BEAM ANTENNAS for the H.F. RANGE

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The author presents a multiband beam antenna designed for 10, 15, 20, and 40 meters. He has avoided the use of traps and interlaced elements by employing tuning stubs switched by relays. The approach has been experimental and the antenna, while it performs satisfactorily now, is still being worked upon. The author would like your comments.

For some time I have had a desire to experiment with antennas in the h.f. range with the idea of coming up wtih a new approach to the problem of providing a multiband rotatable array with the desirable gain and front-to-back ratio characteristics.

Design

The first approach was to consider interlaced elements. This was discarded because of the extreme inefficiency in the use of aluminum tubing since only a small fraction of the elements are in use on any one band at a time. The second approach was the use of traps. Two major objections to traps soon ruled these out. First, they complicate the problem of maintaining the mechanical integrity of the element and second, considerable care must be taken in the electrical design to insure that they won't burn out and to keep the losses, which are inevitable, to a minimum. I now had narrowed the approach down to multi-band, trapless elements.

Perhaps the best known trapless multi-band beam now in use is the G4ZU type. I have built both the mini-beam and the super mini-beam and found their performance to be good on 10 and 15 meters and only slightly under par on 20 meters. The mini-beams served as a convincing example of the efficiency and practicability of three very useful principles. First, was the use of stubs to switch from one band to another. Second, was the idea of using an antenna tuning network with low loss open wire line to feed directly into the center of a non-resonant radiator. And third, that elements could be shortened to as little as 0.3 wavelength without seriously affecting their efficiency.

Because of the complexity of the problem of trying to match a multi-frequency antenna of this sort to a single feed line, the impracticability of running separate feed lines for each band, and, in my case, the 300 foot run which was required to get to the antenna, it was decided definitely to adopt the use of low loss open wire feeder. It now remained to come up with an element configuration which could handle the desired harmonically related frequencies.

After much juggling of figures it was decided that it should be possible to make one element work on 10, 15, 20, and 40 meters by making it about 45 feet long and bringing it to resonance with stubs in the center. This element length was arrived at by asking what was the maximum useful length which could be used on 10 meters and then, what was the minimum length which could be used on 40 meters and still maintain reasonable efficiency. Since it was desired to keep the pattern of the antenna from splitting into a clover leaf, the maximum element length for the best forward lobe characteristics would be equivalent to the "double extended zepp" or approximately 1.28 wavelengths. (At this point it was decided the frequencies to be considered would be 7.15, 14.3, 21.45, and 28.6 mc.) At 28.6 mc, using the long wire equation $L = 984 (N-.025)/f(mc)$, we have approximately $984 (1.28-.025)/28.6 = 43.2$ ft. On the other hand

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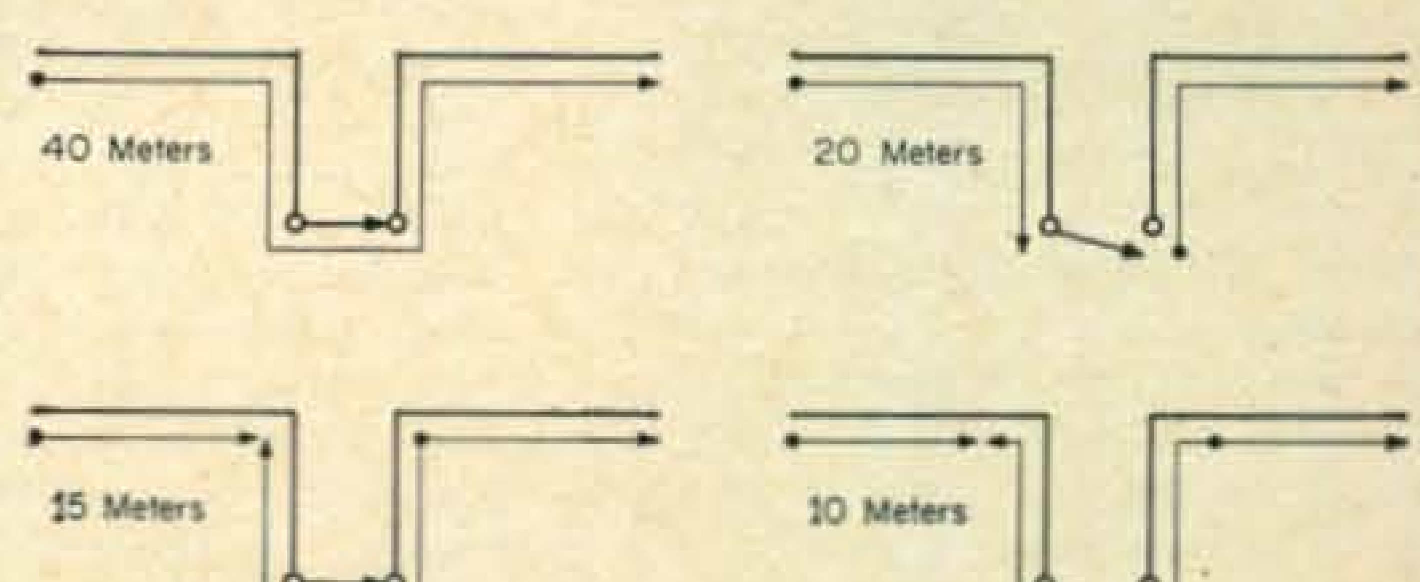


Fig. 1—The resulting element and stub current and phasing for the lengths indicated in the text.

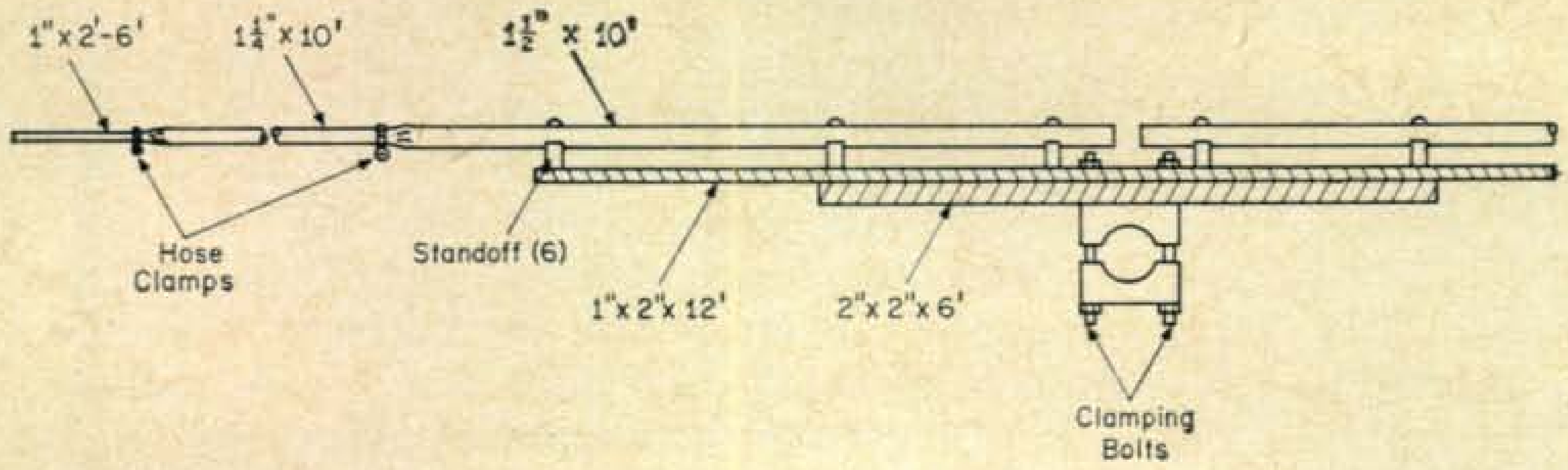


Fig. 2—Construction method used for the elements. The boom clamp is made from 2 × 6 with a 4" diameter hole.

the minimum desirable length for 40 meter use was considered to be .30 wavelength, as illustrated by the mini-beam, $984(.3-.025)/7.15 = 37.8$ ft.

After considering these dimensions it was decided to pick element lengths which would correspond to collinear half-wave operation on 15 meters. Since the actual element length is relatively non-critical it is the resonant length after adding the stub that really counts), a set of figures were settled on for element lengths after consulting most of the well-known beam antenna handbooks and reference books. The element lengths were then settled as follows:

Reflector: $2 \times 501/21.45 = 46.8$ feet
Driven Element: $2 \times 473/21.45 = 44.2$ feet
1st Director: $2 \times 445/21.45 = 41.6$ feet
2nd Director: $2 \times 440/21.45 = 41.0$ feet

Next, the element spacing was determined by similar process of compromises, *i.e.*, what is minimum for 40 meters and what is maximum for 10 meters? After electrical and practical considerations were taken into account, it was decided to equally space four elements on a thirty foot piece of irrigation tubing. This results in just over 0.07 wavelength spacing on 40 meters and just under 0.30 wavelength spacing on 10 meters.

Having settled on the element lengths and spacing it was now necessary to devise a practical method of bringing the elements into resonance, with the proper phasing, at the various frequencies. After quite a number of schemes had been considered, one was finally hatched which appeared to be by far the simplest and most straightforward. It was based on the fact that a 40 meter half-wave antenna would also be approximately resonant on 20, 15, and 10 meters. Therefore, if the resonant length could be made equal to a half-wave on 40 meters and the phasing could be altered from one band to the next to keep the currents in the elements adding in phase, the objective would be met. This was accomplished by taking the basic element earlier derived, splitting it in the center, and inserting a stub, with a shorting relay on the far end, which would bring the antenna to resonance on 40. The resulting element and stub current phasing is shown in fig. 1.

To feed the antenna it had been decided to use open-wire feeders with a tuner at the transmitter end. To keep the s.w.r. to a reasonable level a stub was attached at the center of the driven element the same as with the other elements. The feed line was then attached to the element at the same point as the stub. Although no impedance measurements have been taken, this point of the element should be a medium impedance on all bands. Keeping in mind that if the matched transmission line loss was kept down to 0.5 db by use of open wire line, that the additional loss due to an s.w.r. of 5:1 would only be about 0.7 db. It was decided that this would be acceptable.

Construction

Because of the winter icing conditions and high winds in the Spring at this location it was decided to perform a fairly thorough analysis of the ice and wind load which might be expected on the antenna. After calculating the element loading associated with ½" of radial ice and 70 m.p.h. winds, it was found that, using an average element diameter of 1¼", either force by itself would run between 15 and 20 pounds per half element. Bending moments were then calculated and a rough stress analysis was run to come up with the element construction.

Element Construction

The resulting construction of each half element consists of three pieces of aluminum tubing: 1 piece of 1½" o.d. × 10′ Channel Master t.v. mast, 1 piece of 1¼" o.d. × 10′ Channel Master tv mast, and 1 piece of 1" o.d. long enough to make up the difference.

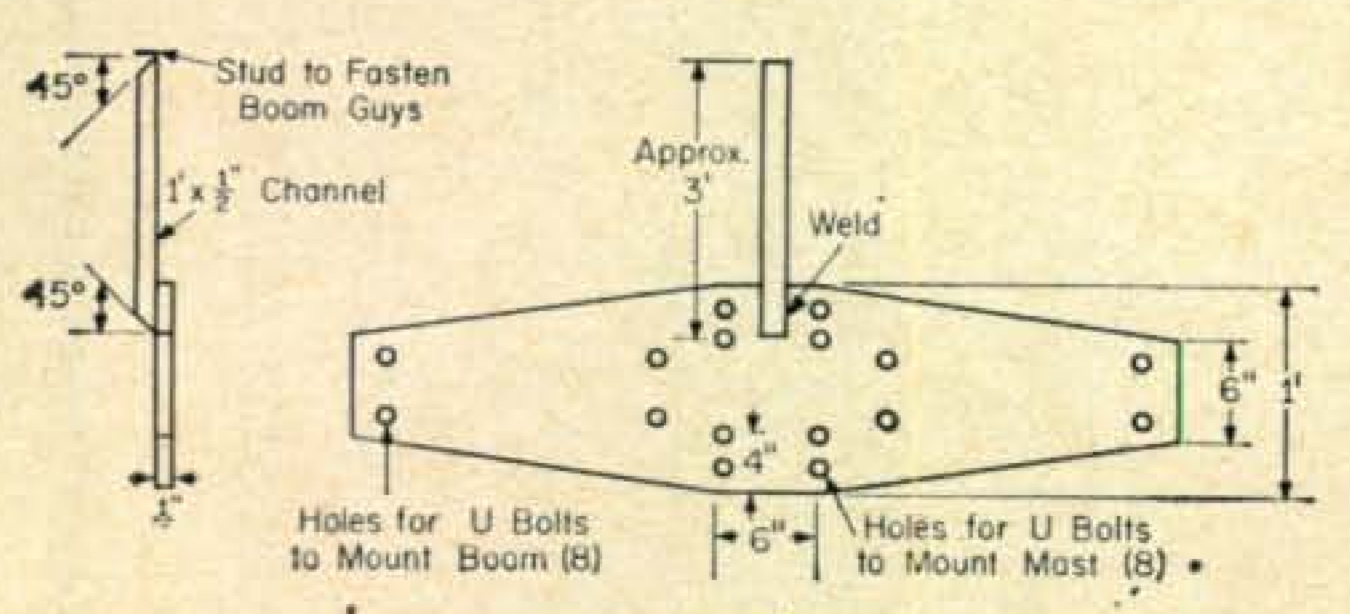
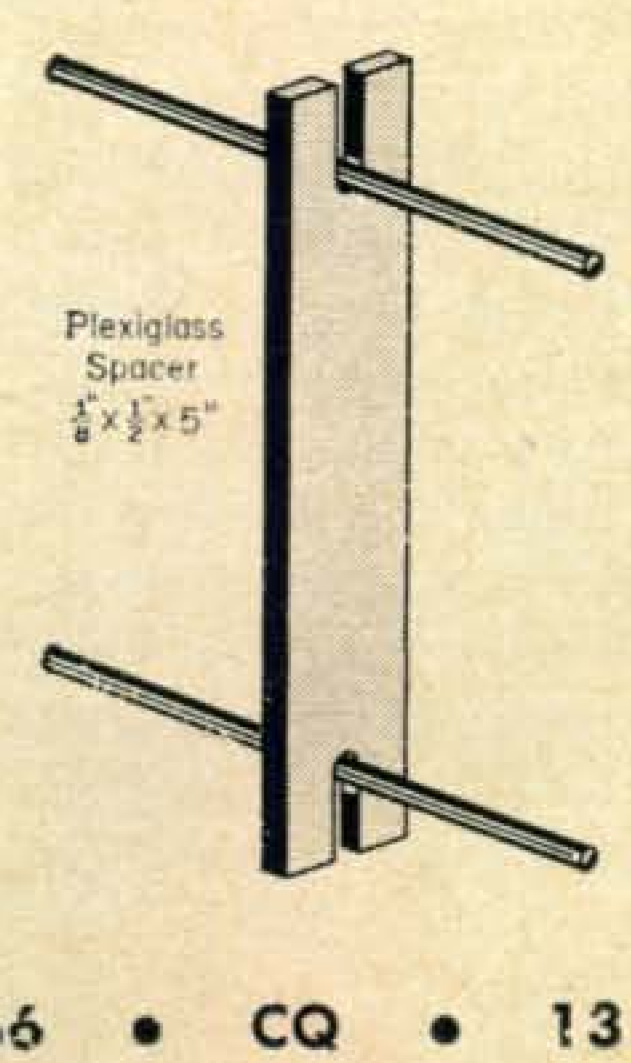


Fig. 3—Dimensions for the mast to boom plate made from ¼" steel plate. The 3 foot angle iron is used to support the boom guy wire.

Fig. 4—Stub construction requires plexiglass spacers ⅛" × ½" × 5" every two feet. The wire is heated with a soldering iron and forced into the plexiglass slot cut with a hacksaw.



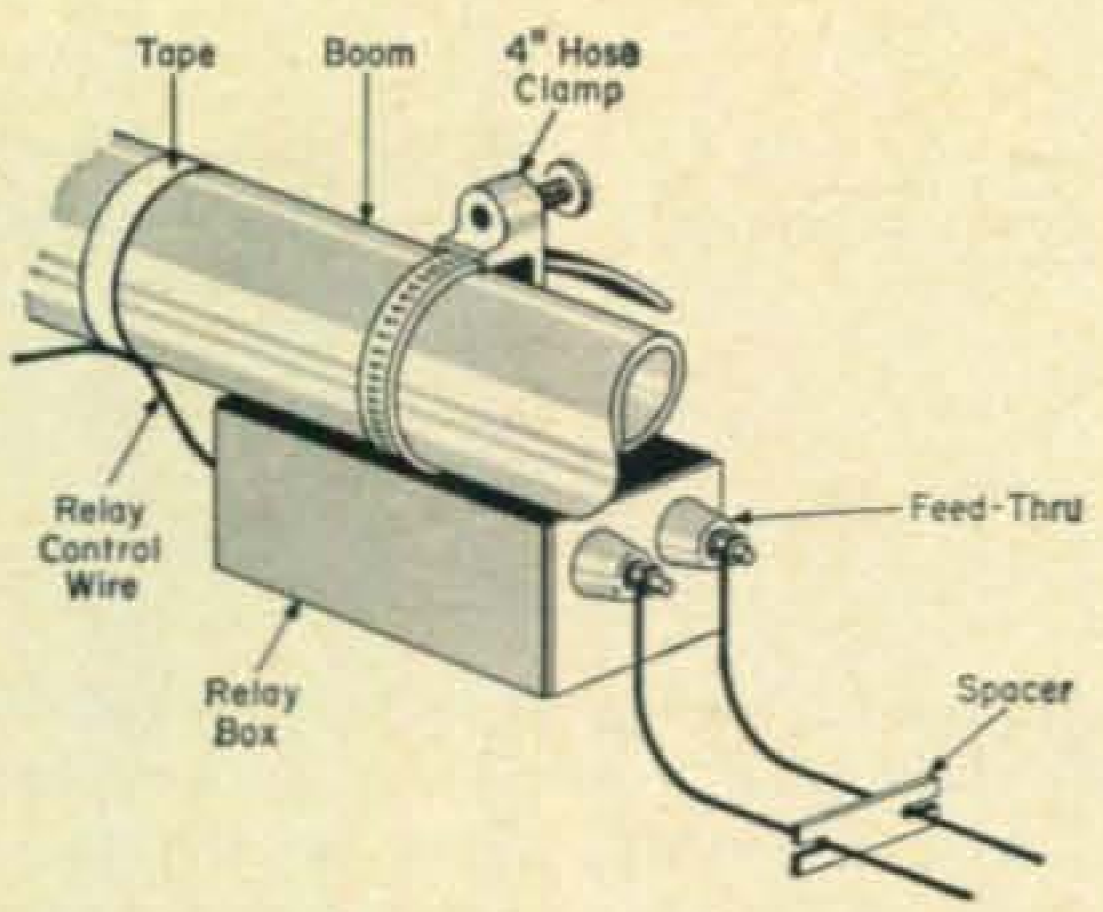


Fig. 5—Mounting of the relay on the boom at the end of the stub. Relay coils should be fed power according to local electrical codes.

The ¼" increments used in element section diameters is made possible by the fact that one end of each mast section is necked down to allow stacking of sections. If however, the little butt tap is removed and the swedged portion is split with a hacksaw, the next smaller size fits snuggly in. The swedged section is about six inches long and when clamped with a standard aircraft hose clamp, it provides a very adequate joint. Standard procedures were followed in steel-wooling the inserted portion of the elements and coating them with a protective compound such as Penetrox.

Three standoff insulators were used for each half element. These were purchased from the Mosely antenna line and are the larger of the two types available, measuring 2½ inches overall height. The element support consists of a 12 foot 1 × 2 glued and and screwed onto a 6 foot 2 × 2. These should have a minimum of two coats of good exterior grade house paint.

The boom to element joint is made by drilling a 4" hole in a piece of 2" × 6". This is then split in a horizontal plane and bolted onto the element support to use as a clamp. (See fig. 2). The boom is a 30' length of 4" diameter irrigation tubing.

After the first element was constructed, it was loaded with a 25 pound weight about 10 feet in from one end. The element sagged several feet, but was quick to return to normal, with no permanent set after the load was removed so the design was considered satisfactory.

Boom To Mast Joint

Next, the boom to mast joint was constructed. This was made as a trunkated diamond shaped plate with four "U" bolts to hold the boom to the plate and four more to hold the plate to the mast. Saddles were made to go between the boom and its mounting bolts to distribute the forces on the boom. These saddles were made by cutting half sections of 4" i.d., ¼" wall, pipe. Since the mast is 2" o.d., ¼" wall steel tubing, it was not felt that saddles would be necessary under the mast mounting bolts. A 3-foot piece of small (approximately ¾") channel was welded to the plate to furnish the boom guying point. With all of the elements and hardware mounted it is possible to see through the inside of the boom from one end to the other without guys, but it was decided to add them anyway as an added safety factor for the boom and to help stabilize the outboard elements. (See fig. 3.)

The other three elements were then built and mounted on the boom, the boom to mast joint was assembled, and this much was mounted about eight feet above the ground ready for the stubs, relays, feedline, and tuning.

The stubs were made by taking two #12 wires and melting on plexiglass spacers about every two feet. (See fig. 4.)

The relays used are heavy duty normally open, double make type with 25 amp contact rating and about ¼" gap when open. These were mounted inside appropriate sized plastic refrigerator dishes with r.f. leads brought out through steatite feedthroughs and the relay control line brought out through a small clearance hole. A mounting plate was added to allow clamping the box to the boom. (See fig. 5.)

The feedline used from the driven element to a point on the stationary side of the rotator is Saxton type INS-500 which is a flexible, fully insulated, web type 500 ohm twin lead. This is anchored to the mast and boom by use of aircraft clamps and standard TV standoffs. (See fig. 6.) From the rotor on down standard 500 ohm open wire line was used.

The cable supplying power to the relays is a standard vinyl jacketed multiconductor flexible cable. It is taped to the boom and mast and a slack loop is left to allow rotation.

The complete antenna is shown in fig. 7.

Tuning

Because of the ease of coupling a grid dip oscillator into the tuning stubs by using a clip lead about a foot long from one side of the stub to the other with two or three turns around the g.d.o. coil, it was decided to approach the tuning problem from the standpoint of resonating each element to a predetermined frequency. Many techniques and different percentage differences between elements have been tried, but only the final set will be presented. Because of the variation in element length and spacing in terms of wavelength on the various bands, the figures represent a compromise which results in reasonably good patterns on all bands.

The procedure requires only a g.d.o. and a

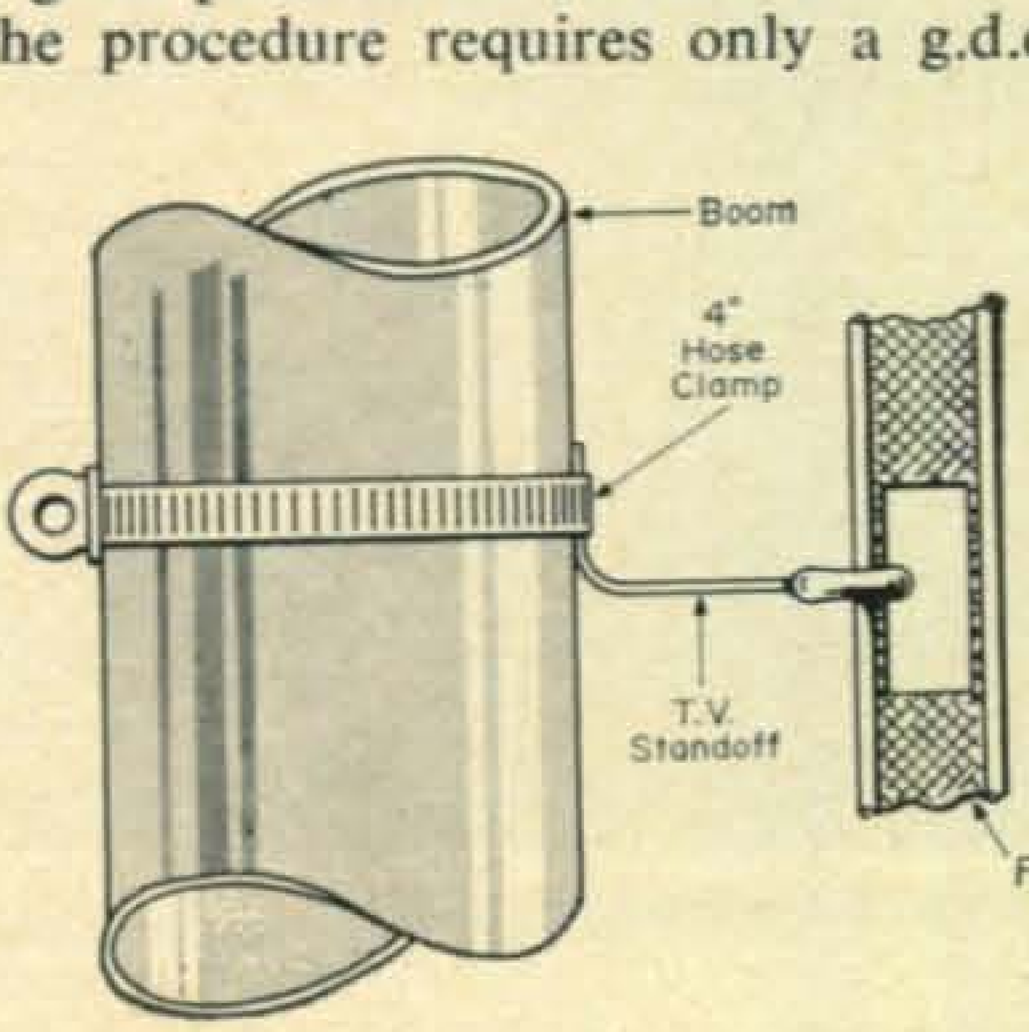


Fig. 6—Method of supporting feedline along the boom.

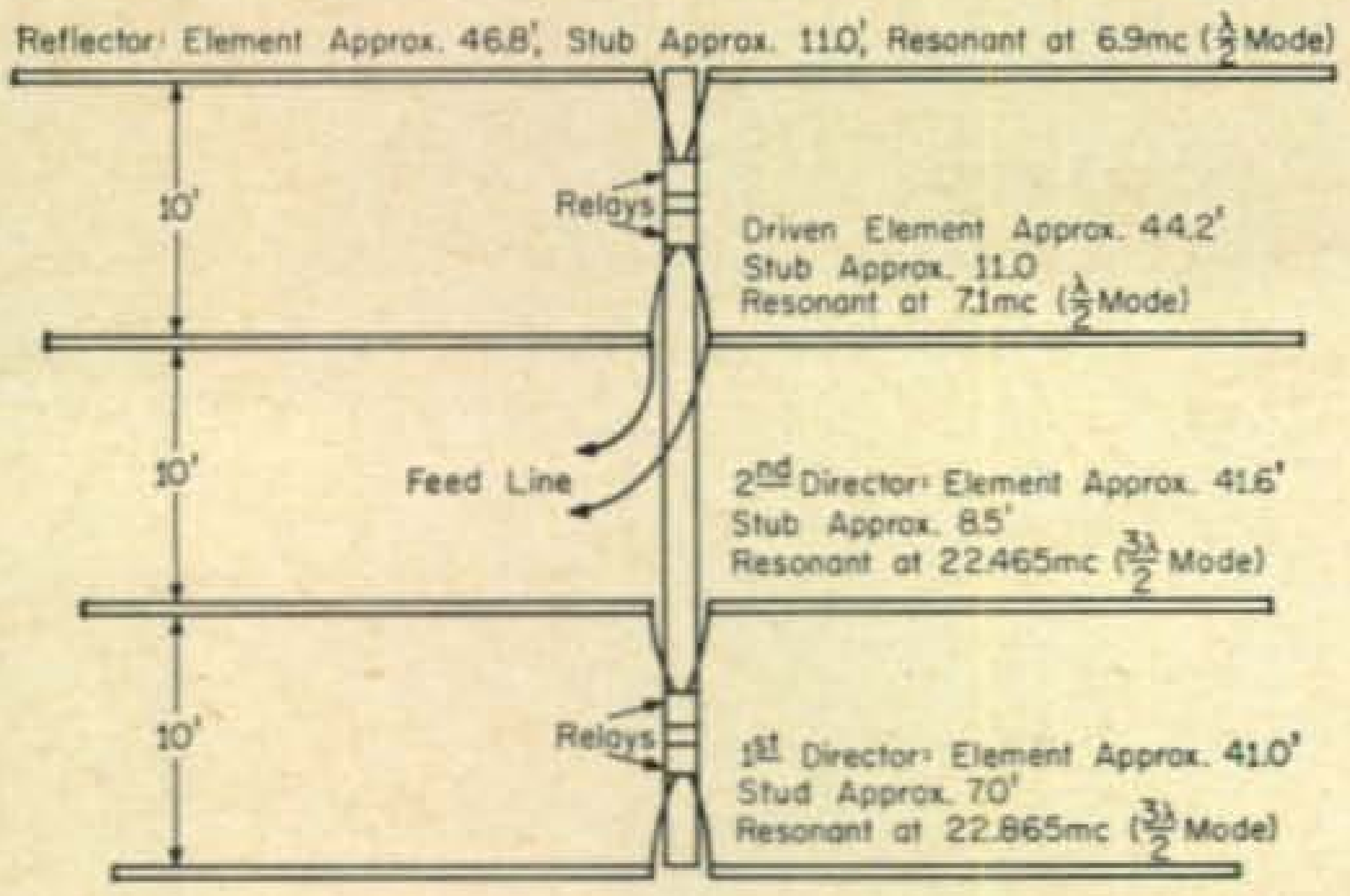


Fig. 7—Complete antenna element and stub dimensions.

general coverage receiver (with a 100 kc calibrator) to check the calibration of the g.d.o. In my case the receiver was moved out to the antenna, set to the desired frequency and monitored with b.f.o. on. When the g.d.o. passed through the desired frequency the audio heterodyne was unmistakable. Although the calibration on some g.d.o.'s is reasonably good, it is recommended that the receiver be used because the loading on the g.d.o. at the element's resonant frequency is often enough to pull the oscillator off calibration by a significant amount. It is also suggested that frequencies derived below be adhered to within plus or minus 0.5 to 1.0%. Beam patterns taken under various element tuning conditions indicated that changes in the order of 1 to 2% had a definite effect on the antenna pattern.

Because of the effective lengthening of the elements with increasing frequency (noted by checking that resonance occurred at less than harmonic multiples), it was decided to resonate the reflector on 40 meters. This insured that on all higher frequencies, its resonant frequency would be below the operating frequency to insure reflector action. Also, at 40 meters the stub should be shorted and the pick-up loop for the g.d.o. accomplishes this.

Although from the standpoint of element "lengthening" the directors should be resonated on 10 meters, they were tuned to slightly shorter than normal lengths on 15 meters to again take advantage of being able to couple into the end of the stubs with a shorting loop.

The driven element was somewhat of a toss up, but since the biggest compromises up to this point had been taken on 40 meters, it was decided to try to help even things out by tuning it on 40.

After looking over figures that others had used, a height correction factor to correct for the capacitive loading effect of the ground on the antenna of 100 kc on 40 meters and 35 kc on 15 meters was decided on. This is to help compensate for the change in tuning when the antenna is raised from 8 feet to the operating height of 53 feet. Another correction which was considered was that the relays would add some length to the stubs when they were connected. To compensate for this the leads on the g.d.o. pickup coil were made approximately equal to this.

After all these compromises and corrections were made the following self-resonant element frequencies were calculated.

Reflector:
$(7{,}150 - 2\%) - 100 = 6.900$ kc
Driven Element:
$7{,}200 - 100 = 7.100$ kc
First Director:
$(21{,}450 + 5\%) - 35 = 22{,}465$ kc
Second Director:
$(21{,}450 + 7\%) - 35 = 22{,}865$ kc

Standard beam tuning techniques were used from this point on. Stubs were cut plenty long to start out and shortened a little at a time, switching from one element to the next without trying to bring an element all the way in on the first pass. Coupling between elements is quite appreciable, so those which were not being tuned had their stubs shorted to keep them near resonance.

Results

Figure 8 shows the final patterns taken with the antenna at 53 feet. These patterns were taken by receiving a signal (transmitted from a few miles away) on an NC-183D with the a.g.c. turned off and figuring 5 units per "S" unit and one unit per db above S9. Upon checking the receiver with a calibrated signal generator it was found that about 2.5 units equal one true db. (Pattern dissymmetry was caused by local conditions.)

In operation the antenna has provided most gratifying results. It has compared quite favorably on all bands with other antennas in the vicinity after appropriate compensation was made for height and power variations. These included the usual assortment of quads, tribanders, monoband yagis, and a commercial 40 meter beam with loaded elements.

Mechanically the antenna has held up very well for nearly two years now. This period has seen icing up to about ¼" and numerous storms with winds from 50 to 70 m.p.h. The only "failure" was when a stub flipped once in a wind storm shorting itself about halfway along the length. This problem was eliminated by looping the center of the stub back up to the boom and anchoring it with an open wire type of standoff insulator which is held to the boom by a 4" hose clamp.

Future Plans

In the near future I plan to try two changes to this design. First is to drive the reflector with an open wire transmission line from the driving point of the radiator. This line will be transposed to obtain proper phasing for reflector action. This will be used in an attempt to force a higher front-to-back ratio, particularly for 40 meters. The second change will be to fold each half of the loading stub back along its associated half-element with a double fold to bring the ends back to the relay on the boom. This will be done to try to improve the front-to-end

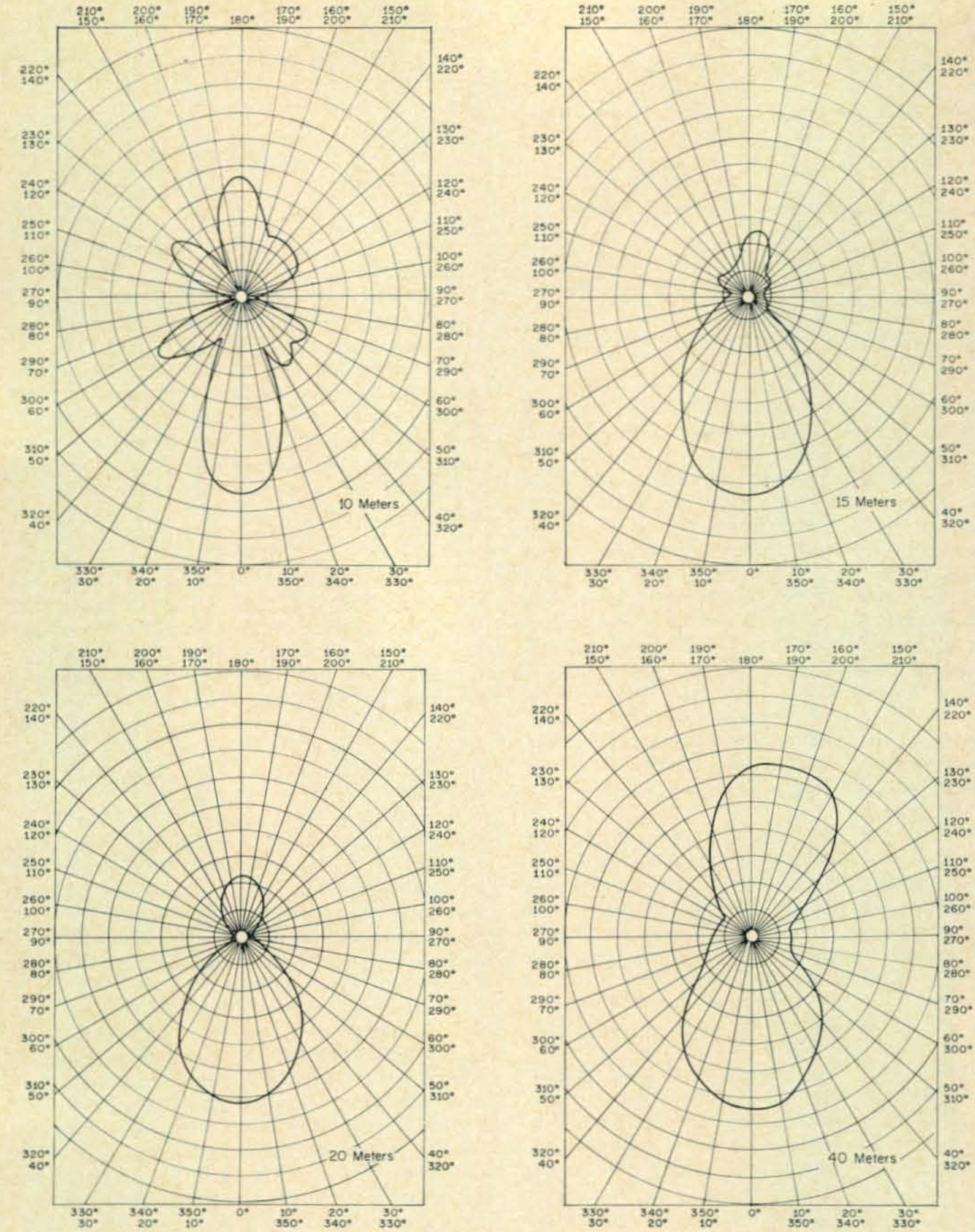


Fig. 8—Polar patterns for the antenna on each of the four bands.

ratio and may provide sufficient current cancelation on 10 meters to provide a more unified pattern.

This article is presented not so much with the idea that someone would choose to duplicate this antenna, but rather as a stimulus to those interested in antenna experimenting to deviate from the beaten path of the conventional yagi and quad. Any comments or questions (accompanied by a s.a.s.e.) would be appreciated.

I would like to thank Floyd, WA2WVL, LaMar, WB2MFX, Howard, W2PUN, Bob, W2ALL, and Ham, WØIVZ for their assistance and encouragement and my XYL for maintaining the "widow's watch" during the many many hours spent "out at the pole." ■