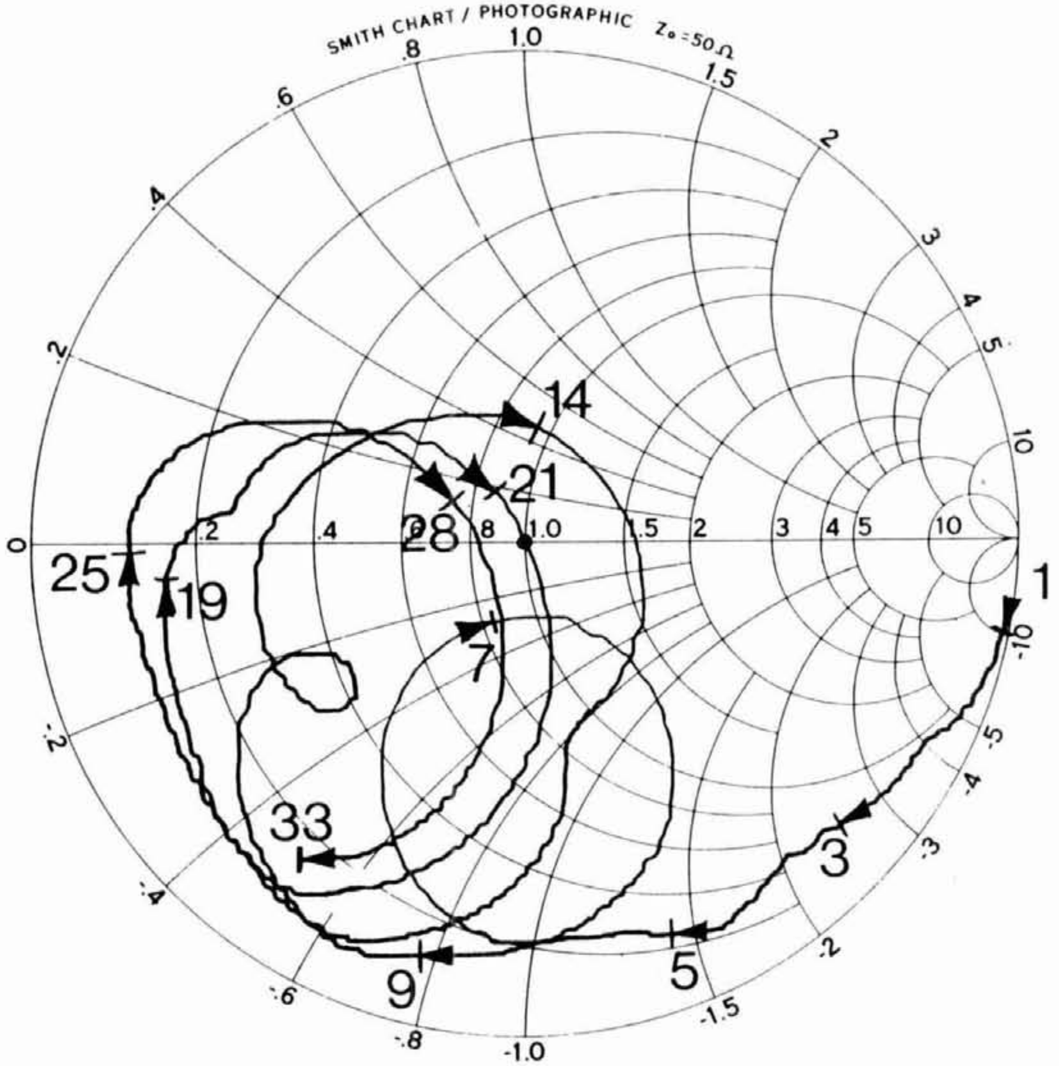

fig. 20. Antenna feedpoint input impedance as shown in fig. 19, but with effect of feeder cable counterbalanced out.

use with a no-tune semiconductor PA or linear, no antenna system could be more appropriate. The VFO is the only control that has to be moved!

Electrically, it's advantageous to have the shield of the coaxial cable at the rf zero potential right down to the shack. It should be emphasized that in order to preserve the balance, the cable should come away from the dipole at right angles until the feeder gets to an object such as the ground beneath the antenna, a tree, or a garage roof, for example, where it may then be turned to run to the shack along the same earth boundary (see **figs. 17** and **18**). This helps reduce VSWR. Observe SWR as shown in **fig. 17**, then pull the feedline to the side and watch the SWR rise from 1.02:1 and go up to 1.3:1. With the thorough balance of the Dipole of Delight it's never necessary to ground the case of the transceiver. There's a complete absence of rf feedback to the microphone and electronic keyer, and never any sign of "hand capacitance."

Because the feedline is at rf zero voltage right to the center balun unit, the Dipole of Delight works well as an inverted V. The support can be metal or any other material and there will be no effect on VSWR or radiation pattern.

helps TVI

Since no current flows down the outside of the feedline, no vertical polarization rf currents are induced into the downleads of nearby TV antennas. One disabled GM operator for whom ham radio is his main daytime activity (he tells me he is on 40 and 80 meters for 8 to 10 hours every day and likes to use his linear all the time) has found that a dual-band Dipole of Delight has not only cured TVI and BCI next door, but has also cured interference to an electronic organ at a church across the street. Now he can operate on Sunday mornings as well! We don't promise purchasers that TVI will be less than they've had with other antennas; in fact, the ground plane versions of these antennas[1,3] are definitely *not* recommended where TVI is a problem, though they are nevertheless useful for low-angle radiation, of course.

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4. J. D. Kraus, W8JK, *Antennas*, McGraw-Hill, 1948. (See Equation 10.59.)
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6. National Research Development Corporation, British Technology Group, 101 Newington Causeway, London SE1 6BU.

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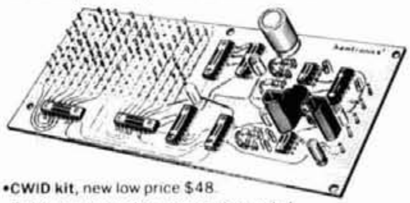

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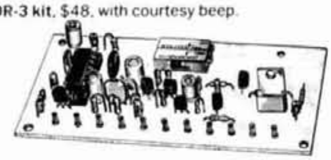

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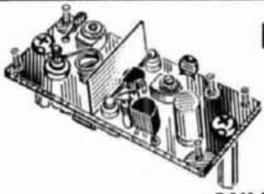

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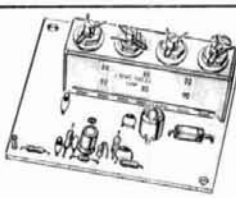

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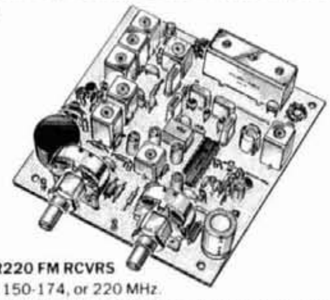

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BY J. FERRELL

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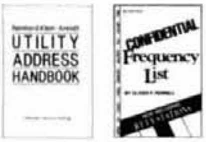

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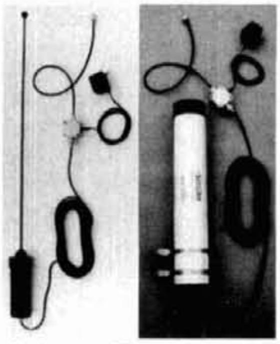

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PRACTICALLY SPEAKING ... Joe Carr K4IPV

grounding, shielding, and isolating: part 2

Last month we discussed the problems of keeping outside interference from adversely affecting our equipment and preventing cross-interference between equipment in the same system.

Grounding problems affect not only single circuits, but collections of equipment as well. In **fig. 1A**, we see a prescription for disaster: the equipment grounds are daisy-chained together and grounded to earth at a point close to only one piece of equipment, identified as *D*. Typically, the ground lines are small-diameter sections of wire not particularly appropriate for the purpose.

One way to correct this problem — the star ground — is illustrated in **fig. 1B**. Ground conductors from all four pieces of equipment are brought together at a common point, which is then grounded. Although it's difficult to achieve the exact configuration shown in **fig. 1B** in an actual Amateur station, we can approximate it using the arrangement shown in **fig. 2**. Keep in mind that our goal is to radiate as much of the available power as possible, while keeping spurious radiations (mostly harmonics) at home. Given the nature of most radio communications situations, if we have to sacrifice a little power at the fundamental operating frequency in order to lower the level of harmonics, then it's to our advantage to do so.

The signal flow logic for an hf station is shown in the inset in **fig. 2**. The output circuit, a low-pass filter and an antenna matching network, surprises

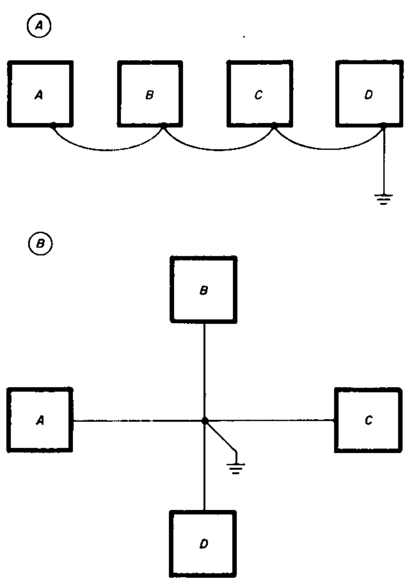

fig. 1. (A) Daisy-chain method of grounding equipment; (B) star grounding.

few Amateurs. The low-pass filter for hf usually has a cutoff frequency above the 10-meter band, but below 6 meters (36 and 42 MHz are often quoted in the advertisements). Above that frequency, attenuation is quite high.

The antenna matcher is seen in many Amateur stations today because solid-state final amplifiers aren't tolerant of high VSWR loads. Such rigs include shut-down circuitry that reduces output power sharply when a VSWR greater than 1:1 is encountered. Previously, many Amateurs didn't use matching networks because tube-type finals used pi networks that could match a wide variety of antenna impedances. Many years ago, former ARRL President Vic Clark (W4KFC) told me that he recommended antenna matching networks even on well-matched antennas because they add another stage of relatively high-*Q* tuned circuitry between the transmitter and the antenna . . . and thus reduce TVI-producing harmonics.

What may come as a surprise to many readers is the low-pass filter at the input of the linear amplifier. Because the exciter/transmitter output signal isn't perfectly clean, and will contain harmonic energy, we should attenuate those signals prior to amplifying them in a 1500-watt amplifier! Use of a low-pass filter helps that situation tremendously.

There is one problem with using a low-pass filter on some solid-state equipment. Many linear amplifiers, especially grounded-grid designs, either don't have a 50-ohm input impedance or have a widely varying input impedance that is frequency dependent. The characteristics of LC low-pass filters are guaranteed only when the correct load impedance is presented to the filter (in our case normally 50 ohms, resistive). If the linear amplifier input impedance varies, then filter performance is adversely affected. In addition, the impedance reflected to the filter input will also vary. This

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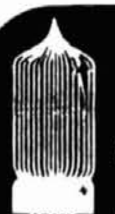

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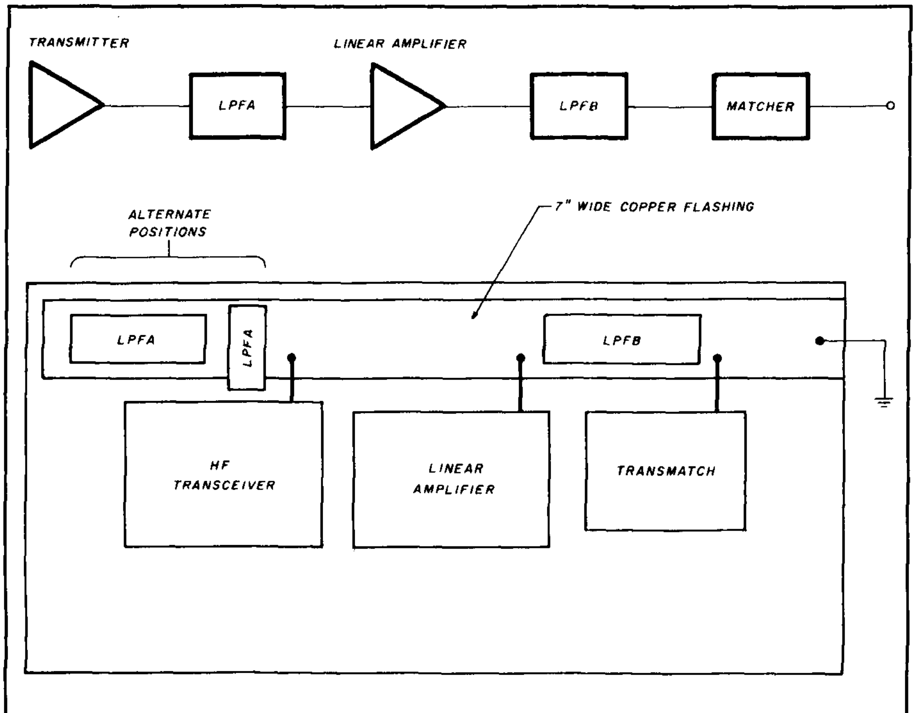

fig. 2. Grounding scheme at my previous QTH.

difficulty will cause a high VSWR to be seen at the transmitter output, causing it to fold back.

I experienced this problem using a Drake low-pass filter between a Kenwood TS-120 transmitter and a Heath SB-220 linear amplifier. There are two possible solutions. First, we can place a 50-ohm attenuator pad between the filter output and the linear amplifier input. The pad swamps out the impedance variations, although at the loss of some power. The attenuator pad method is recommended only where suitable resistors are available, and there's plenty of power to drive the linear and accommodate a 1- to 3-dB power loss. Second, we can either replace the low-pass filter with a variable matching network or add an antenna matcher to the circuit between the filter and amplifier. When I owned the TS-120, my solution was to use a Drake MN-4 matcher in place of LPF A (see **fig. 2**).

Note the configuration of the operating position in **fig. 2**. The equipment was mounted on a door converted into a table. The grounding system consisted of a piece of 7-inch wide copper roofing flashing along the back of the table. Though you probably won't find copper flashing at your local hardware store, it should be available from metal distributors and professional roofing supply outlets. (I found mine at a metal distributor after asking a neighbor, a contractor, where he bought his copper roofing supplies.)

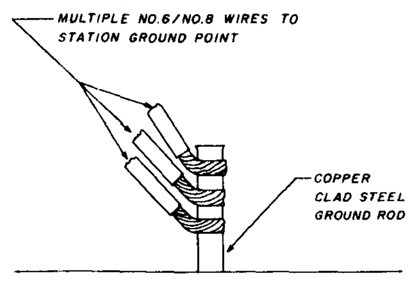

fig. 3. Multiple-wire grounding lowers inductance.

Although the cost per foot (or per pound, as some sell it) for the amount that you need will probably be relatively low, the distributor may want a $50 to $100 minimum purchase. Joining with other Amateurs in a group order, therefore, might be wise. Copper flashing, or similar copper stock, is sometimes available through artists' supply outlets in areas where copper bas relief engraving and smithing is popular. The stock he showed me was only about half as thick as roofing flashing, but should work just as well.

The copper flashing on my desk is grounded at one end with a ground rod. In the station where I used this system, the building was a well-constructed (i.e., heated and air-conditioned) shed in the backyard. I was able to drop the copper foil through a break between the wall and the floor, then sweat-solder it directly to a ground rod driven into the earth. In other cases, it's necessary to use a heavy ground wire between the desk and the ground rod.

ground wires

A ground wire must be short and nonresonant, and possess low inductance. As a result, it's usually best to use a piece of heavy flat braid rather than circular wire. You'll find braid for sale at some outlets, but it's often quite expensive. I've found it cheaper to strip the shield carefully from an appropriate length of RG-8 or RG-11 coaxial cable.

Low inductance is achieved by using a wide, short conductor. The braid mentioned above possesses this property. It's also possible to cut some of the copper flashing into slices thinner than 7 inches and use it for a ground conductor. In other cases, it's possible to approximate the ideal by using ordinary circular wire conductors, but be sure to use multiple lengths of conductor in parallel (**fig. 3**). Automotive parts stores are often the best sources for such wire stock. Use either No. 6 or No. 8 "primary wire" or copper battery cable wire.

The conductors can be either clamped to the ground pipe (or rod) or sweat-soldered. Because of the heat sinking capacity of the pipe and ground, it's usually necessary to use a torch for sweat-soldering. Either a propane torch, one of the home "brazing" torches sold in hardware stores, or a jeweler's torch will suffice for this job. Choose your solder carefully, however. Some of the solder used for this purpose, and sold in local hardware stores, is acid-core. Also, some solders don't have the right metals mix. You want either resin core or coreless solder with resin flux, lead/tin solder of 50/50 or 60/40 mix.

Finally, make sure that the ground wire isn't resonant on either the fundamental frequency or one of the low order harmonics (e.g., second and third). Try to avoid even 1/8 or 1/4 wavelengths, even though this requirement may be difficult to achieve in practice on 80- to 10-meter antennas.

ground rods

The goal in a station ground system is to reduce the resistance between the radio and the earth. In most cases, this requirement translates to surface area in contact with the ground — and our job is to maximize that area. Several different options are available to us regarding ground rods.

First, we could do what a friend of mine did 20 years ago: he found an old copper bathtub in his grandfather's garage and buried it in an 8-foot deep hole. Considering the amount of work involved in burying a bathtub 8 feet underground, I'd prefer to sell the bathtub either for its metal content or its antique value . . . and use the proceeds to buy a truckload of proper ground rods!

Second, we could build a ground matrix grid on our property. When I was in high school, a local Amateur built a new home nearby. He arranged for several "custom extras" to the house. First, a concrete pedestal for the 60-foot tower was installed. Around the base of the tower was a series of eight or ten 8-foot copperclad steel ground rods. He then constructed a grid of No. 12 solid copper wire (bare) over the entire 150 x 175-foot lot. At each crossover point on the grid the conductors were soldered together. He also added several more ground rods at nodes around the lot. The grid was clamped and soldered to the tower grounding system, then attached to a rather massive 3-inch copper pipe coming through the wall of the house from the intended operating position. After this extensive ground system was installed, sod was brought in by the builder, who was clearly bewildered by the seemingly odd behavior of his eccentric client.

Third, we can use copperclad steel ground rod, available in several lengths from electrical supply outlets. Although this type is preferred for Amateur applications, surprisingly few Amateur outlets sell these rods in the proper lengths. The non-copperclad type, though less useful for Amateur applications, is also available.

Copperclad steel rods are normally sold in 4-, 6-, and 8-foot lengths. Ten-foot lengths, used by some power companies, are also occasionally available. Of these, the 8-foot length is probably the best, and may be the only one legal in your area. (Your local electrical inspector may have an enforceable opinion regarding your choice of ground rod. In many jurisdictions, electrical codes specify the 6- or 8-foot minimum length for towers and sometimes even Amateur stations.)

The 4-foot types, typically used by TV antenna installers, are the most common. But because they're less effective for both radio grounding and lightning protection, they should be avoided — except, perhaps, where multiple rods are used.

Another alternative is shown in **fig. 4**. This ground system, which uses a copper plumbing pipe, is especially useful for areas with hard clay-rich soil. The top end of the pipe is fitted with a "Tee" connector and short pipe sections to be used as a handle. One end of the handle is closed off with an end cap, while the other is fitted with a spigot nipple of the sort used to connect a garden hose. The bottom end of the 1-inch x 8-foot pipe is beveled to a point with a hacksaw. Drive the pointed end into the ground and apply water pressure. Although a bit messy, this method will allow you to work the pipe down into the soil with relative ease.

When you finish driving the copper pipe into the ground you will discover

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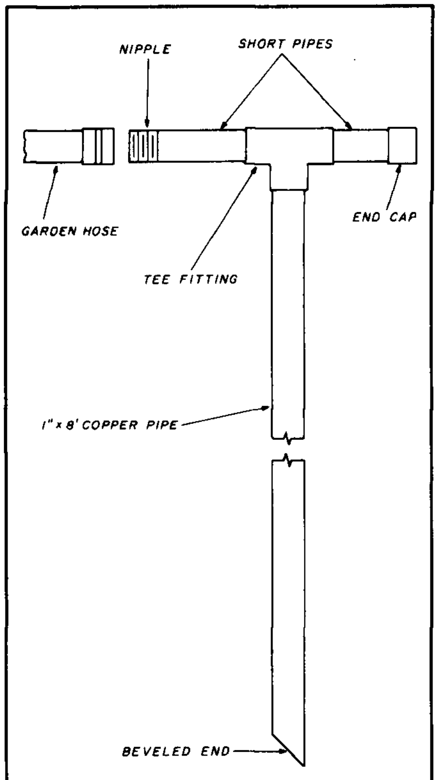

fig. 4. Pipe ground uses water pressure to simplify installation in hard soil.

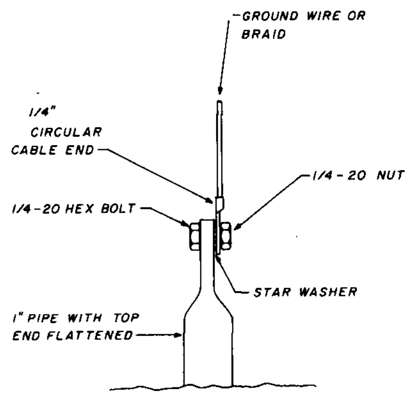

fig. 5. Adding connections to pipe ground.

one of the advantages of this system. With conventional ground rods you must either sweat-solder the ground wire (which is sometimes difficult), or use a clamp (which easily comes loose). The pipe end can be flattened with a heavy pair of pliers, hammer (with a 2 x 4 backstop used as an "anvil"), or other means. You can then drill one or more 1/4-inch holes in the flattened end to accept a nut and bolt to hold the ground wire (see **fig. 5**).

A word of caution is needed for those who are going to drive ground lines into the earth. Find out where the gas, water, sewer, and power lines are on your property. Although you can usually make intelligent guesses, some configurations are hard to determine. For example, at my old QTH, the gas line ran in a dog-leg path from the shutoff valve on the street to the meter on the back of the house. Unless you knew that the gas company was trying to serve two dwellings with the least amount of pipe, you wouldn't easily guess its path. Information on utility service run locations is often recorded on your survey plate, or in the local building inspector or engineer's office, or can be obtained from the utility involved. An 8-foot ground rod can disrupt these utilities — and that's always expensive and sometimes dangerous.

a warning on some defibrillator capacitors

In an earlier column I mentioned using medical defibrillator capacitors in high-power, high-voltage dc power supply filters. While that advice is still valid, a reader pointed out one possible pitfall. Some manufacturers of these machines depend upon the fact that defibrillator capacitors are charged for only a few minutes to de-rate some capacitors. As a result, in 7000-volt circuits they use capacitors with as little as 2000-WVDC dielectric strength. The small size of these capacitors enhances the portability of the product.

The capacitors to which I referred are high quality units manufactured by well-respected companies such as CDE and Sangamo; marked for 7500-WVDC or 10,000-WVDC, they're oil-filled and quite large. My reference capacitors came from American Optical and Hewlett-Packard (Model 7802) machines. No one has miniaturized those high-voltage capacitors significantly, so if a surplus defibrillator capacitor seems too small to be a 7 kV unit, then it probably isn't what it seems to be.

ham radio

gamma matching programs for the C-64/128

Simplify antenna matching with WB0IKN's handy program

WB0IKN's article, "Basic Gamma Matching"[1] provided a useful program for the Apple II+ computer. Because I needed gamma matching data for a homebrew project but have a C-64, I decided to convert the program. (If you own a Commodore 128, simply set the computer to 64 mode and you're ready to calculate.)

Figure 1 lists the revised program. The most significant modifications appear in the calculation lines. These changes were made to avoid exceeding the C-64's maximum input of 80 characters per statement.

I renumbered and compacted the program, adding an Option Menu from which you may choose to print hard copy, start new calculations, or end the program.

The final results were also truncated to two decimals; for practical purposes, this number of significant digits should be sufficient. The last three inputs of **line 10** change the screen/border/letter colors. If you prefer the standard blue, omit all POKE statements and colons in **line 10**.

design examples and program notes

To demonstrate the conversion program, and to allow you to check operation as well as the correctness of your data entry, I've used WB0IKN's design examples. I suggest you read his article; for convenience — or in case you don't have a copy of the January, 1985, issue — I've summarized details below.

The hardest part will be determining the driven element impedance. Fortunately, the feedpoint characteristics of most common antennas are sufficiently documented to provide good data. Use your impedance meter or noise bridge, if no published data are available. You must know the diameter of your driven element and gamma rod. Then select an arbitrary gamma rod spacing. Use common sense, as in any homebrew project.

Load and run the program. Input the requested data when prompted. The computer will then calculate and display the results in the format shown in **figs. 3** and **4**.

If the values aren't acceptable, select Menu Option 2 ("all new calculations"). By trying a different gamma rod spacing or diameter, or varying the feedpoint impedance by slightly changing the length of the driven element, you can find the best combination with reasonable mechanical and electrical parameters. If the antenna isn't suitable for gamma rod matching, you'll learn this quickly, without tedious experimentation.

Figure 2 shows the screen display on a run for a computer-generated six-element, 20-meter Yagi design by Lawson.[2] The calculated feedpoint impedance of the antenna is 20 + j7.5 ohms. In this example, the assumptions are a 1.5-inch diameter element, a gamma rod diameter of 0.25 inch, and a gamma rod spacing of 3 inches.

additional designs

The results of two additional gamma match designs for the Yagi antenna are shown in **fig. 3**. In **fig. 3(A)** the gamma rod spacing has been increased to 6 inches; in **fig. 3(B)** the gamma rod diameter has been increased to 0.5 inch.

Figure 4 shows the results for a monopole approximately 1/4 wavelength high. In this case the

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```
10 PRINTCHR$(19)CHR$(147):POKE53280,9:POKE53281,0:POKE646,5
20 REM***********************************
30 PRINT "GAMMA MATCH DESIGN"
40 PRINT "BY RICHARD A. NELSON - WB0IKN"
50 PRINT"FOR APPLE II+ COMPUTER"
60 REM*******************************************
70 PRINT:PRINT"ADAPTED & CUSTOMIZED FOR C64 WITH"
80 PRINT"OPTIONS FOR PRINT/NEW CALCS.& END"
90 PRINT"BY - FRED A.SONTAG,P.E. - N0CAO
100 REM*******************************************
110 PRINT"* VERSION 1.3 *":PRINT
120 DEF FN CSH(X)=LOG(X+SQR(X*X-1))
130 PRINT"ENTER <M> FOR MONOPOLE":OPEN1,0
140 PRINT"ENTER <D> FOR DIPOLE > ";:INPUT#1,DM$:PRINT
150 IF DM$="D" OR DM$="M" THEN GOTO170
160 GOTO130
170 PRINT "ENTER FREQ IN MHZ > ";:INPUT#1,F:PRINT
180 PRINT"ENTER FEEDPOINT RESISTANCE > ";:INPUT#1,RA:PRINT:IFDM$="D"THENRA=RA/2
190 PRINT"ENTER FEEDPOINT REACTANCE > ";:INPUT#1,XA:PRINT:IFDM$="D"THENXA=XA/2
200 PRINT "ENTER FEEDLINE RESISTANCE > ";:INPUT#1,RO:PRINT
210 PRINT:PRINT:PRINT"** THE FOLLOWING ARE IN INCHES **"
220 PRINT:PRINT"ENTER DRIVEN ELEMENT DIAMETER > ";:INPUT#1,K:PRINT
230 PRINT "ENTER GAMMA ROD DIAMETER > ";:INPUT#1,B:PRINT
240 PRINT "ENTER GAMMA ROD SPACING > ";:INPUT#1,S:PRINT:CLOSE1
250 H=(1+((FNCSH((4*S*S-K*K+B*B)/(4*S*B)))/(FNCSH((4*S*S+K*K-B*B)/(4*S*K)))))↑2
260 ZO=60*FN CSH((4*S*S-K*K-B*B)/(2*K*B)):T=H/ZO:A=((RO*XA)/(H*RA-RO))
270 W=(RO*((RA)↑2+(XA)↑2))/(H*RA-RO):Q=A+SQR(A*A+W)
280 XS=H*((RO*XA+SQR((RO*XA)↑2+RO*(H*RA-RO)*((RA)↑2+(XA)↑2)))/(H*RA-RO))
290 LDGA=ATN(Q*T):LDG=(LDGA*360)/(2*3.14159)
300 E=(RO/RA)*(((RA)↑2+(XA)↑2)/Q):G=(RO/RA)*XA
310 CR=1000000/(2*3.14159*(E+G)*F):PRINTCHR$(147)
320 IF DM$="D" THEN RA=RA*2:IF DM$="D" THENXA=XA*2:PRINT
330 IFDM$="D" THENPRINT"DIPOLE ANTENNA"
340 IFDM$="M" THENPRINT"MONOPOLE ANTENNA"
350 PRINT:PRINT"FREQUENCY <MHZ> = ";F
360 PRINT"DRIVEN ELEMENT DIAM = ";K:PRINT"GAMMA ROD DIAM = ";B
370 PRINT"GAMMA ROD SPACING = ";S:PRINT"DRIVEN ELEMENT RESISTANCE = ";RA
380 PRINT"DRIVEN ELEMENT REACTANCE = ";XA:PRINT"FEEDLINE RESISTANCE = ";RO
390 PRINT:N=LDG:GOSUB550
400 PRINT"GAMMA LENGTH <DEGREES> = ";U$:FT=(948/F)*(LDG/360):N=FT:GOSUB550
410 PRINT "GAMMA LENGTH <FEET> = ";U$:IN=FT*12:N=IN:GOSUB550
420 PRINT "GAMMA LENGTH <IN> = ";U$:CM=IN*2.54:N=CM:GOSUB550
430 PRINT"GAMMA LENGTH <CM> = ";U$:N=CR:GOSUB550
440 PRINT"GAMMA CAP IN PF = ";U$
450 PRINT:PRINTTAB(13)CHR$(18)"OPTION MENU"CHR$(146):PRINT
460 PRINT"1. HARDCOPY"
470 PRINT"2. ALL NEW CALCULATIONS"
480 PRINT"3. END"
490 OPEN1,0:PRINT"PRESS OPTION NO.- THEN PRESS RETURN ";:INPUT#1,X:PRINT
500 IFX=1THENCLOSE1,0:GOTO530
510 IFX=2THENCLOSE1,0:GOTO10
520 IFX=3THENCLOSE1,0:PRINTCHR$(147):END
530 OPEN3,3:OPEN4,4:PRINTCHR$(19);:FORI=0TO679:GOTO540
540 GET#3,A$:PRINT#4,A$;:NEXT:CLOSE3:CLOSE4:PRINTCHR$(147):GOTO470
550 U$=STR$(N):L=LEN(U$):PD=0:FOR I = 1 TO L:IF MID$(U$,I,1)="."THEN PD=I
560 NEXT I:IF L <= (PD+2)THENRETURN
570 R$=MID$(U$,(PD+3),1):U$=LEFT$(U$,(PD+2)):IF R$<"5"THENRETURN
580 U=ABS(VAL(U$))+.01:U$=STR$(U*SGN(N)):RETURN

READY.
```

fig. 1. Gamma matching program listing for the C-64/128.

```
GAMMA MATCH DESIGN
BY RICHARD A. NELSON - WB0IKN
FOR APPLE II+ COMPUTER

ADAPTED & CUSTOMIZED FOR C64 WITH
OPTIONS FOR PRINT/NEW CALCS.& END
BY - FRED A.SONTAG,P.E. - N0CAO
* VERSION 1.3 *

ENTER <M> FOR MONOPOLE
ENTER <D> FOR DIPOLE > D
ENTER FREQ IN MHZ > 14.200
ENTER FEEDPOINT RESISTANCE > 20.0
ENTER FEEDPOINT REACTANCE > +7.5
ENTER FEEDLINE RESISTANCE > 50


** THE FOLLOWING ARE IN INCHES **

ENTER DRIVEN ELEMENT DIAMETER > 1.5
ENTER GAMMA ROD DIAMETER > .25
ENTER GAMMA ROD SPACING > 3.0



DIPOLE ANTENNA

FREQUENCY <MHZ> =  14.2
DRIVEN ELEMENT DIAM =  1.5
GAMMA ROD DIAM =  .25
GAMMA ROD SPACING =  3
DRIVEN ELEMENT RESISTANCE =  20
DRIVEN ELEMENT REACTANCE =  7.5
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  28.8
GAMMA LENGTH <FEET> =  5.34
GAMMA LENGTH <IN> =  64.09
GAMMA LENGTH <CM> =  162.78
GAMMA CAP IN PF =  188.92

            OPTION MENU

1. HARDCOPY
2. ALL NEW CALCULATIONS
3. END
PRESS OPTION NO.- THEN PRESS RETURN
```

fig. 2. Screen display for a sample run showing the sequence of data entry and output. (See text for 20-meter Yagi description.)

gamma rod is a length of No. 10 wire (approximate diameter = 0.1 inch). **Figure 4(A)** is for a 60-foot tower used as a vertical radiator on 3.8 MHz. (WB0IKN's computer analysis shows its impedance to be approximately 33 + j1.3 ohms. **Figure 4(B)** is for a 55-foot tower operated on the same frequency. The results show how a smaller gamma capacitor may be used if the radiator is made capacitively reactive by reducing its overall height.

```
DIPOLE ANTENNA

FREQUENCY <MHZ> =  14.2
DRIVEN ELEMENT DIAM =  1.5
GAMMA ROD DIAM =  .25
GAMMA ROD SPACING =  6
DRIVEN ELEMENT RESISTANCE =  20
DRIVEN ELEMENT REACTANCE =  7.5
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  25.32
GAMMA LENGTH <FEET> =  4.7
GAMMA LENGTH <IN> =  56.34
GAMMA LENGTH <CM> =  143.12
GAMMA CAP IN PF =  241.89
```

fig. 3A. Calculated results for additional run on the antenna described in fig. 2, showing gamma rod spacing increased to 6 inches.

```
DIPOLE ANTENNA

FREQUENCY <MHZ> =  14.2
DRIVEN ELEMENT DIAM =  1.5
GAMMA ROD DIAM =  .5
GAMMA ROD SPACING =  3
DRIVEN ELEMENT RESISTANCE =  20
DRIVEN ELEMENT REACTANCE =  7.5
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  38.34
GAMMA LENGTH <FEET> =  7.11
GAMMA LENGTH <IN> =  85.32
GAMMA LENGTH <CM> =  216.72
GAMMA CAP IN PF =  262.10
```

fig. 3B. Calculated results for additional run on the antenna described in fig. 2, showing gamma rod diameter increased to 0.5 inch.

```
MONOPOLE ANTENNA

FREQUENCY <MHZ> =  3.8
DRIVEN ELEMENT DIAM =  12
GAMMA ROD DIAM =  .1
GAMMA ROD SPACING =  12
DRIVEN ELEMENT RESISTANCE =  33
DRIVEN ELEMENT REACTANCE =  1.3
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  44.82
GAMMA LENGTH <FEET> =  31.06
GAMMA LENGTH <IN> =  372.69
GAMMA LENGTH <CM> =  946.64
GAMMA CAP IN PF =  122.62
```

fig. 4A. Results of run for a 75-meter vertical monopole antenna on 3.8 MHz, (60-foot tower).

```
MONOPOLE ANTENNA

FREQUENCY <MHZ> =  3.8
DRIVEN ELEMENT DIAM =  12
GAMMA ROD DIAM =  .1
GAMMA ROD SPACING =  12
DRIVEN ELEMENT RESISTANCE =  25
DRIVEN ELEMENT REACTANCE = -38
FEEDLINE RESISTANCE =  50

GAMMA LENGTH <DEGREES> =  53.73
GAMMA LENGTH <FEET> =  37.24
GAMMA LENGTH <IN> =  446.82
GAMMA LENGTH <CM> =  1134.92
GAMMA CAP IN PF =  76.99
```

fig. 4B. Results of run for 75-meter vertical on 3.8 MHz, (55-foot tower).

As stated previously, I strongly recommend that you read WB0IKN's article and also the publications dealing with gamma matching design and construction referenced therein.

references

1. Richard A. Nelson, WB0IKN, "Basic Gamma Matching," *ham radio*, January, 1985, page 29.
2. James L. Lawson, W2PV, "Yagi Antenna Design", *ham radio*, July, 1980, page 19.

ham radio

VHF/UHF WORLD

Joe Reisert W1JR

optimized 2- and 6-meter yagis

Several years ago I decided to take a different approach to 2-meter EME. The idea was to build an array of eight small Yagis mounted on a short tower. The stacking frame would be attached to a single boom not exceeding 30 feet. Such a system could be mounted conveniently in my back yard with minimum interference to existing structures and would be easily transportable for EME DXpeditions.

It seemed reasonable that a physically small Yagi with a clean radiation pattern and high gain-per-unit boomlength could be designed.[1] Small Yagis require only short, low-loss phasing lines. If this approach was successful on 2 meters, I concluded, the design could later be scaled to 70 cm (432 MHz), where the individual Yagis could be rear-mounted and possibly rotated in polarity for EME operation.[2]

I decided that a 12-foot boom, 144-MHz Yagi might be the ideal answer for the individual antenna; 12-foot boom material is readily available, and short Yagis can be mounted on towers that are only 12 to 15 feet high.

Several designs emerged for both 2 and 6 meters. While some of the results of this study were unexpected, they do answer several frequently asked questions.

where to begin

I started by designing a 2-meter Yagi on a 12-foot boom. Obviously, the boomlength could not exceed 142 inches — which, at 144 MHz, is approximately 1.75 wavelengths. I wanted the sidelobes to be as low as possible, at least 16 to 18 dB in the E plane, and a minimum of 13 dB in the H plane. If improved performance was possible, so much the better.

I studied but quickly discarded the NBS Yagis because the only designs near my requirements, 1.2 or 2.2 wavelengths, were either too short or too long.[3] Then I considered the Greenblum designs.[4] Unfortunately, design information was incomplete; furthermore, previous Yagi designs using the Greenblum tables didn't produce very clean radiation patterns, especially in the H or vertical plane.

Several articles in the *IEEE Proceedings* discussed a method of optimizing Yagi performance through the use of nonequally spaced and nonuniform length elements.[5,6] They started with an initial six-element design using equal spacing and director lengths. The elements were 0.0067 wavelengths in diameter on a 1.49 wavelength boom. The reflector was 0.51 wavelengths long and spaced 0.25 wavelength behind the driven. All directors were equally spaced at 0.31 wavelength and were 0.43 wavelengths long.

They ran a program similar to that used by Morris[7] — the forerunner of the one used by W2PV[8] — on a large IBM computer. It calculated the gain of this antenna at 11.2 dBi, with relatively high first sidelobes.

Maintaining the same reflector length and spacing, believed to be near optimum, the director spacings were mathematically iterated (adjusted in small steps) for maximum gain. This step increased the Yagi gain by 1.65 dB to 12.85 dBi. However, the boomlength had increased to 1.70 wavelengths, and all director spacings were now unequal. The pattern was definitely cleaner, but not terrific. The next step involved adjusting the reflector length and spacing, but very little improvement resulted.

A further improvement in the computer program through the use of larger matrices allowed for the simultaneous iteration of element spacing *and* length. The results were quite gratifying. After several optimizations, a new Yagi design with approximately the same boomlength (1.69 wavelengths with a gain of over 13.4 dBi) emerged, showing *an improvement of 2.2 dB* over the original constant length and spacing design and a cleaner radiation pattern.

Some preliminary conclusions can be drawn as a result of this study. With a fixed number of elements, there is a particular boomlength for optimum gain. Furthermore, gain and pattern aren't optimum when constant director length and spacing are used. For best Yagi performance, the boomlength and all element spacings and lengths must be individually optimized.

implementing the design

Limited practical information was, however, available for the "optimized" Yagi design. No element diameter scaling information was available to me at that time (in the mid-1970s) and the diameters recommended were rather impractical — over 0.5 inch at 2 meters! *Therefore I decided to scale my own design by overlaying the element lengths on an NBS-type of scaling graph.*[3] I designed a 144-MHz Yagi using 3/16-inch diameter rod (0.0023 wavelength diameter at 144 MHz).

I built this antenna and tested it on a commercial antenna range. The gain was as predicted. However, the bandwidth for maximum gain was very nar-

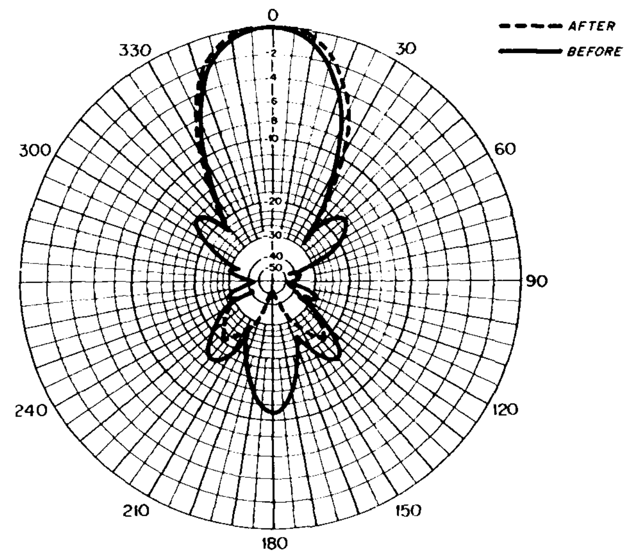

fig. 1. E plane radiation pattern of the original (solid lines) and modified (dotted lines) Yagi. Modifications involved lengthening the reflector and significantly shortening the last director.

row, only about 1.0 MHz at the −1 dB points, and gain peaked near 146 MHz. Back to the drawing board!

Based on the data taken on the antenna range, I was able to correct my scaling graph. I then scaled the design to 50.1 MHz. It worked like a champ. The lengths and spacings chosen are shown in the first and second columns of **table 1**. A typical antenna radiation pattern is shown in **fig. 1**.

Upon close inspection of the radiation pattern, however, the f/b ratio wasn't worth writing home about. Dave Olean, K1WHS, figured that he could trade gain, if necessary, for a better f/b ratio. He left the element spacings constant, but shortened the last director by almost 10 inches; by lengthening the reflector a few inches, he was able to obtain a nearly infinite f/b ratio, though over only a very narrow bandwidth. The cost was about 1 dB in forward gain. The pattern of the modified Yagi is superimposed on the original design in **fig. 1**. The final element lengths chosen are shown in column 3 of **table 1**.

A close inspection of the patterns illustrated in **fig. 1** shows that the sidelobes aren't as good as my original design goals. Also, the improved f/b design had lower gain than desired. With the help of John Kenny, W1RR, a computer optimization was conducted on a similar six-element Yagi design scaled to 2 meters.* The results were similar to those reported in references 5 and 6. Either maximum gain or reasonable f/b ratio *could* be achieved, *but not simultaneously!*

I decided to make another search and again reviewed the Greenblum designs.[4] Using his designs, I found that eight elements were required for a 1.75-wavelength boom. I quickly calculated a 144-MHz design and W1RR computed the radiation pattern with his program. The gain was right on the money, but as previously speculated, the radiation pattern had very high sidelobes.

Next John ran an optimization routine on my new eight-element design. The input design parameters were maximum gain with all side and rear lobes at least 18 to 20 dB down in the E plane, with the overall boomlength fixed at 1.734 wavelengths (142 inches at 144 MHz).

After many computer iterations, a new design emerged. The pattern looked too good to be true. The gain penalty for a clean radiation pattern was only a few tenths of a dB, not a big compromise for over 13 dBi gain! The bandwidth of the design was also very good — several MHz at the −1 dB points.

I hurriedly ran out and built the optimized design using leftover materials from Cushcraft 2-meter beams. Cushcraft uses above-the-boom element mounting, which requires a 0.312-inch element extension when mounted on a 1.0-inch diameter boom. A T match with a 4:1 half-wave balun completed the design. Construction details on the final design are shown in **fig. 2**.

Soon afterwards, the improved design was measured on a commercial antenna test range and was found to be satisfactory. A typical radiation pattern is shown in **fig. 3**. All side and rear lobes were about 20 dB down, and the gain was only 0.75 dB less than the NBS 2.2-wavelength design that used a trigonal reflector. Not bad for a design with a lot less hardware, six fewer elements and a 36-inch shorter boom!

Seven more copies were built along with the necessary phasing lines. They were assembled into a "quick and dirty" 2-meter EME array consisting of a 30-foot irrigation tube for the main boom, four 12-foot vertical masts, and a 12-foot portable tower. The spacing was 8-1/2 feet horizontally and 8 feet vertically. The VSWR of the entire array was fine. A photo of the completed array is shown in **fig. 4**.

The rest is history. On October 17, 1981 — even before making a single QSO — we broke it down and immediately set off for Rhode Island, where we fired it up for the first time on EME. In two nights of activity, we worked 25 stations in 16 states off the moon. Several stations completed a 2-meter WAS; only two stations scheduled were missed, but they turned out to be no-shows. Not bad performance for a small transportable array with only 64 elements!

*Yagi analysis programs for computing gain and patterns of specific Yagi designs are readily available.[8-11] However, the programs used to *optimize* Yagi designs are much more complex and not available for distribution. They're experimental, use proprietary software, and usually require a large mainframe computer. Therefore, I'd urge you *not* to contact persons doing such work until their programs are suitable for distribution.

insulated element mounting

Since the original Yagi was constructed, insulated through-the-boom element mounting has become quite popular.[9] Fortunately, the same dimensions as those shown in **fig. 2** can be used, since the correction factor for through-the-boom with insulated elements is about the same as the one used in the original design. Just maintain a 1.0-inch diameter boom and 3/16-inch element diameters with insulators and keepers as described in reference 9. However, the driven element length and/or the lengths and spacings of the T match will probably have to be optimized if low (1.2:1 maximum) VSWR is to be maintained.

I've used the eight-Yagi, 2-meter array on EME for several years. WAC was accomplished with less than 600 watts of output in the shack. Several European stations are using this Yagi on tropo and meteor scatter. Several local Amateurs and I have also used it to put rare grids on the air, since it's so compact and uncluttered.

This Yagi design is highly recommended where a small, simple, high-gain antenna with excellent sidelobe suppression is preferred. It's easily duplicated and can be used singly or as part of an array. Despite its size, four of these Yagis stacked 8-1/2 feet horizontally and 8 feet vertically make a good beginner's 2-meter EME array. Eight are better for the more serious EMEer, yet still affordable.

A secondary benefit of this 2-meter array hasn't previously been discussed, but may be worth mentioning. Because of space limitations, I can't fit both a 2-meter and a 135-cm (220 MHz) EME array in my back yard at the same time. But fortunately, if you use the 4.2-wavelength NBS Yagi designs on 135 cm, the mechanical spacings used on 2 meters just happen to be the same as the optimum mechanical spacing for 135 cm.[3] In my case, when I change bands I just swap out the Yagis, reconnect the same phasing lines, change the power dividers, and presto! For just an hour or so of changeover effort, I'm on 135-cm EME. (A photo of this array on a 1984 expedition to New Hampshire, using the same tower and stacking frame, is shown in reference 10).

6-meter Yagi

Shortly after this 2-meter Yagi design was completed, several Amateurs who needed a high-performance, high-

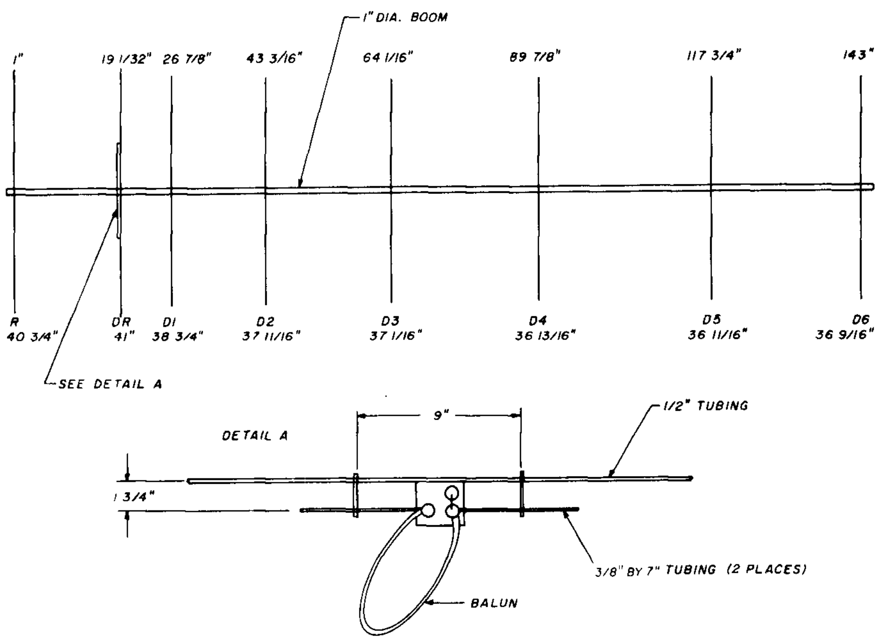

fig. 2. Optimized eight-element, 2-meter Yagi construction details. The reflector and directors are 3/16-inch rod. Element location is referenced from rear of boom to avoid tolerance buildup. A 4:1 half-wave type balun made from RG11 75-ohm coax is used. Overall length of the balun including connectors is 25 inches.

Table 1. Length and spacing for six-element, 6-meter Yagi.

Element	Spacing (inches)	Element length (inches)*	Element length (inches)**
R		113.75	117.0
	59.0		
DR		113.0	113.0
	68.0		
D1		104.75	104.75
	95.5		
D2		103.88	103.88
	75.5		
D3		104.25	104.25
	100.0		
D4		103.88	93.88

*Maximum gain model.

Optimized for best f/b ratio. A 2-inch diameter, 33-1/2 foot boom is used. The elements are 3/4-inch diameter, and are attached to the boom with U-bolt mounting as shown in **fig. 5C. A 0.625-inch element lengthening correction is included for this method of boom mounting.

gain 6-meter Yagi with clean radiation patterns — one that would also be usable on EME — approached me. Their requirements seemed to call for a frequency-scaled copy of the 2-meter design. At 6 meters, this would require a boomlength of about 35 feet.

Several mechanical configurations were evaluated. It appeared that a boom diameter of at least 2 inches was in order. "Through-the-boom" element mounting (**fig. 5A**), either directly in contact with or insulated from the boom, was immediately discarded since it would severely degrade the mechanical strength of the boom. Insulated elements mounted above the boom are advisable, but require special materials (**see fig. 5B**).

Several commercial element mounting methods were also evaluated. Cushcraft uses large diameter (3/4 inch) elements on its 6-meter "Boomer"™ and places a U-bolt directly through the element with a stiffening half-diameter element above and below the element (**fig. 5C**). Wilson antennas (now out of production) used a different mounting method that doesn't pierce the element (**fig. 5D**). Finally, with the help of Don Cook, K1DPP, a homebrew nonpiercing above-the-boom mounting was also fabricated (**fig. 5E**.)

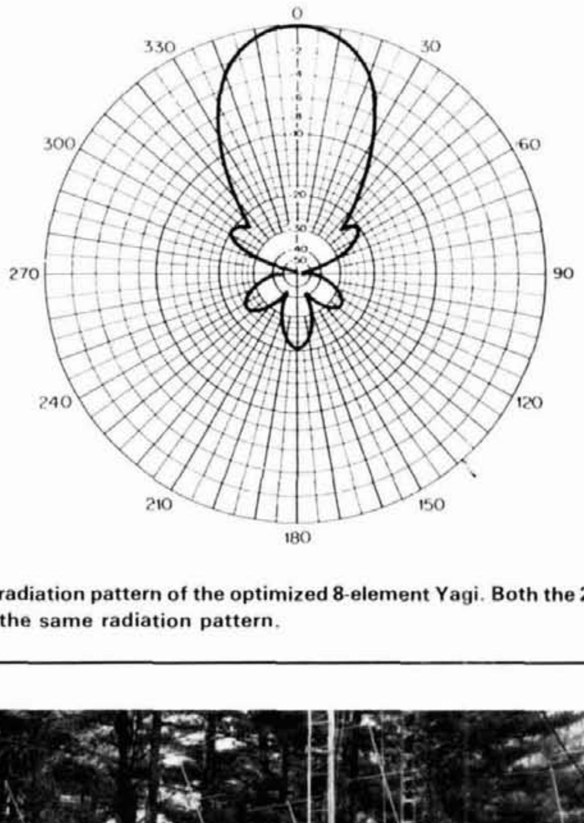

fig. 3. E plane radiation pattern of the optimized 8-element Yagi. Both the 2- and 6-meter models have the same radiation pattern.

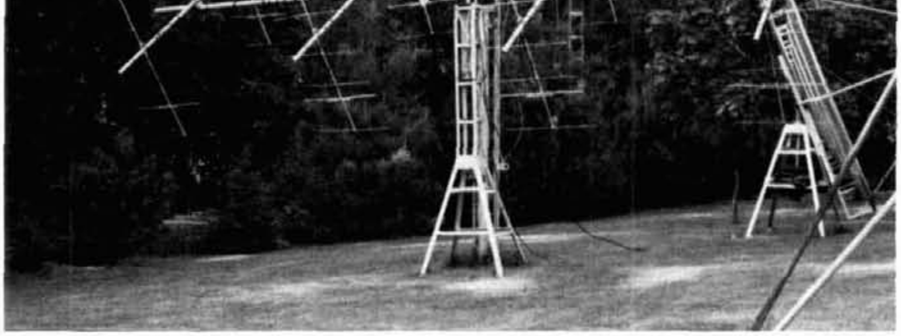

fig. 4. 2-meter EME array uses eight of the optimized Yagis.

The final element mounting scheme chosen was that shown in **fig. 5D**, since many of the older Wilson eight-element antennas are still available and easily modified for the new design. However, any of the above-the-boom mounting schemes shown will work satisfactorily. If you don't have an old Wilson beam to modify, I recommend the element mounting scheme shown in **fig. 5E**. More on this shortly.

Based on the use of an obsolete Wilson eight-element Yagi, the 2-meter design was scaled to 50.1 MHz. This design uses a 4-foot section of 5/8-inch diameter tubing for the inner portion of the elements and 1/2-inch diameter tubing for the outer portion of the elements. Construction details are shown in **fig. 6**.

Several 6-meter Amateurs have used this design. Each has used a slightly different set of tubing for the driven element matching, so the sizes shown for the driven element matching assembly may need some final adjustment. Either the length of the driven element and/or the length and spacing of the matching section may have to be changed slightly to suit your individual design.

If you build your own from scratch, the element mounting schemes shown in **figs. 5C, D** or **E** are recommended. The elements used may be either 1/2-, 5/8-, or 3/4-inch diameter tubing, or you can use graduated tubing as shown in **fig. 6**, since the difference in tuning is negligible (less than 100 kHz). If you use insulated mounted elements as shown in **fig. 5B**, each of the elements should be shortened approximately by 5/8 inch.

If you're building from scratch, I

recommend the use of a 30-foot length of irrigation pipe measuring 2 inches in diameter. This is available in farming supply stores. To obtain the required 35-1/2 foot length, a 1-7/8 inch outside diameter tube can be telescoped into the end of the tubing near the last director. Suitable tubing can be obtained from WD4BUM.**

Any boom this length and size should be supported from above. Two suggested methods are shown in **fig. 7**. This beam is large and has a high wind load, so any short cuts can turn into an expensive disaster.

If you decide to build your own, use the element mounting method shown in **fig. 5E**. A 2-inch wide aluminum channel measuring 1/2 inch thick and 5 to 6 inches long is recommended. It's easy to file out a semicircular groove in the channel to match the boom curvature. *Don't file too deeply; the strength of the channel will be diminished if you go all the way down to the base plate.*

The elements are held to the channel with short pieces of aluminum straps approximately 1/2 inch wide, 1/16 inch thick, and 2-1/2 inches long. These straps are held in place with stainless steel screws, nuts, and washers. For best element alignment, each channel should be attached to the boom using two U-bolts. Suitable stainless steel U-bolts can be purchased from suppliers such as WB9IPG*** or homebrewed.

At the suggestion of K1DPP, I made my own U-bolts using 3/16-inch diameter stainless steel welding rods available from a local welding supply house. All that was required was a 10-32 die, a die handle, and some patience. If you'd like to try this, First de-burr the edges of the rod and then cut the required length of threads on both ends. Next, place a 2-inch diameter tube upright in a bench vise. Place about a 6-inch piece of suitable diameter tubing over each threaded end of the rod. Then carefully bend the

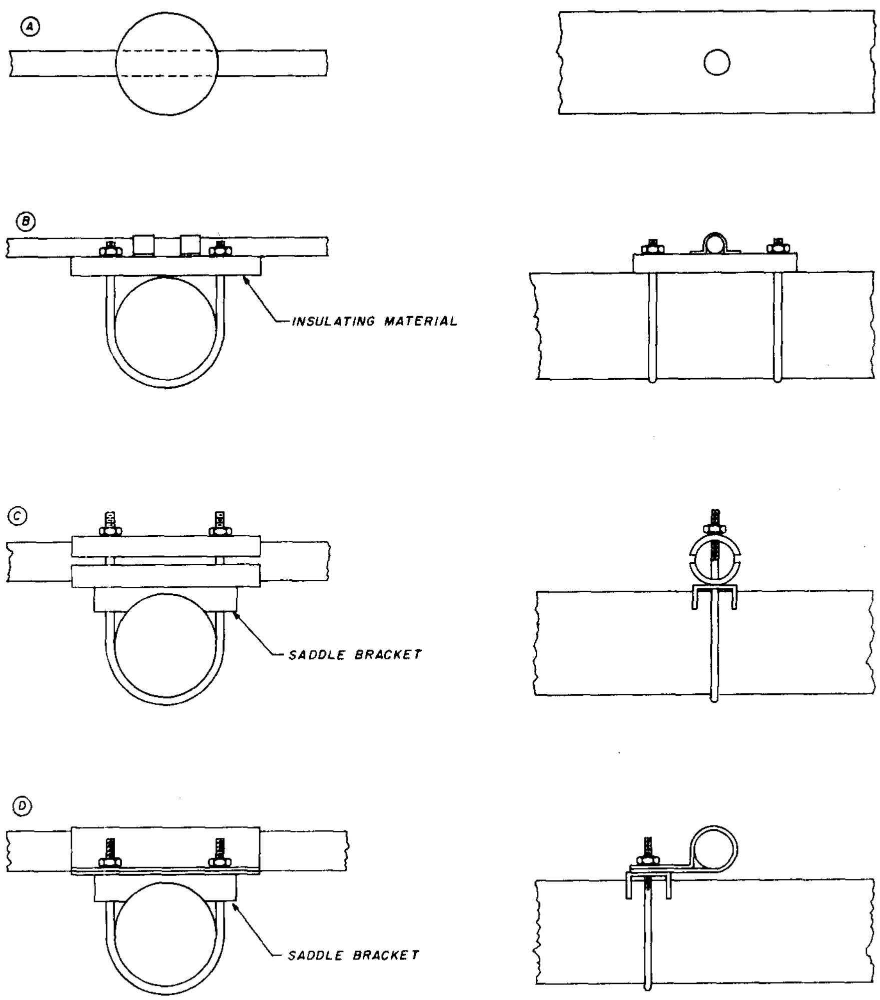

fig. 5. Typical element mounting methods: (A) through-the-boom insulated, or in direct contact with the boom; (B) insulated above the boom; (C) element held in contact with the boom by a U bolt; (D) element held by special bracket. (Because of last-minute production problems, fig. 5E will appear next month. — Ed.)

rod around the 2-inch diameter tube until the desired U-shape is obtained.

6-meter results

The performance of the 6-meter Yagi design has been gratifying to all who built one. Some Amateurs used it in contests to set high scores. Compared with most other designs, the pattern is very clean, and the gain definitely matches or exceeds that of any other 6-meter Yagi designs, even those with more elements or longer boomlengths.

Ray, WA4NJP, who's been active on 6 meters for many years and has used several different Yagi designs, recently built a large array for 6-meter EME. After finding his results only marginal, he asked for my recommendation.

I gave him the details shown in **fig. 6**, and he built four of the 6-meter Yagis, stacking them 28-1/2 feet in the E plane and 24 feet in the H plane. He started hearing EME echoes on 50 MHz immediately. Recent tests have yielded EME echoes regardless of where the moon is in the sky; previously, he could use the moon only when it was at low elevations to obtain horizon gain. Echoes more than 10 dB above the noise are now quite common off the moon — even on SSB!

**George Shira, WD4BUM, Route 7, Box 258, Anderson, South Carolina 29624.

***H. C. Van Valzah Company (WB9IPG), 1140 Hickory Trail, Downers Grove, Illinois 60515.

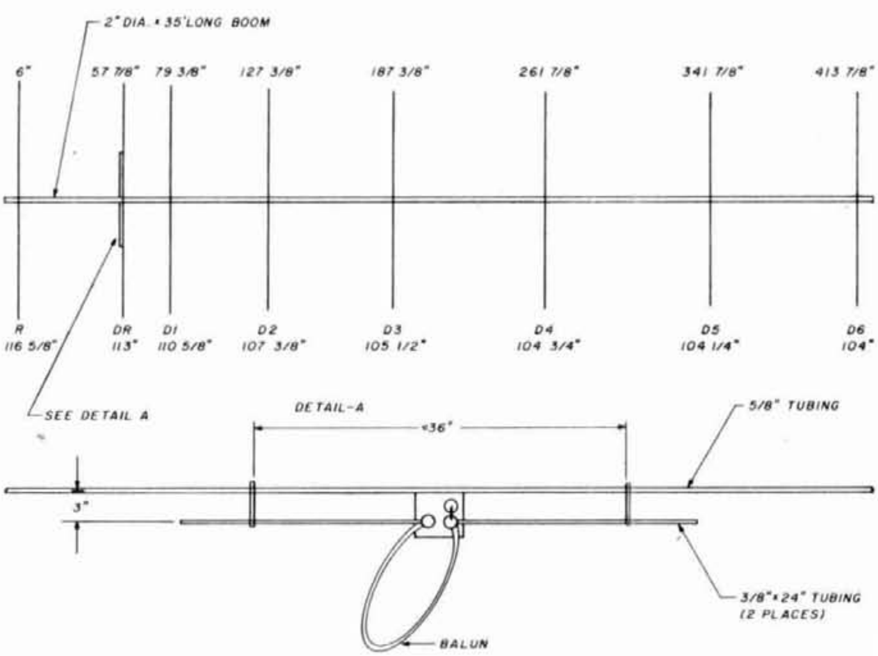

fig. 6. Optimized eight-element, 6-meter Yagi construction details. Element location referenced from rear of boom to prevent tolerance buildup. A 4:1 half-wave type balun made from RG11 75-ohm coax is used. Overall length of the balun including connectors is 78 inches. Coax can be coiled up in a 6- to 9-inch diameter and taped to boom.

summary

Since these Yagis were originally designed, additional data has indicated that optimum boomlengths exist for Yagi antennas, especially those shorter than 4 wavelengths.[1] The optimum boomlength for short Yagi designs seems to be an odd multiple of quarter-wavelengths (i.e., 0.25, 0.75, 1.25, and 1.75 wavelengths). If these boomlengths are used with the proper number of elements, optimum gain and pattern can often occur simultaneously. According to my analysis, the optimum number of elements for any specific boomlength seems to follow those recommended by Greenblum.[4] Furthermore, the use of a T match with a built-in 4:1 half-wave type balun, as shown in **figs. 2** and **6**, is strongly suggested.

This month's column was primarily aimed at the design of shorter boomlength Yagis. Emphasis was on performance, with high gain-per-unit boomlengths and clean radiation patterns. Several designs for 2 and 6 meters that meet the criteria specified above were discussed. These designs should be just the ticket for those who want high performance with an antenna they can modify or build for themselves.

acknowledgements

Any project this size requires plenty of help. I'd especially like to thank John Kenny, W1RR, for his work on optimizing the designs. Thanks also to Dave Olean, K1WHS, for his assistance with measurements and the optimization of the f/b ratio on the six-element 6-meter design. Stan Jaffin, WB3BGU, has been particularly helpful in analyzing my results and comparing notes on this and other designs. Thanks also go to Don Cook, K1DPP, for his help with the 6-meter antenna mounting brackets and hardware. Finally, thanks to Ray Rector, WA4NJP, for trusting my designs enough to build his large 6-meter EME array that works so well. I hope I didn't forget anyone!

new records

In last month's column I predicted

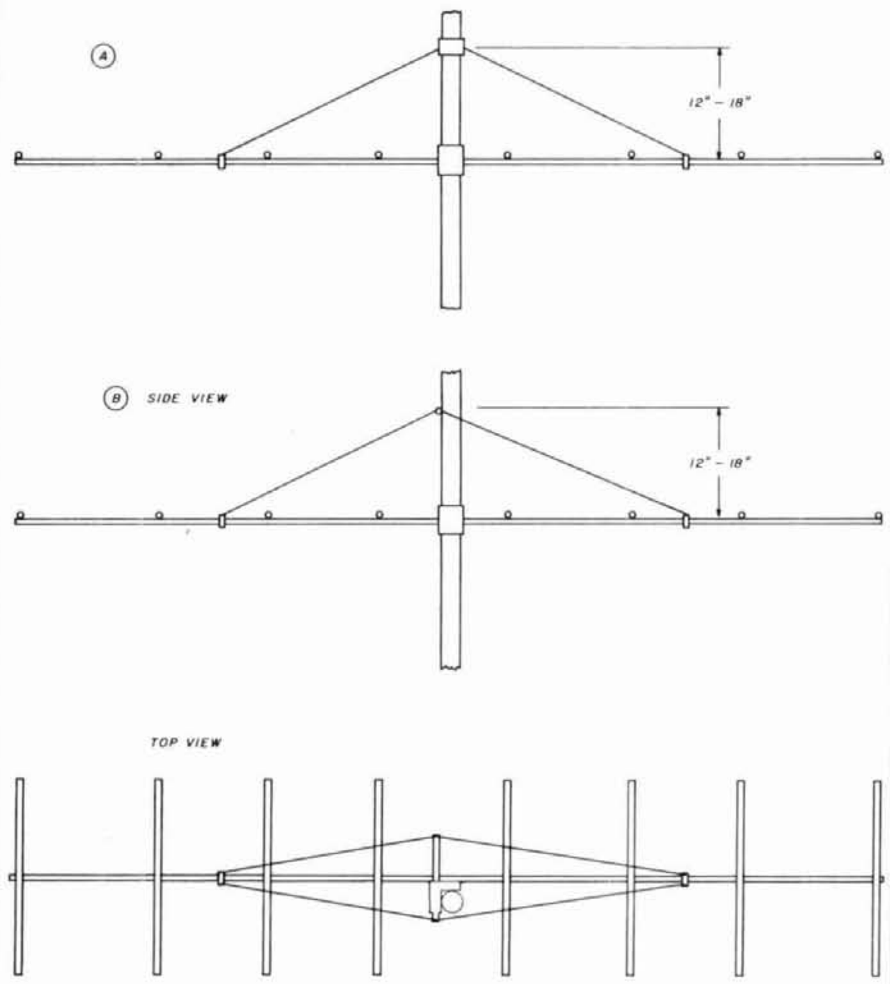

fig. 7. Recommended boom mounting method for extra strength: (A) use 1/2-inch or larger diameter tubing approximately 10 feet long mounted about 18 inches above the boom at the center. Flatten tubing ends and attach to mast and boom with U bolts. (B) Use Phillystran™ or equivalent cable mounted as shown to prevent swaying (side and top views).

that before the April issue was printed, the 33-cm (903 MHz) record would again be broken.[12] On Christmas Eve, 1986, another unexpected Midwest tropo opening occurred; this time, Sam, W2PGC (FN02OR), completed a two-way QSO with Gary, K3SIW/9 (EN52WA), for a record-shattering distance of 478 miles (769 km). Both stations were using modest setups, 10 and 70 watts, respectively, and single-loop Yagi antennas. Signals were S9 each way, and the contact was completed on two-way SSB. Congratulations to Sam and Gary.

East Coast VHF Society

One of the first of its kind, the East Coast VHF Society is now being reactivated by president Russ Pillsbury, K2TXB, vice-president Roger Amidon, K2SMN, secretary Allen Katz, K2UYH, and treasurer Tom Kirk, KA2VAD. There are plans for a newsletter and an annual flea market, as well as antenna and noise figure measuring contests in July. Equipment loan and activity to various rare grids are also planned. Contact K2UYH for further information.

MININEC 3 is available

From time to time I've mentioned computer-aided antenna modeling programs. Till now, these computer programs were either difficult to obtain, not generally available, or suitable only for mainframe or other large computers.

All that has changed. MININEC 3 is now available for general distribution for use on IBM and IBM-compatible personal computer systems. This program is faster than its predecessor and has more available options. To obtain your copy, send an MS DOS-formatted, double-sided, double-density disk with sufficient return postage and a note requesting a copy of MININEC 3 to Jim Logan, Code 822, Naval Ocean Systems Center, 271 Catalina Boulevard, San Diego, California 95152-5000.

important VHF/UHF events

May 2-3	West Coast VHF Conference (contact WB6GFJ)
May 5	Predicted peak of the Eta Aquarids meteor shower at 1300 UTC
May 8	ARRL 902-MHz Spring Sprint Contest (Friday evening)
May 9	2304 EME special by WA2WEB (contact K2UYH for skeds)
May 14	ARRL 1296-MHz Spring Sprint Contest (Thursday evening)
May 15	EME perigee
May 15-17	13th Annual Eastern VHF/UHF Conference, Nashua, New Hampshire (contact W1EJ)
May 23-24	ARRL 50-MHz Spring Sprint Contest (Saturday evening)
June 7	Predicted peak of the daytime Arietids meteor shower at 1900 UTC
June 10	Predicted peak of the Zeta Perseids meteor shower at 0400 UTC
June 13	EME perigee
June 13-15	ARRL June VHF QSO Party
June 20-21	SMIRK 6-Meter QSO Party Contest (contact KA0NNO)
June 21	±1 month. Peak of Sporadic E propagation

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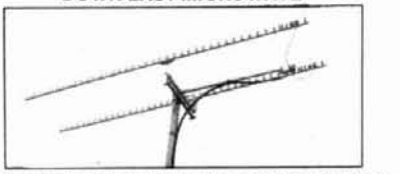
ham radio

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AT-150	Automatic antenna tuner	445.00	349^{95}
FL-32	500 Hz CW filter	66.50	
EX-243	Electronic keyer unit	56.00	
UT-30	Tone encoder	17.50	

IC-745	9-band xcvr w/.1-30 MHz rcvr	1049.00	899^{95}
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EX-241	Marker unit	22.50	
EX-242	FM unit	44.00	
EX-243	Electronic keyer unit	56.00	
FL-45	500 Hz CW filter (1st IF)	66.50	
FL-54	270 Hz CW filter (1st IF)	53.00	
FL-52A	500 Hz CW filter (2nd IF)	108.00	99^{95}
FL-53A	250 Hz CW filter (2nd IF)	108.00	99^{95}
FL-44A	SSB filter (2nd IF)	178.00	159^{95}

IC-751A	9-band xcvr/.1-30 MHz rcvr	1649.00	1399
PS-35	Internal power supply	199.00	179^{95}
FL-32	500 Hz CW filter (1st IF)	66.50	
FL-63	250 Hz CW filter (1st IF)	54.50	
FL-52A	500 Hz CW filter (2nd IF)	108.00	99^{95}
FL-53A	250 Hz CW filter (2nd IF)	108.00	99^{95}
FL-33	AM filter	35.25	
FL-70	2.8 kHz wide SSB filter	52.00	
RC-10	External frequency controller	39.25	

Other Accessories:		Regular	SALE
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PS-15	20A external power supply	169.00	154^{95}
PS-30	Systems p/s w/cord, 6-pin plug	299.00	269^{95}
OPC	Opt. cord, specify 2, 4 or 6-pin	10.00	
MB	Mobile mount, 735/745/751A	24.50	
SP-3	External speaker	61.00	
SP-7	Small external speaker	49.00	
CR-64	High stab. ref. xtal (745/751)	63.00	
PP-1	Speaker/patch	159.25	149^{95}
SM-6	Desk microphone	44.95	
SM-8	Desk mic - two cables, Scan	78.50	
SM-10	Compressor/graph EQ, 8 pin mic	136.25	124^{95}
AT-100	100W 8-band auto. antenna tuner	445.00	389^{95}
AT-500	500W 9-band auto. antenna tuner	559.00	489^{95}
AH-2	8-band tuner w/mount & whip	625.00	549^{95}
AH-2A	*Antenna tuner system, only*	495.00	429^{95}

ICOM

Other Accessories - continued:		Regular	SALE
GC-5	World clock	91.95	89^{95}

6-meter VHF Portable		Regular	SALE
IC-505	3/10W 6m SSB/CW portable	549.00	489^{95}
EX-248	FM unit	55.50	
LC-10	Leather case	39.50	

VHF/UHF base multi-modes		Regular	SALE
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BC-10A	Memory back-up	9.50	
IC-271A*	25W 2 meters ... **CLOSEOUT**	859.00	699^{95}
AG-20*	Internal preamplifier	64.00	
IC-271H	100W 2m FM/SSB/CW	1099.00	969^{95}
AG-25	*Mast mounted preamplifier*	95.00	
IC-275A	25W 2m FM/SSB/CW w/ps	1199.00	1049
IC-471A*	25W 430-450.... **CLOSEOUT**	979.00	769^{95}
AG-1*	Mast mounted preamplifier	99.50	
IC-471H*	75W 430-450 ... **CLOSEOUT**	1399.00	999^{95}
AG-35*	Mast mounted preamplifier	95.00	

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PS-35	Internal power supply for (H)	199.00	179^{95}
SM-6	Desk microphone	44.95	
EX-310	Voice synthesizer	46.00	
TS-32	CommSpec encode/decoder	59.95	
UT-15	Encoder/decoder interface	14.00	
UT-15S	*UT-15S w/TS-32 installed*	*92.00*	

VHF/UHF mobile multi-modes		Regular	SALE
IC-290H	25W 2m SSB/FM, TTP mic	639.00	569^{95}
IC-490A	10W 430-440 SSB/FM/CW	699.00	599^{95}

VHF/UHF/1.2 GHz FM		Regular	SALE
IC-27A	Compact 25W 2m FM w/TTP mic	429.00	369^{95}
IC-27H	Compact 45W 2m FM w/TTP mic	459.00	399^{95}
IC-37A	Compact 25W 220 FM, TTP mic	499.00	439^{95}
IC-47A	Compact 25W 440 FM, TTP mic	549.00	479^{95}
PS-45	Compact 8A power supply	139.00	129^{95}
UT-16/EX-388	Voice synthesizer	34.99	
SP-10	Slim-line external speaker	35.99	
IC-28A	25W 2m FM, TTP mic	459.00	399^{95}
IC-28H	45W 2m FM, TTP mic	489.00	429^{95}
IC-38A	25W 220 FM, TTP mic	489.00	429^{95}
IC-48A	25W 440-450 FM, TTP mic	489.00	429^{95}
HM-14	TTP microphone	55.50	
UT-28	Digital code squelch	37.50	
UT-29	Tone squelch decoder	43.00	
HM-16	Speaker/microphone	34.00	
IC-3200A	25W 2m/440 FM w/TTP	599.00	529^{95}
UT-23	Voice synthesizer	34.99	
AH-32	2m/440 Dual Band antenna	37.00	
AHB-32	Trunk-lip mount	34.00	
Larsen PO-K	Roof mount	20.00	
Larsen PO-TLM	Trunk-lip mount	20.18	
Larsen PO-MM	Magnetic mount	19.63	
RP-3010	440 MHz, 10W FM, xtal cont.	1229.00	1089
IC-120	1W 1.2 GHz FM Mobile	579.00	499^{95}
ML-12	*1.2 GHz 10W amplifier*	*379.00*	339^{95}
IC-1271A	10W 1.2 GHz SSB/CW Base	1229.00	1069
AG-1200	Mast mounted preamplifier	105.00	
PS-25	Internal power supply	115.00	104^{95}
EX-310	Voice synthesizer	46.00	
TV-1200	ATV interface unit	129.00	119^{95}
UT-15S	CTCSS encoder/decoder	92.00	
RP-1210	1.2 GHz, 10W FM, 99 ch. synth	1479.00	1289

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IC-2AT	with TTP	299.00	259^{95}
IC-3AT	220 MHz, TTP	339.00	299^{95}
IC-4AT	440 MHz, TTP	339.00	299^{95}
IC-02AT	2-meters	365.00	299^{95}
IC-02AT/High Power		399.00	329^{95}
IC-03AT	for 220 MHz	449.00	399^{95}
IC-04AT	for 440 MHz	449.00	389^{95}
IC-u2A	2-meters	299.00	269^{95}
IC-u2AT	with TTP	329.00	289^{95}
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A-2	5W PEP synth. aircraft HT	599.00	499^{95}

Accessories for IC series		Regular
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BP-8	800mah/8.4V Nicad Pak - use BC-35	74.25
BC-35	Drop in desk charger for all batteries	74.50
BC-16U	Wall charger for BP7/BP8	20.25
LC-11	Vinyl case for Dlx using BP-3	20.50
LC-14	Vinyl case for Dlx using BP-7/8	20.50
LC-02AT	*Leather case for Dlx models w/BP-7/8*	54.50

Accessories for IC and IC-O series		Regular
BP-2	425mah/7.2V Nicad Pak - use BC35	47.00
BP-3	Extra Std. 250 mah/8.4V Nicad Pak	37.50
BP-4	Alkaline battery case	15.25
BP-5	425mah/10.8V Nicad Pak - use BC35	58.50
CA-5	5/8-wave telescoping 2m antenna	18.95
FA-2	Extra 2m flexible antenna	11.50
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FL-63	250 Hz CW filter (1st IF)	54.50	
FL-44A	SSB filter (2nd IF)	178.00	159^{95}
EX-257	FM unit	42.50	
EX-310	Voice synthesizer	46.00	
CR-64	High stability oscillator xtal	63.00	
SP-3	External speaker	61.00	
CK-70 (EX-299)	12V DC option	12.25	
MB-12	Mobile mount	24.50	
R-7000	25 MHz-2 GHz scanning rcvr	1099.00	969^{95}
RC-12	Infrared remote controller	67.25	
EX-310	Voice synthesizer	46.00	
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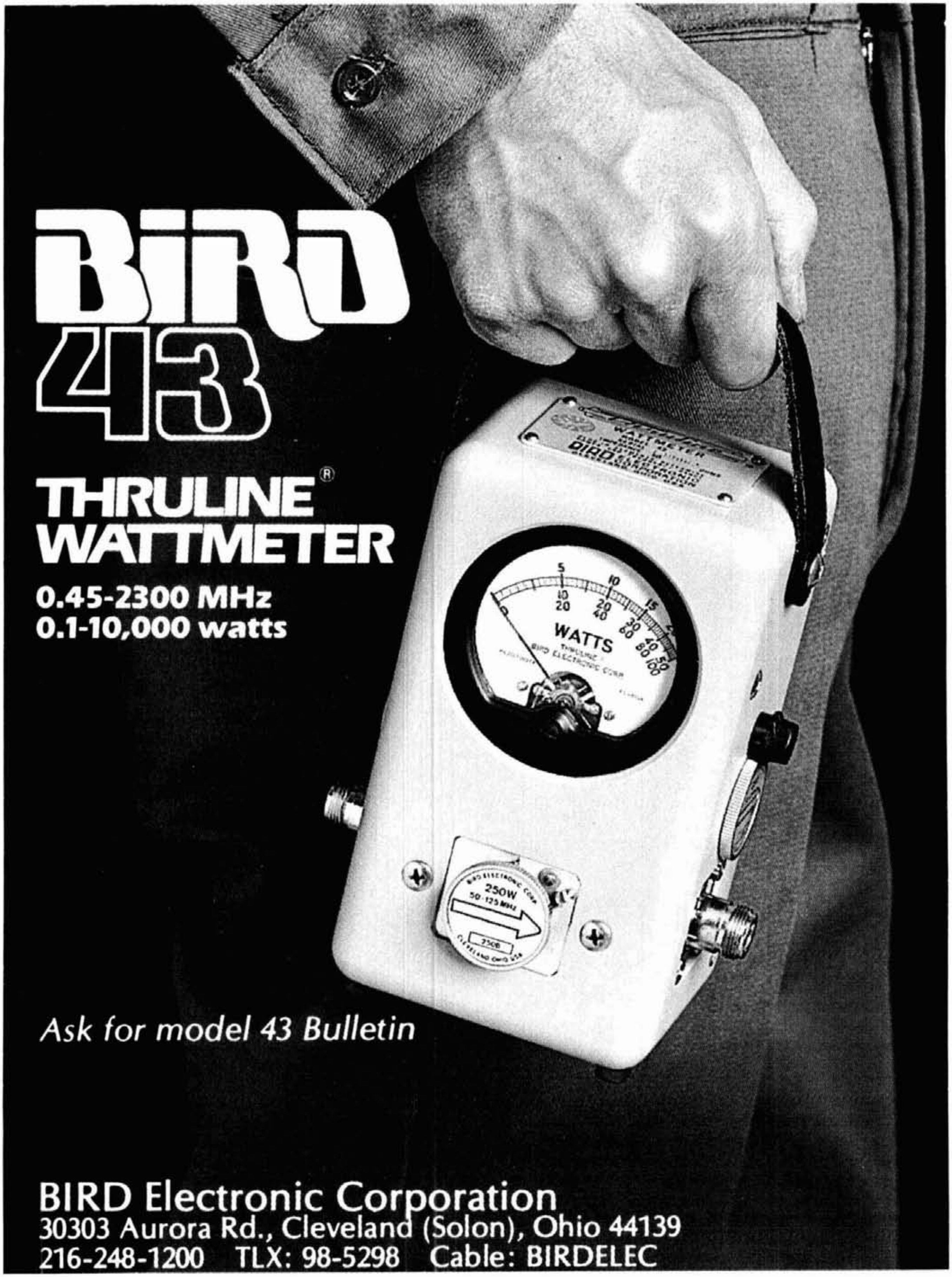
More Details? CHECK—OFF Page 130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DX FORECASTER

Garth Stonehocker, K0RYW

1986 propagation review

Now that most of the geophysical and propagation data for 1986 is in and has been analyzed, let's review the significant events so you can compare them with your DX operating log.

There were only four major geomagnetic-ionospheric disturbances (i.e., those with a geomagnetic A index greater than 40) during the year and eight large ones (i.e., those with an A index greater than 30). Surprisingly, April was the quietest month. The four major disturbances occurred in February, May, September, and November; with the exception of the September disturbance, these occurred as the 27-day solar flux cycle was decreasing. The February event (from February 5 to February 10) was so extraordinary that it warranted special coverage in the July, 1986, column.

The next major solar event, which occurred from May 1 through May 4, included a geomagnetic-ionospheric disturbance (to K7) at 1200 UT on May 2. On May 3, an old-cycle solar flare at 2017 UT (with signal attenuation in the United States and in the Pacific area) produced protons at the polar regions at 1255 UT on the following day, with the next geomagnetic-ionospheric disturbance (to K6) about 2100 UT on May 5. A decrease of as much as 22 percent in mid-latitude maximum usable frequencies (MUF) occurred on east-west paths, which included QSB.

On September 11 at 1837 UTC, the next major event occurred during a period of relatively constant solar flux. Possibly attributable to a small new-cycle flare, it produced a sudden-commencement geomagnetic-ionospheric disturbance. As a result of a favorable sun-earth equatorial alignment, an A of 49 and a K of 7 were registered, with an aurora visible as far south as Albuquerque, New Mexico, and Columbia, Missouri. MUFs decreased 25 percent on September 12, with considerable fading and weak signals occurring on east-west paths. There must have been good transequatorial openings to southern areas on this one, but I didn't hear of them.

The last of the four events took place in early November, as the solar flux decreased from its October 23 peak. The driving forces for this event were probably several small old-cycle flares and numerous solar flux bursts, the largest of which occurred on October 31 at 2249 UT. A sudden-commencement geomagnetic-ionospheric disturbance (to K6) started on the November 3 at 2354 UT and ended at 1500 UT on the 5th. A decrease of 20 percent in the MUF during the early part of the 4th was experienced on east-west paths to Europe from this short disturbance. This MUF decrease is related to equatorward extension of the lower F layer electron density of the auroral Atlantic trough situated between 60 to 70 degrees north latitude. Signal levels on the normal great circle paths are lower and QSB is experienced. However, perhaps other less common paths were useful and resulted in some interesting DX in your log.

new forecasting tool —via computer BBS

In October 1978 the Institute for Telecommunication Science of the Department of Commerce in Boulder, Colorado, stopped providing radio propagation quality information to the public via mailed weekly bulletins and WWV broadcasts of "N7's" at 14 minutes after the hour. These were replaced with solar flux and geomagnetic A and K data included with the geophysical alert announcements at 18 minutes after the hour. With the help of articles by Ted Cohen, N3AT, George Jacobs, W3ASK, and others of us, hams became their own forecasters.

Now the Space Environment Services Center (SESC) in Boulder has resumed radio quality reporting with an expanded, worldwide version of the "N7" report/forecast system. They've divided the northern hemisphere into a grid of four longitude quadrants, 0 to 90 and 180 degrees east and west, and five latitude zones, 0-10-30-55-70-90 degrees north. A two-digit code (such as N7) appears in each grid space. The letter (W, U, or N) represents conditions for the current 6-hour period; the number (1 through 9) indicates the forecast for the next 6-hour period. The primary forecast is at 0600 UT daily with 6-hour updates.

You can use your computer terminal to obtain these forecasts from SESC's "bulletin board" service. Call (303) 497-5000 with the usual 300/1200-baud, 8-bit (1 stop bit, no priority) conventional protocol of bulletin board systems. An simple menu will allow copying data for up to 5 minutes. Registration (entering your name and intended use) will give you a user number and extend available data-copying time to 15 minutes. User acceptance of the experimental service will assure permanence and menu expansion.

last-minute forecast

The higher frequency bands, 10 through 30 meters, are expected to be favorable for DX openings the first and last weeks of the month, when the possibility of higher solar flux is greatest. Short-skip sporadic-E openings are also possible during the last week or so. On the lower bands, the middle weeks should be best, with higher daytime and nighttime signal strengths. Atmospheric noise (thunderstorms) may be building up generally now, but not significantly — so enjoy these bands while you can.

Of interest to moonbounce DXers, the lunar perigee occurs on the 15th with a full moon occurring on the 13th. The Aquarid meteor shower, of interest to meteor-burst DXers, peaks be-

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8267 RG213 ... 55c/ft.
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8448 8 conductor rotor cable ... 33c/ft.
9405 Heavy duty 2-16 Ga 6-18 Ga ... 56c/ft.
9258 RG8x ... 20c/ft.
9269 RG-62A/U ... 16c/ft.
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25 watts	–	25A	25B	25C	25D	25E
50 watts	50H	50A	50B	50C	50D	50E
100 watts	100H	100A	100B	100C	100D	100E
250 watts	250H	250A	250B	250C	250D	250E
500 watts	500H	500A	500B	500C	500D	500E
1000 watts	1000H	1000A	1000B	1000C	1000D	1000E
2500 watts	2500H					
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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_	_30_	_20_	20	20	20	20	20	20	_20_	_30_	_20_	20	20	20	20	20*	15	15	15	20	N
EUROPE	20	20	20	20	15	15	15	15	15	15	20	20	20	20	_30_	_30_	_20_	20	20	30	_30_	_30_	_30_	30	NE
S. AFRICA	20	20	15	15	12	12	10	10	10	12	12	15	20	20	20	20	15	15	_20_	_30_	_20_	_20_	_20_	20	E
S. AMERICA	10	10	10	12	12	12	12	12	12	15	20	20	_20_	_30_	_20_	_20_	20	20	20	20	15	15	12	12	SE
ANTARCTICA	15	15	15	15	20	20	20	_40_	_40_	_40_	_40_	_40_	30	30	30	30	30	30	30	20	20	20	15	15	S
NEW ZEALAND	12	12	12	12	12	15	20	_20_	_20_	_20_	_20_	_20_	20	20	20*	15	15	12	12	10	10	10	10	12	SW
OCEANIA AUSTRALIA	10	12	12	15	20	_30_	_30_	_30_	_30_	_20_	20	20	20	20	20	20*	15	12	10	10	10	10	10	10	W
JAPAN	15	20	20	20	20	20	_30_	_30_	_30_	20	_30_	_30_	_30_	20	20	20	20	20	15	15	15	15	15	15	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_	_30_	_30_	20	20	20	20	20	20	20	20	_20_	_20_	_30_	20	20	20*	15	20	20	20	N
EUROPE	20	20	20	20	20	15	15	15	15	15	20	20	20	20	20	_30_	_30_	_30_	20	20	_30_	_30_	_30_	20	NE
S. AFRICA	20	20	15	15	12	12	10	10	10	12	12	12	15	20	20	20	20	20	_20_	_30_	_20_	_20_	_20_	20	E
S. AMERICA	12	10	10	10	10	12	12	12	12	12	15	20	20	_20_	_30_	_20_	_20_	20	20	20	15	15	12	12	SE
ANTARCTICA	15	15	15	20	20	20	20	_40_	_40_	_40_	_40_	_40_	_40_	40	40	30	30	30	30	20	20	20	15	15	S
NEW ZEALAND	10	12	12	12	12	12	_20_	_20_	_20_	_20_	_20_	20	20	20	20	20	15	15	12	12	12	10	10	10	SW
OCEANIA AUSTRALIA	10	12	12	15	20	_30_	_30_	_30_	_30_	_30_	20	20	20	20	20	20	15	15	12	12	10	10	10	10	W
JAPAN	15	15	20	20	20	20	_30_	_30_	_30_	_30_	20	20	20	_30_	_30_	_30_	20	20	20	20	20	15	15	15	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	_30_	_30_	_30_	20	20	20	20	20*	15	15	20*	20	20	20	_20_	_20_	_20_	_20_	20	20	20	20	N
EUROPE	20	20	20	20	20*	15	15	15	15	20*	20	20	20	20	20	20	_30_	_30_	_30_	_30_	_30_	30	20	20	NE
S. AFRICA	20	20	15	15	12	12	10	10	10	10	12	12	12	15	20	20	20	20	_20_	_30_	_20_	_20_	_20_	20	E
CARIBBEAN S. AMERICA	12	12	10	10	10	10	12	12	12	15	15	15	20	_20_	_30_	_20_	_20_	20	20	20	20	15	12	12	SE
ANTARCTICA	20	20	20	20	20	20	20	_40_	_40_	_40_	_40_	_40_	_40_	40	40	40	30	30	30	30	30	20	20	20	S
NEW ZEALAND	10	12	12	15	15	15	20	_20_	_20_	_20_	_20_	20	20	20	20	20	20*	15	15	15	12	12	10	10	SW
OCEANIA AUSTRALIA	10	12	12	15	15	_30_	_30_	_30_	_30_	_30_	20	20	20	20	20	20	20	15	15	12	12	10	10	10	W
JAPAN	15	15	20	20	20	20	_30_	_30_	_30_	_20_	20	20	20	20	20	_20_	_20_	20	20	20	20	20	15	15	NW

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

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

tween May 4 and 6, with rates of 10 to 25 per hour for the northern and southern hemispheres, respectively.

band-by-band summary

Ten, twelve, fifteen, and twenty meters will support DX propagation from most areas of the world during daylight and into the evening, with long-skip out to 2000 miles (3500 km) per hop. Signals on the upper three bands arrive mainly from the southern countries and occur near noontime. Sporadic-E short-skip will be available on some days toward the end of the month near local noon. The direction of propagation will follow the sun across the sky: morning to the east, south at midday, and west in the evening.

Thirty, forty, eighty, and one-sixty meters are the nighttime DXers' bands. Because of low solar flux in midmonth, daytime DX — particularly in the early mornings — may be worthwhile. The direction of propagation follows the darkness path across the sky: evening to the east, south and north around midnight, and toward the west in the predawn hours. Distances will decrease to 1000 miles (1600 km) generally, for skip on these bands. Sporadic-E openings will be observed most frequently around sunrise and sunset toward the end of the month.

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Super ComShack 64
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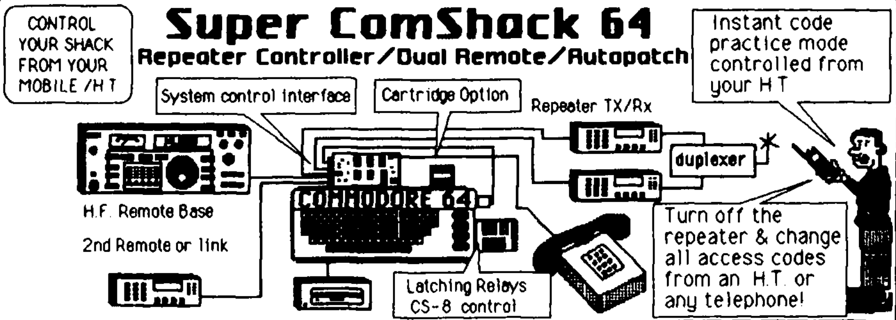

Super Repeater Controller
- *Remotely programable with Touchtones/ change up to 9 sets of access codes from H.T. or telephone!
- *Synthesized speech consisting of high quality male or female digitized human voice
- *Dual Remote base (H.F. & V.H.F.)
- *Autopatch & Super Repeater Controller
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- *Multiple commands can be executed at once (up to 16 digits per command string)
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- *Alarm clock & auto-excute command string!
- *Optional autoboot cartridge (no disk drive needed)
- *Send system commands from telephone line!

Special Club Features
- *Generates random code practice @ any speed with voice readback after each 20 random code group!
- *Set CW speed & pitch from your H.T.
- *Input up to 22 vocab words & letters as ID or mail box message @ speed dial rates from H.T.
- *Enable/disable up to 50; tel. #'s + wild cards

Autopatch Specifications
- *300 *Touchtone loadable Autodial numbers* plus 10 Emergency Autodial (quick access)
- *300 Reverse patch call signs uploaded from your H.T./general or directed page modes
- *Incoming caller receives voice message to enter 3 digit code to selective page a call sign (D.P. mode)
- *Phone number memory readback
- *Enable/disable 50 area codes + wild card #'s
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- *Reverse patch active in all modes

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  - + automatic PTT fan control/master all off code
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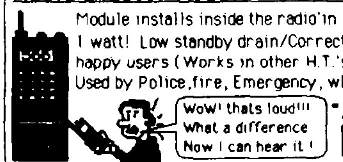
Audio Blaster Module IC-02AT/IC-04AT/IC2AT



Module installs inside the radio in 15 Min. Boost audio to 1 watt! Low standby drain/Corrects low audio/1000's of happy users (Works in other H.T.'s too) Used by Police, fire, Emergency, when it needs to be loud!

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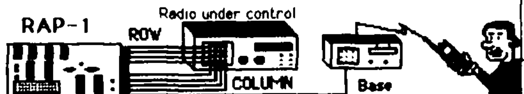
RAP-1



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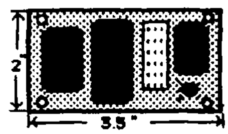
50,000 combinations



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COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: Please indicate in your announcements whether or not your Hamfest location, classes, exams, meetings, flea markets, etc, are wheelchair accessible. This information would be greatly appreciated by our brother/sister hams with limited physical ability.

MASSACHUSETTS: April 19. Spring Flea at MIT. Sponsored by the MIT Electronics Research Society and W1XM/R. 10-4 PM. Albany and Main Streets, Cambridge. Buyers admission $1.50. Sellers $5. per space. Talk in on 146.52, 449.2 W1XM/R.

NEW YORK: June 14. The Hall of Science ARC Hamfest, New York Hall of Science parking lot, Flushing Meadow Park, 47-01-111 Street, Queens. 9 AM to 3 PM. Donations—buyers $4.00; sellers $6.00 per space. Talk in on 144.300 simplex link 223.600 repeat and 445.225 repeat. For information call Steve Greenbaum, WB2KDG (718) 898-5599 or Arnie Schiffman, WB2YXB (718) 343-0172 evenings.

LOUISIANA: May 2 and 3ᵉ The Baton Rouge ARC Hamfest 50 and LA State Convention, Gym Armory, campus of LSU, Baton Rouge. Sat 8 AM—3 PM. Sun. 8 AM—2 PM. Free admission. Forums, ARRL speakers, Advanced swap tables reservations accepted. Dealers, tours, VE exams both days 9 AM. SASE, 610, check for $4.00 payable to ARRL/VEC to George Perry, W5LVX, 17424 Lady Constance, Greenwell Springs, LA 70739. Talk in on 146.19/79. For more info SASE to Rick Pourciau, NV5A, 879 Castle Kirk Dr, Baton Rouge, LA 70808. There will be Cajun food and entertainment Saturday nite. Come pass a good time!

PENNSYLVANIA: May 17. The Warminster ARC's 13th annual Hamfest, Middletown Grange Fairgrounds, Penns Park Rd, Wrightstown. Gates open 7 AM. 6 AM for Vendors. Donation $3.00. Non-hams and kids free. 8' indoor tables/power $5.00 by pre-registration only. Unlimited outdoor 8' space $5.00. Talk in on 147.69/09 and 146.52. For info and pre-registration contact Frank Charlton, KA3FBP, 1479 Kingsley Drive, Warminster, PA 18974. (215) 675-2549.

MARYLAND: May 24. Maryland FM Association's annual Hamfest, Howard County Fairgrounds, West Friendship, 30 miles west of Baltimore. Gates open 8 Am to 3 PM. Advance inside tables $7.00. At the door $10. Donation $3. Talk in on 146.16/76, 222.16/223.76 or 449.1/444.1 MHz. For tables or information: Jim Clifford, N3FBV, 7461 Terry Street, Ft. Meade, MD 20755. (301)674-4752.

COLORADO: May 16.Pikes Peak Radio Amateur Association 1987 Swapfest, Rustic Hills Mall, Palmer Park and Academy Blvd, Colorado Springs. 8:30 AM. Free admission. Tables $8.00 advance; $10.00 at door. VE testing. Talk in on 146.37/97. For information or reservations: Al, N0CMW (303) 4731660 or write PPRAA Swapfest, POB 1652, Colorado Springs, CO 80935.

ARIZONA: May 1-3. The Cochise Amateru Radio Association (CARA) will hold its 1987 Hamfest, club training facility, South Moson Road, Sierra Vista. Free tailgating. Talk in on 14y.52 or 146.16/.76. For information: Don Morgain, W7ACI, (602) 458-5293 or CARA, POB 1855, Sierra Vista, AZ 85636.

MISSOURI: May 17. The Western Illinois ARC will hold its 2nd annual Tri-State Swapfest, Haerr Field, Taylor. Tailgate flea market, aircraft exhibits, plane rides and VEC exams. Flea market setup 8 AM. General admission 9 AM. Talk in on 147.03 repeater. For information: Western Illinois ARC, POB 3132, Quincy, IL 62301

NEW HAMPSHIRE: May 15-17. The 13th annual Eastern VHF/UHF Conference, Rivier College, Nashua. For information contact Lewis D. Collins, W1GXT, Publicity Chairman, Eastern VHF/UHF/SHF conference, 10 Marshall Terrace, Wayland, MA 01778. (617) 358-2854 (6 to 10 PM EST)

NEW YORK: May 17. LIMARC will sponsor the ARRL Long Island Hamfair, New York Institute of Technology, Rt 25A, Northern Blvd, Old Westbury, NY. Sellers 7:30 AM. Buyers 9 AM. Outdoor tailgating. Sellers car space $5.00. General admission $3.00. Non-hams and kids admitted free. Talk in on 146.85. For information call Hank Wener, WB2ALW (516) 484-4322 evenings.

PENNSYLVANIA: June 7. The 33rd annual Breeze Shooters Hamfest, White Swan Amusement Park, Rt 60, near Pittsburgh International Airport. Free admission and Flea Market, family amusement park. 9 Am to 4 PM. For information and table reservations Bud Faulhaber, N3DOS, 1059 Balmoral Drive, Pittsburgh, PA 15237 (412) 366-5097.

OKLAHOMA: May 15-17. Green Country Hamfest, sponsored by the Broken Arrow and Tulsa ARCs, Vo-Tech SE Campus, 4600 S. Olive, Broken Arrow. Friday night mixer 6-10 PM at the Travelodge. Flea market and dealers open 9-5 Saturday and 9-01 Sunday. ARRL FCC exams. Children's room. Non-ham programs. Family BBQ dinner. For information contact Ron gamel, N5WX, (918) 663-0385 or write Green CountryHamfest, POB 4970, Tulsa, OK 74159.

MICHIGAN: May 16. Teh Wexaukee ARA's 27th annual Swap Shop, Wexford civic Arena, US 131 and 13th Street, Cadillac. 9 Am to 2 PM. Admission $3.00. Reefreshments available. Talk in on 146.97. For table reservations and more info call John Craddock, (616) 797-5491 or write Wexaukee ARA, POB 163, Cadillac, MI 49601

OHIO: May 17. TheAthens County ARA's 8th annual Hamfest, City Recrreation Center, East State Street, Athens. 8 AM to 3 PM. Admission $4.00. License exams. Send Form 610 and $4.35 check payable to ARRL/VEC to John Cornwell, NC8V, 101 Coventry Lane, Athens, OH 45701. Free paved outdoor flea market space. Bring your own tables. No reservations. Indoor space by advance registration. Contact Walt Jones, N8DDL, 17 Berkley Dr, Athens, OH 45701 (614) 593-7871. For general information Carl Denbow, KA8JXG, 63 Morris Ave, Athens, OH 45701.

PENNSYLVANIA: May 24. The Ephrata Area Repeater Society's 2nd annual Hamfest. Walk in VEC exams. Packet and ATV demos.

MICHIGAN: May 30. The Central Michigan Amateur Repeater Association (CMARA) 13th annual Hamfest, Midland Comunity Center, Midland. 8 AM to 1 PM. Admission $3. Food available. Dealers welcome. Packet radio, new/used Amateur electronics and equipment. License exams. Talk in on 147.00/60 Midland. For information CMARA Hamfest, POB 67, Midland, MI 48640. Please SASE. (517) 631-9228 evenings and weekends.

ILLINOIS: May 17. The Knox County Radio Club's annual Hamfest, Knox County Fairgrounds, Knoxville, IL. Gates open 7 AM. Building open 8 AM. Free flea market spaces available. ARRL/VE testing. For table reservations, pre-registration for testing and advanced tickets write Keith L. Watson, WB9KHL, 119 South Cherry Street #3, Galesburg, IL 61401-4527 or call (309) 342-3885 evenings.

NEW YORK: May 30. First Skaneateles Ham and Computer Fest, Allyn Arena, Jordan and Austin Streets. 8 AM to 5 PM. Vendors, ham gear and computer displays, exhibits. VE license exams. For reservations, info, motel list, contact Hank Bryant (315) 685-7658 or write Skaneateles Hamfest, 49 Elizabeth Street, Skaneateles, NY 13152.

ILLINOIS: May 17. The Chicago Amateur Radio Club's annual Mini-Hamfest, North Park Village, 5801 N. Pulaski, Chicago. 9 AM to 3 PM. Admission $1. Half table $3. Full table $5. Admits one seller. For info call 545-3622.

NEW JERSEY: May 9. The Cherryville Repeater Association's annual Hamfest, Hunterdon Central High School, Flemington. 8 AM to 4 PM. Indoor tables plus tailgating. FCC exams, forums displays and more. Talk in on 146.52, 147.975/.375. For further information or reservations call Bill Inkrote, K2NJ (201) 788-4080 or Don Mazak, NR2H (201) 782-1114.

COLORADO: June 20. The Grand Mesa Repeater Society will hold its 8th annual Western Slope Amateur Radio and Computer Swapfest, 9 AM to 4 PM, National Guard Armory, 482-28 Road, Grand Junction. Free admission. Swap tables $5.00 each. Indoor swapfest, Amateur Radio exams, auction and refreshments. Talk in on 146.22/.82 and 449.20. For tables or information SASE to Les Scott, NV0F, 2105 Yellowstone Rd, Grand Junction, CO 81503 or call (303) 242-5296.

CALIFORNIA: May 1, 2, and 3: The Fresno Amateur Radio Club will hold its 45th annual Hamfest, Fresno Airport Holiday Inn. Air conditioned dealer spaces and swap tables. FCC exams. Good programs and parking. Demonstrations and forums. Talk in on 146.34-94. For information: Glen T. Caine, Fresno ARC, PO Box 783, Fresno, CA 93712 or (209) 292-4611.

NEW YORK: May 3. The Suffolk County Radio Club's indoor/outdoor flea market, 8 AM to 2 PM, Republic Lodge No. 1987, 585 Broadhollow Road, Rt. 110, Melville, L.I. General admission $3.00. Spouse and kids under 12 free. Indoor tables $10. each. Outdoor spaces $7.00 each. Includes one free admission. Talk in on 144.61/145.21 and 146.52 simplex. For information: Bill Sullivan, N2ETG (516) 689-9871 evenings.

NEW JERSEY: May 3. The Tri-County Radio Association's annual Indoor Hamfest/Flea Market, Passaic Township Community Center, Stirling. 9 AM to 3 PM. Donations $3.00. Tables $8.00; w/power $10.00. Reserved tailgating. Refreshments. Talk in on 147.855/.255, 146.52 and 444.975/449.975. For information: Dick Franklin, W2EUF, POB 182, Westfield, NJ 07090. (201) 232-5955.

ARKANSAS: May 2. The Northwest Arkansas ARC will hold its 7th annual Hamfest, Rogers Youth Center, 315 West Olive Street, Rogers. 8 AM to 4 PM. Doors open 6 AM for exhibitors. General admission and parking free. Nearby recreational areas and parking for RV's and campers. Talk in on 16/76 or 03/63. For information: Roy Milliren, AF5W, 2014 S. 16th Street, Rogers, AR 72756 (501) 636-6750.

VIRGINIA: May 3. The Lynchburg ARC will hold its annual Swapfest, Brookville High School grounds, Route 460 West, just outside Lynchburg. Rain or shine. Starts 9 AM. Admission $1.00. Tailgaters pay general admission plus $2.00. VE exams beginning 1 PM. Please pre-register. For more information write Lynchburg ARC, PO Box 4242, Lynchburg, VA 24502.

RHODE ISLAND: May 16. The RI Amateur FM Repeater Service will hold their annual Spring Flea Market and Auction, American Legion Fairmount Post 85, 870 River Street, Woonsocket. Flea market opens 9 AM and spaces are $5.00 each. Auction from noon to 5 PM. Free admission. Food and beverages available. Talk in on 34/94 and 52 simplex. For information: Rick Fairweather, K1KYI, Box 591, Harrisville, RI 02830 or call (401) 56;8-0566, 7-9 PM.

CONNECTICUT: May 31. The Newington Amateur Radio League will hold its fourth annual Flea Market, Newington High School, Willard Avenue, Newington. 9 AM to 2 PM. New/used ham gear, computer equipment. Admission $2.00 at the door. Indoor tables $8.50, $10 after May 23. Tailgaters $5. Guided tours of ARRL Hq. Amateur Radio exams. Talk in on 146.52 and W1AW/R, 144.85/145.45 and 223.24/224.84. For exam information or table reservations: Les Andrew, KA1KRP, 23 Grove St, West Hartford, CT 06110. (203) 523-0453. Please SASE.

ILLINOIS: May 17. The Kankakee Area Radio Society's annual Hamfest, Kankakee County Fairgrounds, 8 AM to 4 PM. Admission $2.50 advance; $3.00 at the door. FCC and ARRL booths.Free flea market tables. Free parking. Talk in on 146.34/94. For information: KARS c/o Frank DalCanton, KA9PWW, RR 1, Box 361, Chebanse, IL 60922. (815) 932-6703 after 5 PM CST or (815) 937-2452 before 5 PM.

MINNESOTA: May 9. The Arrowhead Radio Amateur Club's Swapfest '87, First United Methodist Church, 230 East Skyline Parkway, Duluth. 10 AM to 3 PM. Admission $4.00. 4' tables $5.00. License exams 9 AM. For Amateur exams contact Eddy Lonnstrom, N9DHG, 2026 Baxter Ave, Superior, WI 54880 (715) 392-2415. General information: Ron Carlson, K0BR, 5128 Wyoming Street, Duluth, MN 55804 (218) 525-6860.

SOUTH CAROLINA: May 2 and 3. The Blue Ridge Amateur Radio Society's 48th annual Greenville Hamfest and Electronic Flea Market, American Legion Fairgrounds, Greenville. Saturday 8 AM to 5 PM. Sunday 8 AM to 3 PM. Admission $3.50 advance and $5.00 at gate. Indoor/outdoor flea market, license exams, free parking, food. For tickets or information SASE to Blue Ridge ARA, PO Box 6751, Greenville, SC 29606.

NEW HAMPSHIRE: May 9. New England's favorite—The Hosstraders Spring Tailgate Swapfest, Deerfield Fairgrounds. Admission $2.00 per person including sellers and commercial dealers. Friday night camping at nominal fee only after 4 PM. Profits benefit Shriners' Burns Hospital. Last year's gift over $13,500! For map, SASE to WA1IVB, RFD Box 57, West Baldwin, ME 04091.

PENNSYLVANIA: May 3. The Delaware County ARA is sponsoring their 8th annual Hamfest, Drexel Hill Middle School, State Road and Penn Avenue, Drexel Hill. Doors open 8 AM. Setup 7 AM. Admission $3. Reserved indoor tables/elec. available for $3.00 per space. License exams. Refreshments available. Talk in on 147.96/36, 224.5 and 146.52. For registration and information write Hamfest, DCARA, PO Bkox 236, Springfield, PA 19064 or call Barbara, N3DLG (215) 535-1616.

1987 "BLOSSOMLAND BLAST" Sunday, September 20, 1987. Write "BLAST" PO Box 175, St. Joseph, MI 49085.

VIRGINIA: June 7. The Ole Virginia Hams present the Annual Manassas Hamfest, Prince William County Fairgrounds. 8 AM to 4 PM. General admission $4.00. Children under 12 free. Tailgating $5.00/space. Dealers, ARRL booth, CW proficiency award. Talk in on 146.37/97, 146.52. For information write: Ole Virginia Hams ARC, POB 1255, Manassa, VA 22110. John Gunsett, KI4VP (703) 361-5255 or Gene Roberts, N4HFW (703) 361-3983.

NEW JERSEY: May 17. OBRA Annual Festival. Old Bridge Civic Center Arena, Cottrel Road and Hwy 516, Old Bridge. Sellers 6 AM $12.00. Buyers 8 AM, $5.00. Tailgating $8.00. FCC exams, pre-registration suggested. Walks in 9 AM. Testing 10 AM. Talk in on 7.12/7.72. For information N2DHN.

NORTH CAROLINA: May 23. The Durham FM Association's annual Hamfest, Lower rear deck South Square Mall, Durham. 8 Am to 4 PM. FCC exams, vendors and free tailgating. Talk in on 147.825/.225, WA4WTX.

MICHIGAN: June 7. The Chelsea Swap and Shop, Chelsea Fairgrounds, Chelsea. Sellers 5 AM. Buyers 8 AM to 1 PM. Donation $2.50 advance and $3.00 at the gate. Children under 12 and non-ham spouses free. Talk in on Chelsea Repeater 146.980. For information: Robert Schantz, 416 Wilkinson St, Chelsea, MI 48118. (313) 475-1795.

WISCONSIN: May 2. The Ozaukee Radio Club will sponsor its 8th annual Cedarburg Swapfest, Circle B Recreation Center, Highway 60 and County I, Cedarburg. 8 Am to 1 PM. Admission $2.00 advance, $3.00 at the door. 4' tables $3.00 each. Food and refreshments available. For tickets, reservations or information SASE to 1987 ORC Swapfest, 101 E. Clay Street, Saukville, WI 53080 or phone (414) 284-3271.

NEW JERSEY May 17. The Bergen County ARA is sponsoring its Spring Hamfest, Bergen Community College, 400 Paramus Road, Paramus. 8 to 4 PM. Rain or shine. Buyers free. Sellers $5 per space, tailgate only. License exams. Talk in on 146.19/79 and .520 simplex. Forfurther information: Jim, KK2U (201) 445-2855, 444 Berkshire Rd, Ridgewood, NJ 07450.

OPERATING EVENTS

"Things to do . . ."

May 2. The Louisville A.R.T.S. will operate "Run For The Roses" under the call W4CN. 2400 to 0500 May 1 and 1300 to 1700 May 2. For a commemorative certificate send QSL and 39 cents SASE to ARTS Club, W4CN, POB 7391, Louisville, KY 40207.

May 9. The Laurel ARC will operate special event station W3GFS from 1400Z to 2000Z to help celebrate the 4th annual Main Street Festival in Historic Laurel, MD. SASE for 8x11 certificate. QSL to LARC, POB 1436, Laurel, MD 20707.

May 23: The Old Barney ARC os Southern Ocean County, New Jersey announces a special event Amateur Radio operation commemorating the 75th anniversary of the start of construction of the Tuckerton Wireless Tower. 0000lZ May 23 thru 2359Z May 24. For information contact Bob Schenck, N2OO, Publicity Manager, OBARC. (609) 296-0307

May 23, 24, 30. The Carroll County ARC will operate K3PZN in celebration of Carroll County's Sesquicentennial. For 8x11 certificate send QSL and SASE to Carroll County ARC, POB 2099, Westminster, MD 21157.

ARMED FORCES DAY May 16 1987. In recognition of the 38th anniversary of this event, ARS W4ODR aboard NAS Memphis, Millington, Tennessee will be operated by sailors and marines from 1300Z to 2300Z. For additional information Station Custodian, Senior Chief Petty Officer Bob Donan, KA4FAL, (901) 872-2007.

May 16. The Charleston Amateur Radio Society will operate Special Event Station from the deck of the aircraft carrier USS Yorktown CV-10 located in Charleston, SC. Callsign WA4USN. 1000Z to 2200Z. For a special QSL card with photo of the ship (to confirmed contacts) SASE to Special Event Station, 346 Parkdale Dr, Charleston, SC 29407.

THE FOUNDATION FOR AMATEUR RADIO, INC. plans to award 26 scholarships for academic year 1987-88 to assist licensed Radio Amateurs who plan to pursue a full-time course of studies beyond high school and are enrolled or have been accepted by an accredited university, college or technical school. For further information write FAR Scholarships, 6903 Rhode Island Avenue, College Park, MD 20740 prior to May 31, 1987.

ARMED FORCES DAY 1987 May 16. The 38th annual Armed Forces Day Communication Test. Traditional military-to-Amateur cross band operation and broadcast of the Secretary of Defense message are the featured highlights and include operations in CW, SSB and RTTY.

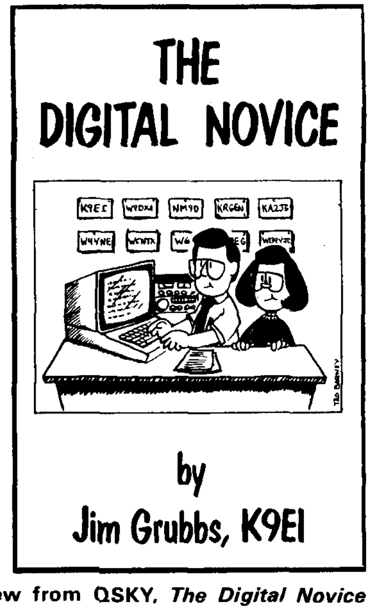
book REVIEW

the digital novice

The man who helped thousands of Amateurs *Get ***Connected to Packet Radio* has done it again. In *The Digital Novice*, author Jim Grubbs, K9EI, explains the fundamentals of digital communications with authority, clarity, simplicity, and wit.

Warning: This is a *very* basic book that covers, rather lightly — but in detail sufficient for most beginners — the whole range of Amateur digital communications, from what Jim calls "cave-dweller digital" to spread spectrum and transmission, via packet radio, of *animated* visual images.

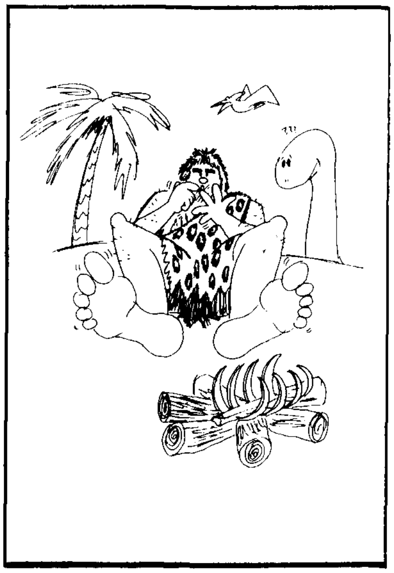
Why are we recommending it to readers of *ham radio* with enthusiasm? Well, for one thing, we know that some readers are dyed-in-the-wool analog types to whom digital technology is something of a mystery. Others understand the technology, but want to acquire an overview of



New from QSKY, *The Digital Novice* introduces beginners — regardless of license class — to digital communications.

equipment available, with an eye toward becoming active in one digital mode or another.

But there's a better reason to read this book. There are some 80,000 Novices out there, and the new Novice enhancement regulations (which Jim spells out in comprehensive, up-to-the-minute detail) will certainly bring in more. Now these people will no doubt expect you, with your higher class of license, to know *everything*. What's more, they're going to be looking to you not only to know it all, but to explain it, too — in terms they can understand — or at least direct them toward appropriate sources of information.



"Cave Dweller Digital" was earliest form of digital communications.

The Digital Novice helps you answer questions like "What exactly is AMTOR?", "How is packet different from earlier digital techniques like RTTY and ASCII?", and "What interface should I buy?" without having your face turn red or getting your tongue all tied up in embarrassing knots — and *without confounding the questioner*. No doubt you can answer all sorts of questions about digital techniques, even roused from a deep sleep after driving home from Dayton for two days straight. But wouldn't it be convenient to just point to *The Digital Novice*, roll over, and go back to sleep?

This isn't another book about packet radio, by the way, or a book about computers, though there's enough about computers to form a solid basis for understanding the material. It isn't "a computer book." It is a book you can give without reservation to any interested beginner, regardless of age. Though it's written for adults, I wouldn't hesitate to give it to a bright, highly motivated eighth-grader. There's no question about it: Jim is a born communicator, a writer who knows his audience and speaks to them in language they understand, simplifying complex subjects without ever "talking down." What might cause us to be rendered essentially inarticulate (as a function of knowing either too much or too little), he explains with refreshing simplicity. As Jim points out, technically knowledgable people aren't necessarily the best "missionaries for the new technologies." Not convinced? Quick: explain spread spectrum in language a Novice can understand.

Describing equipment available, Jim names names and comments, with candor, on every piece of hardware about which Novices need to know, citing advantages and disadvantages of each. Though addresses are not included, they're all here: AEA, GLB, MFJ, Kantronics, Packeterm — and, of course, TAPR and Vancouver as well.

The text is supplemented with an ample glossary plus appendices listing the various digital codes (Morse, Baudot, AMTOR, ASCII). There's a clever little bonus at the end, too: to give readers an opportunity to check how well they've retained what they've read, Jim has included a 33-question test covering topics discussed in the book. Answers are included, plus references to page numbers where subjects covered by questions can be found. Score 80 or better (on your honor), send Jim an SASE, and — just for fun — he'll send you a certificate attesting to your status as an official "Digital Novice."

"Noise Monster" substantiates author's assertion that noise is the natural enemy of digital communications.

Ted Barney's cartoons go a long way toward lightening up *The Digital Novice*. I was pleased, too, by Jim's conscious (but never self-conscious or heavy-handed) effort to ensure gender fairness throughout the text; his deft use of pronouns may help women entering Amateur Radio through the digital modes feel more welcome.

The Digital Novice will be released at this year's Dayton Hamvention®, you can meet the author at his booth (QSKY Publishing, No. 358) if you're there. You can also catch his presentation on Sunday morning at 9:30 AM. Whether or not you make it to Dayton this year, you can order your copy of *The Digital Novice* from Ham Radio's Bookstore Store for $9.95 plus $3.50 shipping and handling.

— KA1LBO

NEW products

solid-state linear amplifier

The latest addition to the Yaesu product line — the new FL-7000 Solid State Linear Amplifier for the 160 through 15 meter bands — features an automatic antenna tuner with automatic band-switching when used with the Yaesu FT-757GX, FT-767GX, or FT-980 transceivers. Antenna switching is also automatic when using the FAS-1-4R remote antenna selector. Power output is 1200 watts, for approximately 70 watts input. A protection circuit prohibits operation with high SWR until the antenna tuner completes matching process. Thermostatically controlled dual fans run even when the amplifier is turned off, if needed for dissipation of heat.

For details, contact Yaesu U.S.A. Amateur Products Division, 17210 Edwards Road, Cerritos, California 90701.

Circle #312 on Reader Service Card.

new dual-port tnc, personal mailbox upgrade

The new KPC-4 Dual Port Communicator from Kantronics features two fully-functional VHF packet ports, digipeating on each port, VHF gateway between ports, and an RS-232 computer port. Digipeating and gateway operations occur simultaneously while you're connected on one or both ports. You can bridge two frequencies on one band and operate crossbands.

The KPC-4's RS-232/TTL terminal interfacing provides universal compatibility to all computers, including Commodores and PC compatibles. Stream switching provides for access to both radio ports, each of which supports AX.25.

Priced at $329.00, the KPC-4 contains the popular Personal Packet Mailbox™ feature (optional on all other Kantronics Packet Communicators), a 256K EPROM that allows you (and others) to leave and collect messages on

NEW products

your system. All other functions of your packet unit continue to be available at the same time. Established and operated from your keyboard, the mailbox uses familiar commands such as SEND, LIST, READ, KILL, and BYE. The number of messages is limited only by the amount of RAM available in your packet unit.

The Personal Packet Mailbox option is currently available for the KAM (Kantronics All Mode), the PKC-1, the KPC-2, and the KPC-2400. To add the Personal Packet Mailbox option to your Kantronics packet unit, contact Kantronics or an authorized Kantronics dealer. The option retails for $39.95 (plus $2.50 for shipping if ordering through Kantronics), and includes a replacement plug-in EPROM and an installation/operations manual.

For further information, contact Kantronics, Inc., 1202 E. 23 Street, Lawrence, Kansas 66046.

Circle #315 on Reader Service Card.

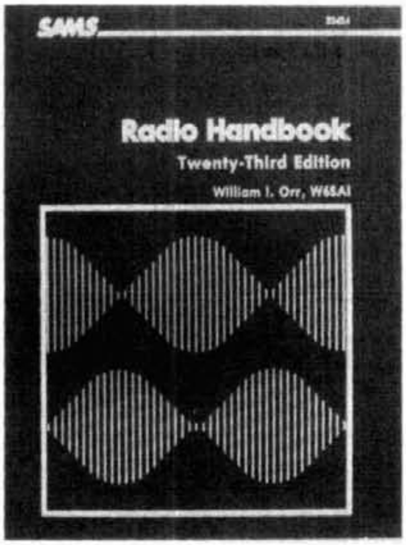
new *Radio Handbook*

The 23rd Edition of Bill Orr, W6SAI's, *Radio Handbook* has just been released by Howard W. Sams & Company.

Completely revised and updated, this edition contains new material reflecting the latest developments in technology, covering everything from HF-VHF amplifier design to interference reduction for VCRs and video disc players.

Readers will find schematics, photos, construction diagrams, tables, and charts right at their fingertips, for expert guidance and instant reference. Specific topics addressed include an introduction to Amateur Radio communications; fundamental of communications receivers; fm and repeaters; mobile, portable, and marine equipment; radio and television interference; equipment design, components, and controls; VHF and UHF antennas; and transmission lines and matching systems.

Licensed as a radio amateur in 1934, Bill has authored or co-authored many books. Editor of the *Radio Handbook* since 1955, he's written



hundreds of technical articles, including a monthly column in *ham radio*.

Bill Orr's *Radio Handbook*, 23rd Edition, (640 pages, hardbound) retails for $26.95 and is available from Ham Radio's Bookstore, Greenville, New Hampshire 03048. Add $3.50 for shipping and handling.

new 900-MHz antennas

Two new 900-MHz antennas available from NCG are specifically designed for operation in the 902-928 MHz band.

The anodized black Model CMW-202N mobile antenna, a 5-dB gain antenna capable of a maximum of 30 watts of drive power, uses a magnetic mount with a double coil whip. The 900-MHz base/repeater antenna, model CFC7-71, is a collinear fiberglass antenna with a gain of 7.14 dB and maximum power capability of 50 watts. Mast mounting brackets and hardware is included.

For information, contact NCG Company, 1275 N. Grove Street, Anaheim, California 92806.

Circle #310 on Reader Service Card.

new hf amplifier

Tokyo Hy-Power Labs' HL-2K/A is a compact hf amplifier utilizing the popular 3-500Z transmitting tubes. Similar to their HL-1K/A, it features a built-in power supply with a heavy-duty transformer that permits continuous key-down operation. The amplifier is equipped with two large panel meters: one monitors plate current, and the other can be switched to read plate voltage, grid current, or power output. A delayed cooling fan system protects the tubes for a timed period after the power has been turned off.

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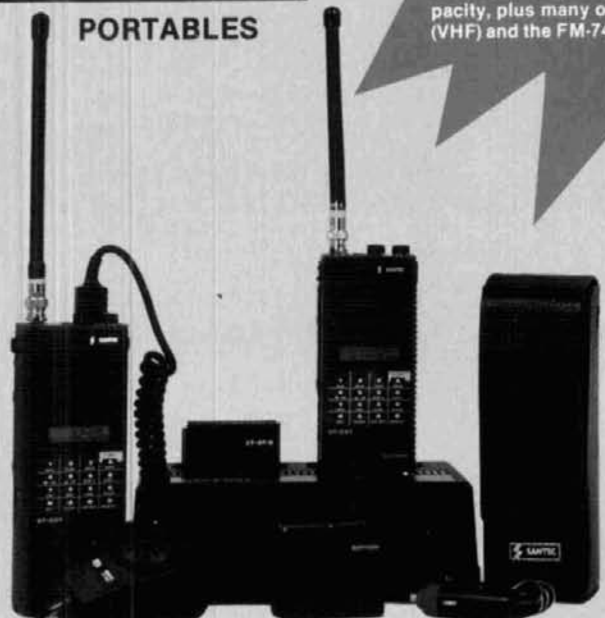

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NEW products

The price of the HL-2K/A is $1695. For details, contact ENCOMM, Inc., 1506 Capital, Plano, Texas 75074.

Circle #309 on Reader Service Card.

Lunar returns to market

Lunar Industries, Inc., of San Diego has re-entered the Amateur Radio market with its well-known line of VHF and UHF preamps and VHF power amps, and has introduced a new line of products scheduled for production early this year. Glenn Rattmann, K6NA, heads the marketing effort.

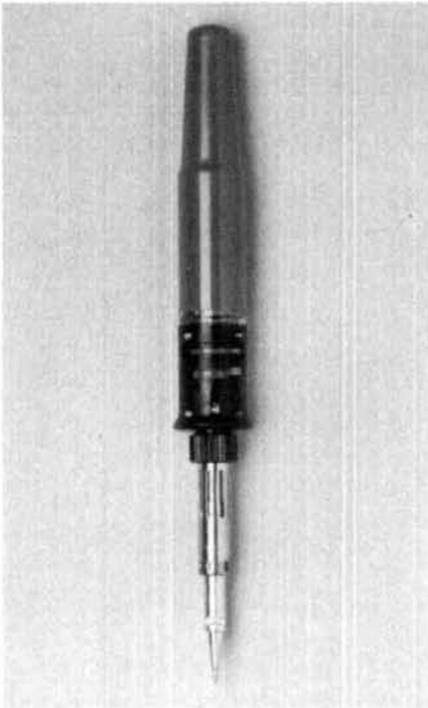
Lunar recently moved into larger facilities in order to accommodate expanded production of Amateur and commercial communications and television equipment. A network of select dealers is being established and inquiries are encouraged. For details, contact K6NA at Lunar Industries, Inc., 7930 Arjons Drive, San Diego, California 92126.

Circle #308 on Reader Service Card.

cordless tool for soldering, welding, heat shrinking

The Ultratorch, available now from Jensen Tools, is a compact, cordless combination soldering iron, flameless heat tool, and torch. The Ultratorch burns ordinary butane lighter fuel to generate infra-red and ultra infra-red heat by means of a catalytic combustion system. Temperature can be adjusted from 394 degrees to 2372 degrees. Normal settings range from 394 degrees to 932 degrees F for soldering; to 1292 degrees for heat shrinking; and to 2372 degrees for blazing, welding, and other high-heat applications. Soldering/heat ejector, torch ejector, tapered needle soldering tip, heat tip, solder

NEW products



sponge, tip cleaner and spanner wrench are all included.

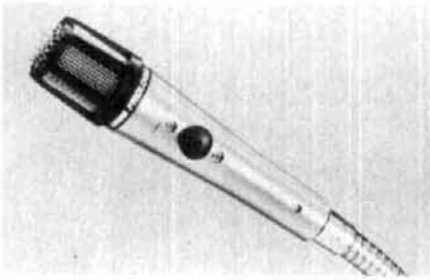
For more information and free catalog, contact Jensen Tools, Inc., 7815 S. 46th Street, Phoenix, Arizona 85044.

Circle #307 on Reader Service Card.

new mic

Shure Brothers Inc. has introduced the Shure Prologue 2L, an economical dynamic microphone for gooseneck applications.

Priced at $40, the Prologue 2L provides a wide-range frequency response with a low-end rolloff and high-end presence boost for intelligibility and clarity. Other features include a long-life, easy-



access momentary push-to-talk switch, a tight cardioid polar pattern for effective rejection of feedback and background noise and chrome-plated metal casing.

For information, contact Shure Brothers Inc., Customer Services Department, 222 Hartrey Avenue, Evanston, Illinois 60202-3696.

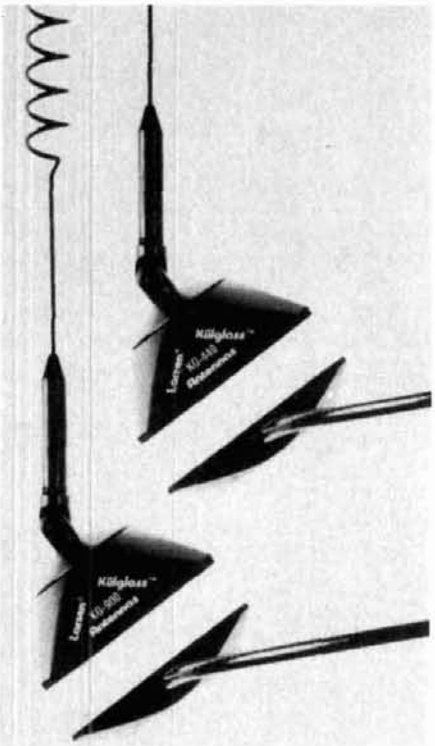
Circle #306 on Reader Service Card.

two new Kulglass™ antennas

Larsen Electronics has added two new models to its line of patented Kulglass antennas: the KG-440 and the KG-900. The two new antennas offer the same features as the earlier KG-450 and KG-825, but extend Kulglass™ convenience and performance to the 440-450 and 902-928 MHz bands.

The Kulglass tuning assembly is placed on the outside surface of the glass — a car windshield, for example. This allows a low-impedance power transfer through the glass.

The KG-440 is based on a single half-wave design that offers unity gain performance without a ground plane and up to 2.4-dB gain in a typical vehicle installation.



The antennas are fully adjustable to vertical for practically any window angle. This permits their resonant design to attain a low VSWR, a low radiation angle, and maximum omnidirectional range without a ground plane. This is especially important with the KG-900 because

NEW products

of the multipath signals and low power used in this band.

Both antennas feature a removable whip (which can come in handy in zero clearance situations, such as at the car wash) and Larsen's exclusive Kulrod T™ plating. The antenna kits include 14 feet of premium RG-58 A/U dual-shield, low-loss coax and choice of connectors.

For further information, contact Larsen Electronics, P.O. Box 1799, Vancouver, Washington 98668.

Circle #305 on Reader Service Card.

HF/VHF packet radio controller with tuning indicator

MFJ Enterprises' latest TAPR TNC-2 clone, the MFJ-1274, ($169.95) works not only for VHF but also for HF, OSCAR, and other non-fm packet. MFJ has made the 1274 modem-selectable for both VHF and HF operation, added their precision 20-segment LED tuning indicator, a TTL serial port, an easily replaceable lithium battery for memory back-up, and a new cabinet.

All you need to enjoy packet radio is an MFJ-1274, your rig, and any home computer with an RS-232 or TTL serial port and terminal program.

If you have a Commodore 64, 128 or VIC-20 you can use MFJ's optional Starter Pack to get on the air immediately. The Starter Pack includes interfacing cable, terminal software on disk or tape and complete instructions . . . everything you need to get on packet radio. The MFJ-1282 (disk) and the MFJ-1283 (tape) are $19.95 each.

With the MFJ-1274, you'll never have to worry about your TNC's becoming obsolete because you change computers or because packet radio standards change. You can use any computer with an RS-232 serial port with an appropriate terminal program. If packet radio standards change, software updates will be made available as TAPR releases them.

With the addition of a suitable external modem, speeds in excess of 56 kilobaud are possible.

The MFJ 1274 features AX.25 Level 2 Version 2 software, hardware HDLC for full duplex, true Data Carrier Detect for HF, multiple connects, 256K EPROM, 16K RAM (expandable to 32K with optional EPROM), simple operation, and socketed ICs.

You get an easy-to-read manual, a cable to connect your transceiver (you have to add a connector for your particular radio), a connector for

NEW products

the TTL serial port and a power supply for 110 VAC operation (you can use 12 VDC for portable, remote or mobile operation).

The MFJ-1274 comes with a double guarantee. If ordered directly from MFJ, it may be returned within 30 days for a prompt refund, less shipping. The MFJ-1274 is also covered by MFJ's one-year unconditional guarantee.

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

Circle #311 on Reader Service Card.

computer control of rf monitoring

The CR 202, a sophisticated new receiver distributed by Ace Communications, allows monitoring of any frequency from 25 to 550 MHz, plus 800 to 1300 MHz.

With both narrow and wide band reception modes in fm and also a-m, the receiver, priced at $445, is excellent for general monitoring and surveillance reception of a wide variety of services.

Uses for the unit include general off-air monitoring, spot frequency monitoring and stength measurement, selective multi-frequency analysis, spectrum surveillance, and detection of unwanted transmissions.

An optional digital control accessory permits the user to interface the receiver to any computer equipped with a standard RS-232C port. The resulting computer control permits virtually unlimited channel monitoring and activity analysis with normal communications, text editing, and data base software. A dedicated menu driver software package and a full line of accessories are available.

For information, contact Ace Communications, Monitor Division, 10707 East 106th Street, Indianapolis, Indiana 46256.

Circle #304 on Reader Service Card.

new battery packs

Two new battery packs for King Radio Corporation products are available from Centurion International Inc. No. KR0105 is a 9.6-volt, 800 MAH nickel-cadmium rechargeable battery pack; No. AL0514 is a 13.5-volt, 2100 MAH throwaway alkaline pack. For prices and details, contact Centurion International, Inc., P.O. Box 82846, Lincoln, Nebraska 68501.

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NEW
products

Super ComShack 64™

On January 1, 1987, Engineering Consulting shipped the first Super Com Shacks 64's to previous purchasers of the Com Shack 64 Duplex/Simplex ham shack and repeater controllers. The first units shipped were designed to upgrade existing systems to allow the features found in the new "Super" version.

New features of the "Super" version include a unique code practice mode, speed dial data entry of command strings consisting of multiple commands, and nine complete sets of access codes which can be changed at any time remotely from an HT or telephone, allowing instant repeater access code changes, which can reduce unauthorized use of repeater functions. The system autopatch supports up to 310 stored telephone numbers; ten emergency numbers may be accessed instantly with two digit commands. The balance of the 300 numbers may be stored via touchtone and recalled at any time.

Three hundred callsigns can be programmed into the new Super ComShack. In the "directed page mode," an unlicensed person can call the repeater telephone line and receive a voice message identifying the repeater and requesting input of a three-digit code. A valid code will voice-page the selected callsign over the repeater. If the page message is answered by the Amateur with the proper answer code, the calling party is then put "on the repeater" and a normal conversation can take place. If a control operator needs to gain access to the repeater, it can be done via telephone or touchtones from an HT.

The Super ComShack system offers dual remote base capability, which allows both UHF and HF radios to be input or linked to the main repeater. Total control of the link radio is provided through the use of serial data. Software is included to control the Yaesu FT-757, FT767, FT980, and FT-727; the Kenwood TS440 and TS940; the TM711/811; and Icom's IC735 transceivers. New radios are being added as manufacturers provide samples for serial data programs to be tested.

A new system — dubbed the "Ultra" — is currently under development. Compatible with the "Super," the "Ultra" will link several systems together, allow for Packet input, and incorporate other advanced features.

The Super ComShack is available from Engineering Consulting, 583 Candlewood Street, Brea, California 92621.

solder 14 different metals — with a match

Quick Silver is a new silver-bearing bonding paste that flows at 430 degrees F using a match, butane lighter, or soldering gun — not 1200 to 1300 degrees F, as in conventional silver soldering. Quick Silver has a tensile strength of 18,000 to 22,000 psi compared to only lead solder's 3,000 psi.

Quick Silver is furnished in a syringe-type applicator that enables the user to apply the paste first and then hold and apply heat. Suitable for electrical work where high conductivity and strength are required, it conforms to pure food laws (i.e. contains no lead, zinc, cadmium or antimony) and provides a good color match to stainless steel. It won't darken or tarnish.

Quick Silver can be used on brass, bronze, chrome-plated steel, chrome-plated copper, copper, gold-filled and gold-plated materials, molybdenum, nickel silver, silver, stainless steel, steel, sterling silver, 800 silver, tin, and zinc. Priced at $9.95 plus $2.00 postage and handling, it's available from E.L. Jones Company, P.O. Box 849, Sanford, North Carolina 27330.

Circle #302 on Reader Service Card.

DX nets, beam headings

DX Net List Around the World provides full information about all active DX nets and updates the DX Net List for 1987. Previous editions of the list — with information about DX Nets that might be reactivated as conditions allow — are still available.

DX Beam Headings Around the World shows bearing, distance in miles and kilometers, and reverse bearing for your QSO partner), for both shortpath and longpath, for more than 450 locations throughout the world. Special care has been taken for the Antarctic, USA, USSR, the Peoples Republic of China, and the Pacific Ocean.

For information, contact Ing. Christian Hohenwallner, OE2CHN, Gneisfeldstrasse 5, A-5020 Salzburg, Austria or Dieter Konrad, OE2DYL, Bessarabierstrasse 39, A-5020 Salzburg, Austria.


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PRODUCT REVIEW/NEW PRODUCTS

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Limit 15 inquiries per request.

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KENWOOD

...pacesetter in Amateur radio

First Again!

TW-4100A

2 m/70 cm FM Dual Bander

A Kenwood original just got better! Kenwood was the first to develop a 2 m/70 cm mobile radio in a single, compact package. Since then, other companies have imitated the concept, but still have not done it the "Kenwood way." The all-new TW-4100A is more compact, more powerful, and packed with more features than ever before! With many new features and accessories, and backed by Kenwood's experience, the all-new Kenwood Dual Bander is light years ahead of the rest!

- Selectable full duplex cross band ("telephone style") operation. Remote base or cross band repeater function possible (a control operator is needed for remote or repeater operation*).
- 45 watts on 2 m. 35 watts on 70 cm. 5 watts (adjustable) low.
- Frequency coverage: 142-149 MHz (allows operation on certain MARS and CAP frequencies) and 440-449.995 MHz.

- New compact size! Only 5.9" W x 1.97" H x 7.87" D and weighs less than 4 pounds!
- Proven high performance Kenwood GaAs FET front end receiver.
- Easy to operate! Only 3 knobs and 8 keys on the front panel.
- Separate antenna ports for VHF and UHF. Minimizes loss and increases reliability and performance!
- 10 memory channels. Lithium battery backs up memory. Store frequency, offset, subtone. Two channels store the transmit and receive frequencies independently **for odd split or cross band operation.**
- Front panel-selectable CTCSS tone (when optional TU-7 is installed.)
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- Selectable frequency step for quick and easy QSY.
- Voice synthesizer VS-2 option.

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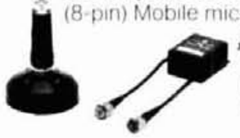

- Digital Channel Link (DCL) option.

*Please check FCC regulations on repeater operation.
Minor modification necessary for repeater operation.
Specifications and prices subject to change without notice or obligation.
Complete service manuals are available for all Trio-Kenwood transceivers and most accessories.

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