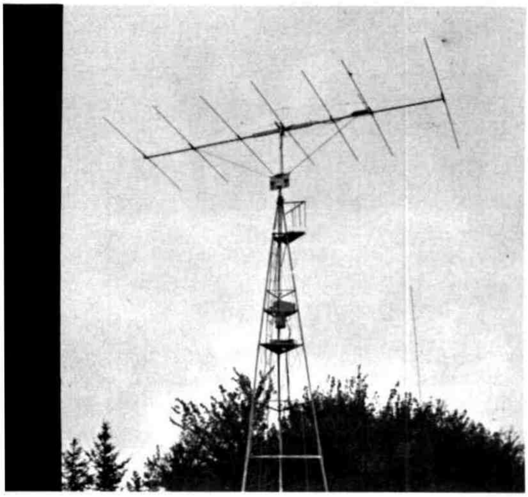

The completed seven-element, remotely - tuned, ten - meter beam mounted on top of the 50-foot tower. The two support struts below the beam are made from dural tubing and give the long boom additional support.

a big beam for ten meters

Here's a beam that's designed for performance–seven elements on a thirty-foot boom

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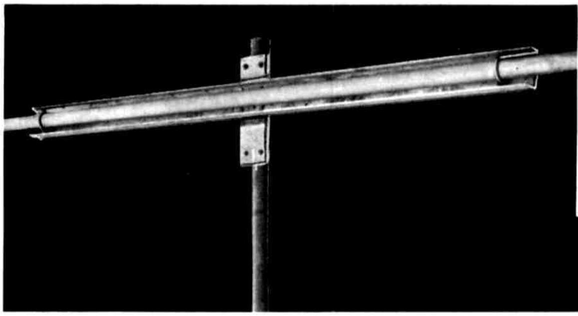
With the 10-meter band returning to life, and the rapidly improving DX conditions, thousands of hams are turning to thoughts of antennas. The usual controversies are developing over which type is best and which to erect. At my station, both beams and quads have been used with excellent results on ten. The last effort, a two-element quad, proved to be especially good.

However, the building urge came along just after the last series of DX contests, and I felt that the next project should be a new yagi. This beam would be somewhat larger than previous efforts, with emphasis on front-to-back ratio and ease of tuning. The last effort along these lines was a four-element affair which performed well enough to indicate that a few more elements would be even better. The antenna which eventually took shape is described here and is an excellent project, even for a beginner. Construction is straightforward, and although the antenna is large, it may be scaled down to a size you consider appropriate for your station.

design

This beam is a seven-element yagi with a 30-foot boom. This configuration requires a lot of attention to mechanical as well as electrical details—particularly if you live in a bad-weather location. However, the results obtained with this beam are well worth the effort put into its construction. An interesting feature, and one which I have never seen described before, is the remotely-controlled gamma match which can be precisely operated from the hamshack. This permits accurate gamma-match tuning over the entire ten-meter band. Anyone who has ever attempted to tune a beam from the top of a tower can appreciate the convenience of this device.

Center support for the boom shown mounted on the mast.



You should start this project with pencil and paper rather than with drill and metal. First, decide upon the number of elements. You should consider cost, availability of materials, time, experience, and probably most important of all, the mechanical characteristics of the tower and rotator. Even with light-weight materials, this antenna presents a lot of stress on its supporting structure. By using standard formulas, you can work out the dimensions (in feet) of the beam elements for any chosen operating frequency:

$$\text{Driven element} = \frac{473}{\text{Frequency (MHz)}}$$

$$\text{Directors} = \frac{450}{\text{Frequency (MHz)}}$$

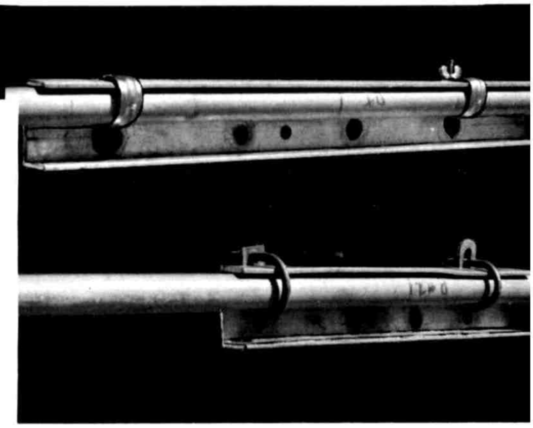
$$\text{Reflector} = \frac{501}{\text{Frequency (MHz)}}$$

Although the number of elements makes the bandwidth narrower than a smaller beam, this is not a disadvantage, since few operators actually cover the entire ten-meter band. In the case of the phone DX'er, for example, the beam would be optimized around 28.4 to 28.6 MHz, while the CW man would prefer a design centered on 28.1 MHz or so.

construction

A look at **fig. 1** will show the general arrangement of elements. The 30-foot boom permits spacing to the operator's preference. For wider bandwidth and less critical adjustment, the elements should be spaced out to about seven feet. However, this will only allow room for five elements. In my case, I was interested in maximum front-to-back ratio rather than gain, so the element spacings I used were selected to achieve this purpose. This is indicated by the wide spacing from driven element to reflector, and narrow spacing from driven element to first director.

Two methods of fastening the elements to the boom mounts—standard pipe clamps and muffler clamps.



With this spacing, I was able to add two more elements, sharpening the beam pattern and increasing the front-to-back ratio.

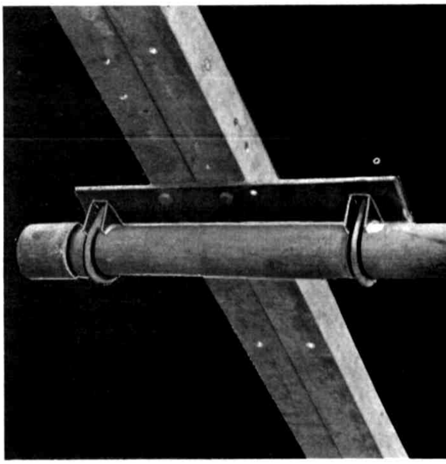
Despite the obvious advantages of so many elements, there is a matching problem because the radiation resistance falls to a low value. This not only makes it more difficult to match the feedline to the driven element, it means that the operating bandwidth for a given SWR is quite narrow. The remote gamma-match tuning was incorporated to overcome this problem.

the elements

In selecting materials for the beam, keep the important factors of strength and weight in mind. Aluminum tubing is the logical choice—6061-T6 alloy. This tubing comes in standard 12- to 13-foot lengths. A full length should be used for the center section of each element. The extension pieces on each end of the element are made from smaller diameter tubing which telescopes into the larger. I used 7/8-inch diameter, 0.058 wall, for the larger tubing, and 3/4-inch diameter for the smaller. The 3/4-inch tubing can have very thin walls because little strength is required in such short lengths. The 0.058-inch wall of the larger tubing results in a snug fit when the sections are telescoped together.

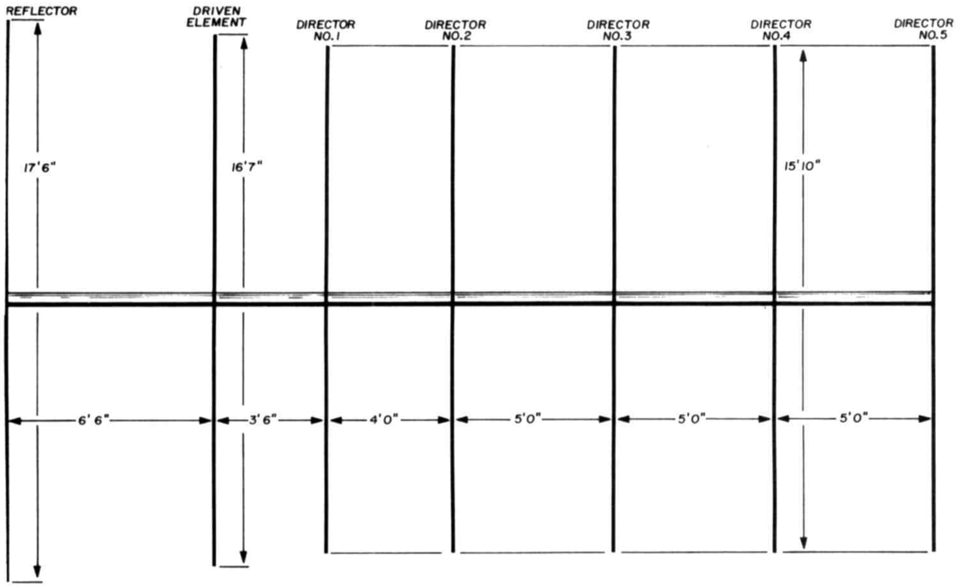
The ends of the large tubing are split with a hacksaw for about one inch. Then the short extension pieces are inserted, and the overall length of each element is adjusted to the proper dimensions. A stainless-steel hose clamp is used to clamp the large center tubing over the smaller end sections. This prevents them from slipping in or out. It's also a good idea to paint the joints with aluminum paint and wrap them with waterproof tape. Each element can be made up in the basement or garage and set aside until they're put on the boom.

Several methods can be used to mount the elements on the boom. I prefer small pieces of aluminum channel which are fastened to the boom with standard automobile muffler clamps. The element is laid in the trough of the channel and fastened securely in place with pipe clamps or small U- or J-bolts. Since aluminum channel is expensive unless you can find some in a junkyard, small sections of angle iron or aluminum will do just as well. Just remember to give special attention to rust-proofing anything that isn't aluminum.



Detailed view of the boom support and boom-to-mast mounting plate.

fig. 1. Overall dimensions of the seven-element beam designed for a center frequency of 28.5 MHz.

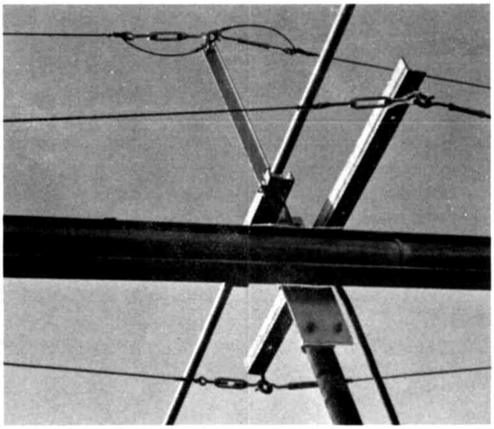


Muffler clamps may still be used to fasten the angle to the boom, and the element can be hung on the side of the angle.

the boom

The boom is made from a 30-foot length of aluminum irrigation pipe. This pipe should have a diameter of two inches or more. I found the two-inch material fine for a four-element beam on a 20-foot boom (an earlier project), but too flexible for this long beam. However, since it had the advantage of light weight, I strengthened it and found it completely satisfactory.

First of all, I used a four-foot support section made from two pieces of aluminum



Closeup of the center of the boom showing the bracing wires, struts and turnbuckles.

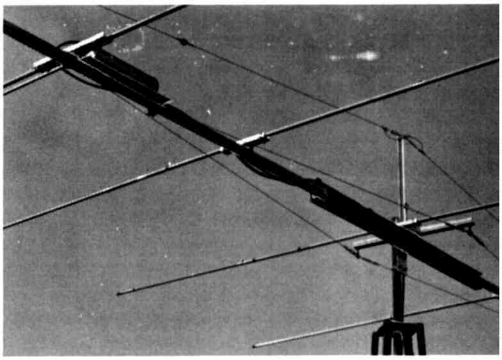
angle at the center of the boom. The boom is fastened to this mount with three clamps, and the boom-to-mast mount is made from 1/4-inch thick iron plate fastened to the angle with bolts. Two more muffler clamps are used to fasten the whole affair to the mast. Careful examination of the photos will show the details.

The elements are fastened to the boom after carefuly checking the spacing. In addition, make sure you have all the elements lined up horizontally with each other. If the array is mounted on a couple of boxes or saw-horses, an inexpensive level can be used to adjust the elements and line them up properly. When all the elements are mounted, the ends of the boom will droop. An upright made from angle iron is mounted at the center of the boom mount. A large eye-bolt is mounted at the top of this upright and two wire braces are run out from it to the ends of the boom. To prevent rusting, the wires should be bronze or aluminum. In addition, they are broken up with small strain insulators to eliminate any resonance difficulties. A small turnbuckle is installed on each wire and adjusted until the boom is straight and level.

There is also a tendency for the boom to whip sideways. This is overcome by another angle brace at the center. This one is bolted at right angles to the boom mount. Four bracing wires are run from it part way out the boom. Four turnbuckles are used to adjust wire tension until the boom is straight and rigid.

When the wires are all taut, the boom is very firm and there is no noticeable flexing. Since I used bronze wire, I wrapped heavy vinyl insulation around the wire where it is looped around the ends of the aluminum boom. These two metals set up an electrolytic action, especially in a salt-air atmosphere, which will eventually weaken the beam.

The assembled beam. The driven element is to the left with the gamma-match tuner. The wire bracing provides rigidity.



the remotely-tuned gamma match

The mount for the gamma-match tuner is made from a thin aluminum plate. This plate is mounted on the boom between the driven

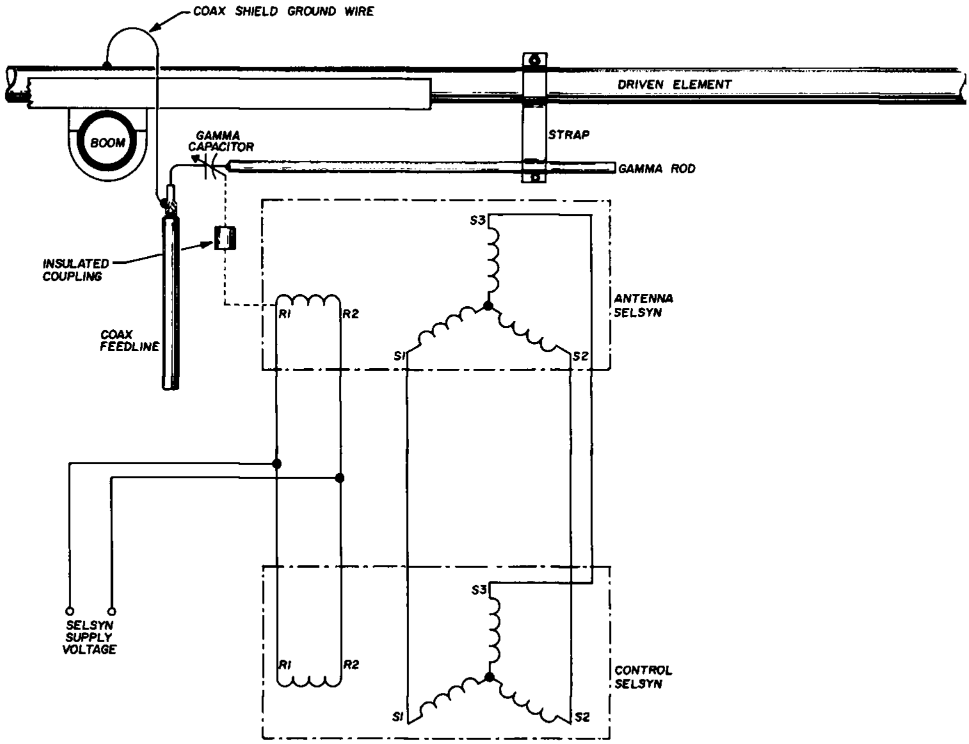


fig. 2. Wiring diagram of the remotely-tuned gamma match and its control system.

element and the first director. The gamma tuner is actually the heart of the beam, but it is very simple to build. It consists of the usual gamma capacitor, driven by a selsyn motor. If you are not familiar with selsyn motors, it is a device which can be remotely controlled through a five-wire cable which is connected to a similar unit. When the system is energized, the shaft of one unit turns until it is in electrical synchronism with the other. Moving one shaft will cause the other shaft to move exactly in step.

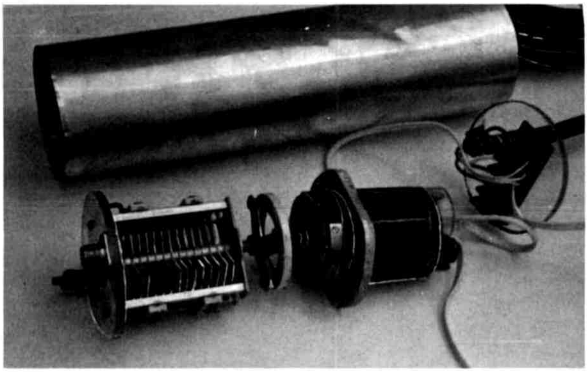
In the remotely-tuned gamma match, the capacitor which is coupled to the shaft of the antenna selsyn will exactly follow adjustments of the controlling selsyn in the shack. By watching an SWR meter in the comfort of your house, you can turn the selsyn shaft and automatically adjust the gamma capacitor on top of the tower. Although it might be simpler to use a small reversible motor for this application, the correct point for the gamma capacitor is very critical. It would be difficult to control a motor accurately enough to adjust the gamma match for an SWR of 1:1. The precise control afforded by the selsyn makes this method much more acceptable.

Ordinary receiver spacing is satisfactory for the gamma capacitor, but the larger spacing will guard against corrosion which may short out the plates after a long period of time. Let the climate be your guide!

To construct the gamma match, I used a pair of surplus selsyns along with a fairly wide-spaced 50-pF capacitor. Suitable selsyns are available from almost any surplus supply house. The antenna selsyn and gamma capacitor were coupled together with an **insulated** coupling and enclosed in a piece of aluminum vent pipe which was intended for electric clothes dryers. This pipe can be opened for easy installation of the gamma-match components and resealed with the locking lip built into the pipe. Two discs made from ¼-inch plexiglass are cut to fit snugly into the ends of the pipe. The capacitor must be insulated from the vent pipe, so it's mounted directly to one plexiglass disc. The coaxial input connector is also mounted on the disc. An aluminum strap is used to connect the capacitor to a large bolt which passes through the disc to the gamma rod. **Fig. 2** shows the wiring diagram of the gamma match; the photos show its construction.

The second disc is mounted in the opposite end of the vent pipe, and the control cable is passed through it to the selsyn. The selsyn body will usually have some sort of mounting lip which prevents it from fitting snugly into the vent pipe, so small pieces of wood or plexiglass are used to wedge it firmly in place. The selsyn body must be firmly clamped in place so it will rotate the capacitor.

Disassembled remotely-controlled gamma-match tuner.



The antenna and control selsyns are then connected together temporarily and checked. As soon as 110 Vac (or whatever voltage is required by the selsyns used) is applied to their rotors, the two shafts should synchronize immediately. Turning one shaft will cause the other shaft to follow exactly. If the two shafts rotate in opposite directions, reverse the connections to any **two stator** terminals (marked with the letter "S") of either selsyn. This isn't too important in this application since it doesn't really matter if they turn in opposite directions or not.

When the gamma-match assembly is operating properly, the whole unit should be sealed against moisture by applying a suitable compound to small cracks and openings. I used ordinary rubber-to-metal cement.

The gamma-match was mounted on my beam with two large surplus Marmon clamps around the vent-pipe enclosure. The bolt ends of the clamps acted as mounting bolts through the plate on the boom. My particular gamma match was fairly heavy because of the large selsyn and capacitor, but any small units may be substituted. Selsyns may be rated for 110, 24, or 36 volts ac, but 110-Vac units eliminate step-down transformers. Use 60-Hertz units to avoid any heating and torque problems. Power is only applied to the units for a short time when tuning up the beam; after that, you only have to adjust the gamma match after a wide shift in operating frequency.

tuning it up

Tune-up must be done with the beam at least ten feet above the ground. The gamma match is adjusted by setting the length of the gamma rod to about 20 inches and adjusting the capacitor for minimum reading on the SWR meter. See **fig. 3** for the set-up required. The setting of the rod will depend a lot upon the number of elements and their spacing, so it may be necessary to try several taps along the driven element before getting the SWR down below 1:1.5. It should be possible to get it down to 1:1 at a point close to the design frequency, but it will rise as the transmitter is tuned up or down from this point.

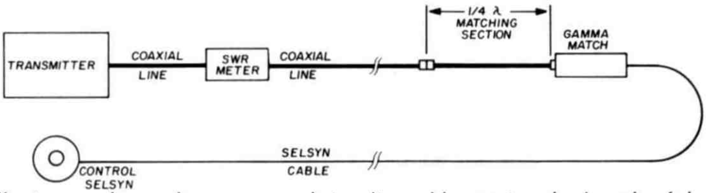


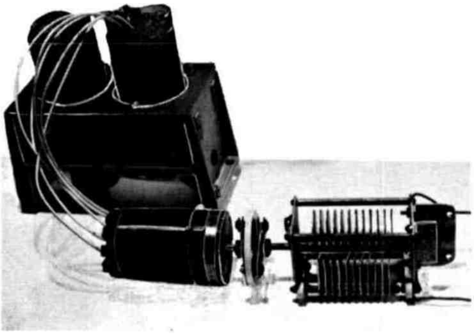
fig. 3. Gamma match adjustment. The use of a quarter-wave section of 52-ohm coax is discussed in the text.

You can get a good idea of the bandwidth by plotting the SWR over a band of frequencies without readjusting the gamma match. With the remote match of course, it is no problem to readjust for minimum SWR. Remote tuning is not necessary, but it does add greatly to operating convenience. If it is left out, all adjustments must be made before the beam is in its final position on the tower; otherwise, the capacitor cannot be reached.

Adjustment of element lengths can be done in order to get the best possible gain or front-to-back ratio, but the process is long and tedious and simply not worthwhile. If the elements have been cut and measured properly, they will be very close to optimum dimensions.

The beam may be fed with either 52- or 75-ohm coaxial cable. However, the more elements you use, the lower the radiation resistance at the center of the driven element.

Workbench setup for testing the remotely-controlled gamma-match tuner.



To match the lower resistance, the gamma rod must be tapped farther and farther out on the driven element to obtain a proper impedance match. To overcome this problem, a quarter-wavelength of lower impedance coaxial cable may be used to produce a terminal impedance which is lower than that of either the feedline or the quarter-wave section.

I used 75-ohm feedline in my installation, connected to an 8-foot section of 52-ohm line. This provides an output impedance of about 27 ohms, a much closer match to the beam impedance than afforded by either the 52-ohm or 75-ohm line by itself. The gamma match can easily compensate for any remaining mismatch, and the gamma rod becomes fairly short (and easier to adjust). Although the quarter-wave matching line would normally restrict the beam to a rather small bandwidth, the remote gamma tuning overcomes this problem very nicely. I can adjust my seven-element version for a maximum SWR of 1.7:1 over the range from 28.0 to 29.0 MHz. Over 75% of this range the SWR can be held below 1.5:1.

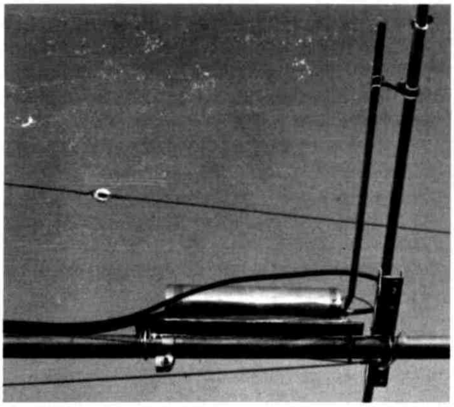
results

The gain and front-to-back ratio of the antenna are excellent. Calibrated tests indicate a front-to-side ratio of a little over 40 dB, a front-to-back ratio of 31 dB, and two very deep nulls of 60 dB about 10 degrees off the axis of the beam to the rear. I can't explain this latter characteristic, but it makes me very happy in any case! Repeated tests show this peculiar pattern is definitely there, but it may not necessarily be the same on a duplicate beam.

Forward gain figures are not available yet because I have not erected a reference dipole, but based on the other known figures, it should be on the order of 12 dB. On-the-air results have been most pleasing!

ham radio

The gamma-match assembly.



editor's note

Although VE1TG used the remotely-tuned gamma match on a ten-meter beam, the same technique could be used just as well on other antennas with built-in tuning sections.

Normally **ham radio** will not publish antenna gain figures because of the many vagaries in making accurate measurements. The figures presented here represent an average of many on-the-air measurements and are given only as a guideline.

WIDTY