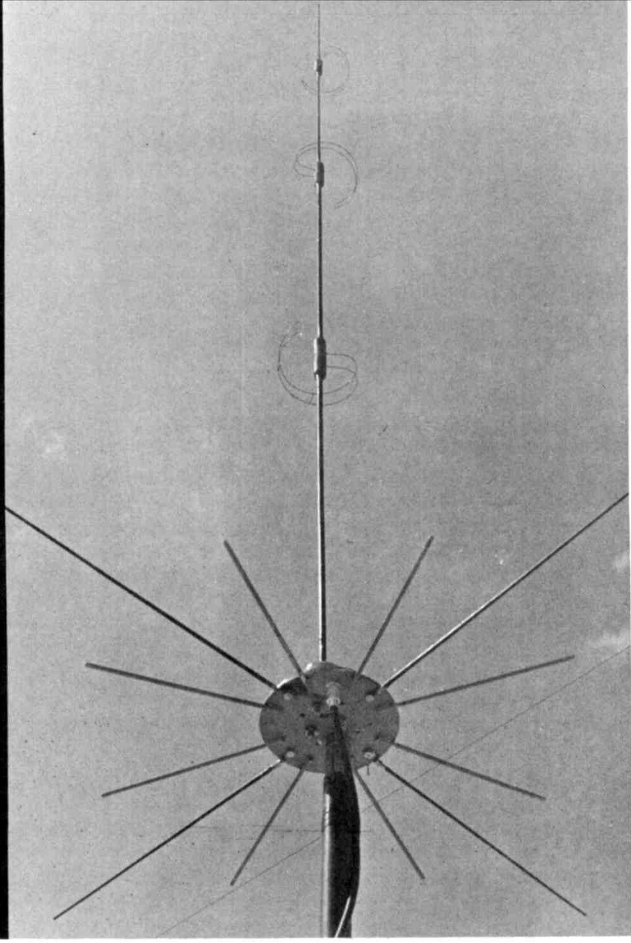


four-element colinear array for two meters

Extended elements with phasing stubs give 14 dB gain over a ground-plane antenna

Bob Dahlquist, WB6KGF

Here is an antenna with as much gain as a medium-sized yagi beam; yet, unlike the yagi, this antenna is omnidirectional. You can easily work stations from all points of the compass without waiting for a rotator to crank the antenna around to the desired azimuth – an advantage when working in a contest, a net, or with mobile stations.

the circuit

The antenna is known as a 4-element extended colinear array. It's an improvement over the classical colinear antenna described in the literature.[1] Instead of ½-wavelength elements, the extended colinear uses 5/8-wavelength elements (except for the topmost element) to obtain gain over the conventional colinear array or the popular ¼-wave ground-plane antenna.

The topmost element is shorter than the other elements to preserve current balance in the phasing stubs. The sketches in **fig. 1** show the electrical circuits and the distribution of current and voltage.

have? I made a comparison test, starting with a simple ground-plane antenna. When the extended 4-element colinear was substituted, the radiated field strength increased by 14 dB. Some of this increase could be attributed to an increase in power input to the colinear, since the colinear was adjusted to near unity swr before it was installed.

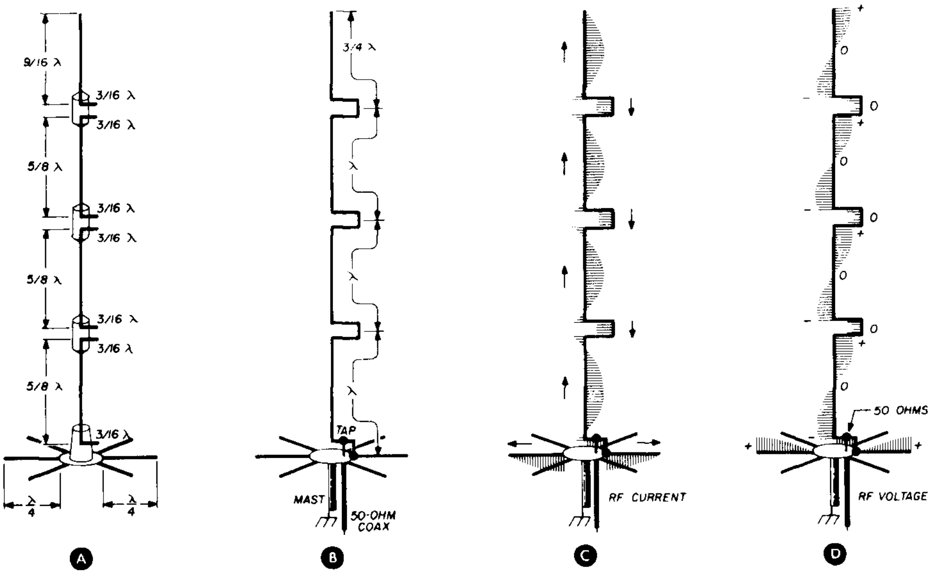


fig. 1. The extended colinear array. Sketch A shows electrical lengths of elements and tuning stubs; B gives the electrical circuit of the complete antenna. Current and voltage distribution are shown in C and D.

features

In addition to the added gain, the extended colinear has extra height compared with the ground plane. The extended colinear is self-supporting to 17 feet above its base on 2 meters. This added height puts the radio horizon several miles further away than that of a ground-plane antenna. The improvement will be more noticeable, of course, if you must roof-mount the antenna than if you can manage a 50-foot tower.

gain

Just how much gain does this antenna

theory

The extended colinear array is a bit longer than the classical 4-element colinear. The added gain results from the increased spacing between current loops, or maxima, in the radiating elements (**fig. 1**). Increasing element length beyond 5/8 wavelength actually decreases gain, because the out-of-phase currents in the element ends then become large enough to cancel some of the radiated field.

phasing

By mounting the four elements linearly and feeding them in phase, the fields radiated by the individual elements will reinforce. The sum of the four fields (total field strength) will be maximum in a plane normal to the axis of the antenna (**fig. 2**). The pattern is like the doughnut-shaped field of a vertical dipole, but much flatter. In the vertical plane, the beam-width is only about 20 degrees, with maximum radiation directed at the horizon (**fig. 3**).

Proper phasing is accomplished with stubs. Placed between each element, a stub of the proper electrical length introduces just enough delay to keep the currents in the elements phased 360 degrees apart (for our purpose, this is the same as zero degrees, or exactly in phase).

Since the elements are longer than usual, the phasing stubs must be shorter by a corresponding amount. Instead of ¼ wavelength, the stubs are 3/16 wavelength from the shorted end to the open end, or 3/8 wavelength all the way around. The length of one element, plus the length of one side of each adjacent stub, equals one wavelength (360 electrical degrees) except for the top element, where the total is ¾ wavelength; the length of the top element is 9/16 wavelength (see **fig. 1**). Lengths of all elements, tuning stubs, and radials are given in **fig. 4**.

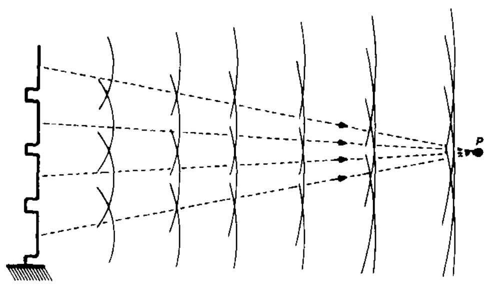


fig. 2. Relationship of waves radiated from each element as a function of range. Since the waves travel approximately equal distances to reach a distant point, P, all arrive in phase and add to produce increased field strength.

feeding and matching

The array is fed at the base through another stub, much like the phasing stubs, except that only half of this stub is constructed. (The other half is a reflection in the ground-plane disc.) Since this stub is unbalanced, coax can be connected directly without a balun. The center conductor is passed through the disc and soldered to the point on the stub

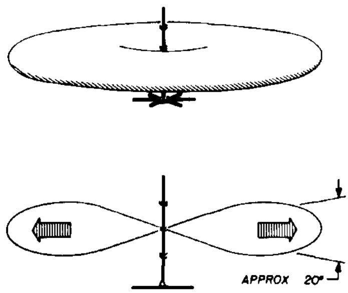


fig. 3. The "squashed doughnut" pattern of the extended colinear antenna. The angle shown is in the vertical plane.

where the impedance matches that of the coax, and the braid is grounded to the disc that secures the ground-plane radials. See **fig. 5**. By alternately adjusting the position where the coax is tapped, and the length of the stub, a match near 1:1 can be obtained. The radials are ¼ wavelength long. They decouple rf from the mast and the outside of the coax, thus making the array independent of actual ground. An overall view of the antenna is shown in **fig. 6**.

construction

This antenna is best assembled by casting the insulators in place. This procedure is not absolutely necessary, but it does produce strong, watertight joints. The casting process is not difficult or expensive; one method is described later in the article.

radiators

Each radiating element should be

strong enough to support both the weight and the wind load of the parts above it. I used tapered elements; it would also be possible to make each element from a different-size tubing. Aluminum alloy is a good choice for material because of its high strength-to-weight ratio, although it's difficult to solder.

If each element is made with a joint of some type, the antenna can be disassembled to make transportation easier. If this isn't done, the antenna should be assembled in a place where its 17-foot length won't become a problem. My tubing had threaded joints; however, lacking these, you can use progressively smaller sizes of tubing. By splitting the end of a tube with a hacksaw, slipping the smaller tube inside and applying a hose clamp or two, you'll have a joint that will allow adjustment as well as disassembly of each element.

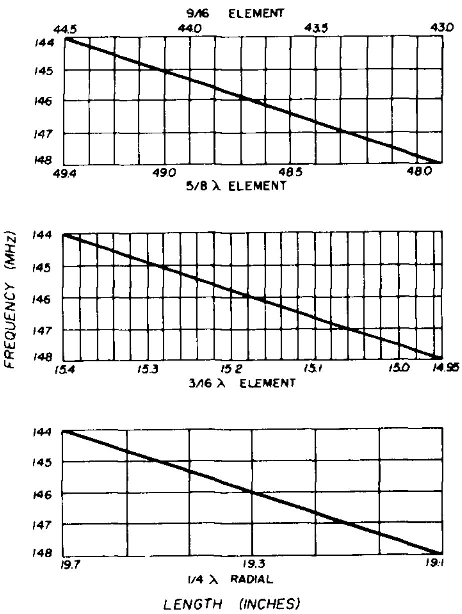


fig. 4. Lengths for elements, stubs, and radials in inches versus frequency. Data is based on 1/2 to 3/8-inch-diameter elements.

Each stub is made in two halves at first, to be joined later. Cut each half to length according to **fig. 4**, but allow a little extra for making the joint to the tubing. Add a little more than this for pruning; say 6 inches. It's best either to solder or weld the wire to the tubing. Make sure all joints are mechanically and electrically sound. Do *not* use acid-core solder.

casting the insulators

For casting, you'll need three basic items: a mold, resin, and a means to hold the parts steadily while the resin cures.

The mold can be made of plaster of Paris. You can make a mold for each insulator and do the casting all at once, or you can make one reusable mold and cast the insulators one at a time except, of course, the base insulator, which requires its own mold. I used the latter method; however, if I were to do it again I'd use the former method, which saves a lot of trouble and resin.

element insulators

Arrange each element with stub wires attached, and with the joints disassembled, so that each element is in its proper relative position with respect to the others. A cardboard mold, fashioned from a quart milk carton, is then used to cast a block of paraffin. When the paraffin has solidified, remove the cardboard mold and carve the paraffin into the shape of the insulator (see photo).

Using another piece of cardboard, cast a block of plaster of Paris around the wax insulator. This will form a mold for the plastic resin, which constitutes the insulator. When the plaster has set, the wax can be melted. You'll need at least one hole in the plaster to drain the melted wax, and another for pouring the resin. These holes can be made during the casting process with two greased, pointed sticks; or after casting, with a drill. Use care when melting the wax, because if it gets too hot the plaster will dry and crumble, or soldered connections on the stubs will melt.

base insulator

Forming the base insulator can be tricky, but here are some hints to make the process easier.

First, drill three holes in the ground-plane disc of the proper size to accept the bolts that will hold the antenna. Then drill another hole in the center of these three holes. (This hole will be used to pour paraffin into a mold.) Turn the ground-plane disc upside-down and place the three bolts into position, threading the nuts on the bolt ends to support the weight of the bolts as they hang (also upside-down) through the holes. See **fig. 7.**

Place the entire assembly on top of a paper cup, with the bolts hanging down inside the cup, but not touching its sides. The cup forms a mold for the paraffin, which is cast to form a pattern for the mold, as before.

After casting the paraffin, turn the base over and carefully remove the paper cup. Place a cardboard cylinder, or a can with the top and bottom removed, around the paraffin pattern to hold the plaster. Arrange a brace to hold the tubing vertically. Heat the end of the tubing, and let it melt its way into the wax pattern until the tubing reaches the proper position. (You'll probably lose some paraffin through the slot melted by the stub wire and have to retouch your pattern.)

When the pattern is ready, be sure that the base plate is absolutely level and the tubing is absolutely vertical. Then pour the plaster. Check to ensure that nothing has shifted out of alignment. When the plaster has solidified, you can melt the wax pattern, as before. It will probably be easier to do this without the radials installed.

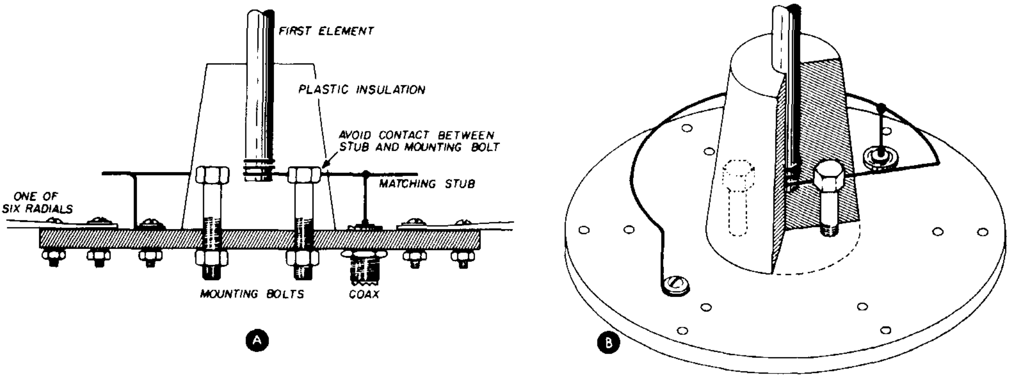


fig. 5. Detail of center insulator, bottom matching stub, and radial anchor plate, A. View B shows the assembly in perspective.

casting in resin

With the molds ready, you can cast all the insulators in plastic at the same time, using only one batch of resin. This will eliminate considerable waste of resin and acetone. Use polyester or slow-curing epoxy resin, of the type used for fiber-glass boats, for the casting. Do not, under any circumstances, use the rapid-curing type of epoxy resin, which is commonly supplied with patching kits. The heat generated by the rapid curing causes a chain reaction inside the mold, because the heat can't escape as fast as it's generated. It can get hot enough to boil, which causes bubbles; or it can even catch fire. When the reaction is over and the

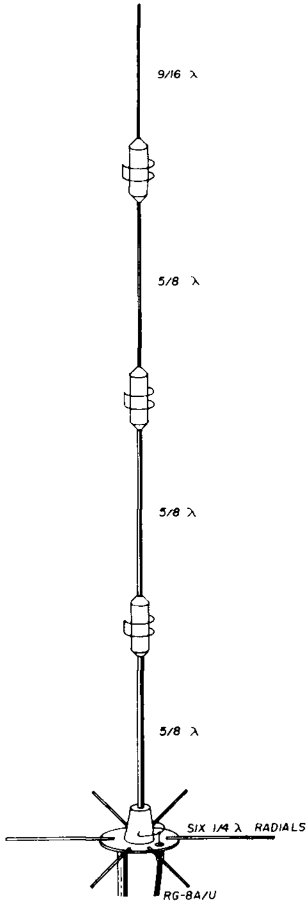


fig. 6. Overall view of the complete assembly.

stuff cools, it will crack. If polyester resin is used, apply twice the usual amount of hardener or catalyst. This will cause the mix to set up a bit faster and will also make the finished casting more flexible and less brittle.

Always measure carefully, and stir with care to avoid mixing bubbles into the plastic. Keep everything out of direct sunlight, and never mix more than you can use at one time. Otherwise the resin will gel, taking on the consistency of something between Jello and rubber. Note: the only thing that will remove resin from hands and tools is acetone. It evaporates so fast you have to see it to believe it, so get about twice as much as you think you'll need.

When the resin has set, you can break away the plaster molds, put everything together except the stubs, and proceed with tuning.

tuning

The stub wires should be soldered or welded to their radiating elements, but not yet connected to each other.

Prune the stub wires to exact length, using capacitive coupling – as loose as possible – to the hot end of a grid-dip oscillator tank coil. Using a receiver to check the oscillator frequency, resonate the three lower elements, with their stub wires, at one wavelength each. Ground one end of the top element to a metal screen or sheet and resonate it to ¾ wavelength. While doing this, try to keep all the stub wires parallel to maintain constant capacitance between them.

Install the radials and tune them all to ¼ wavelength. Now solder the wire ends together, or solder a shorting wire in place, to complete all the phasing stubs; then temporarily ground the end of the matching stub. Check the resonant frequency of the entire antenna with the

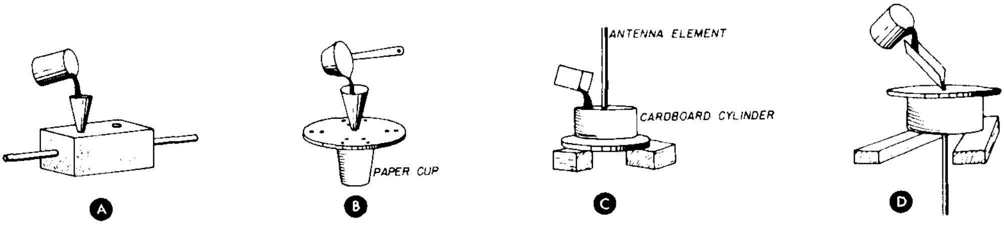
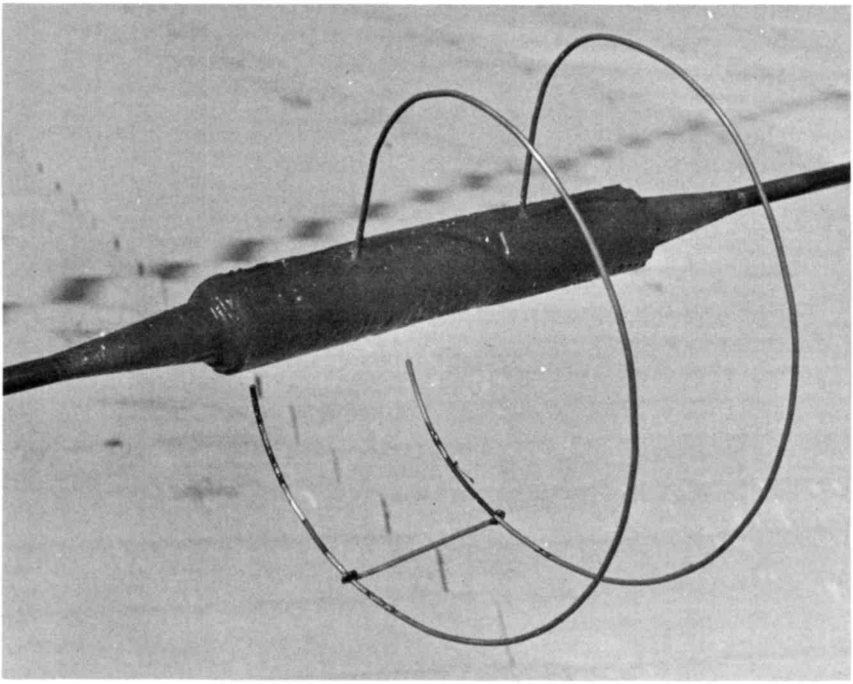


fig. 7. Making the insulators. Final step in casting an element insulator in resin is shown at A (see text) The base insulator is made by pouring a wax pattern, B, around which a plaster mold is formed, C. The wax pattern is then melted out of the mold, and the mold is filled with polyester resin, D.

gdo capacitively coupled to the top end of the antenna, as before. Note that the antenna will resonate at any odd multiple of the quantity (operating frequency divided by 19). For example, if the operating frequency is 190 MHz, the antenna will also resonate at 170, 150, 130, etc., and 210, 230, 250 MHz, etc. So be careful not to tune it on the wrong harmonic. With this in mind, adjust all the stubs equally, a little at a time if necessary, to get the antenna on frequency.

Now set up the antenna in a clear area, at a convenient working height for adjustment of the matching stub. Temporarily connect the coax to about the middle of the stub, and check the swr. If it isn't 1 to 1 (hi hi), move the coax a bit to either side and test again. When you've found the point of minimum swr, and if it isn't quite close to 1 to 1, then shorten the stub a bit by moving the ground point, and try again. If this doesn't improve things, try lengthening the stub. By alternately adjusting the length of the stub and the position of the tap, you should be able to get close to a 1 to 1 match. When you're satisfied with the swr, drill, punch and/or file a hole at the proper place and install a chassis-type coax connector. Reconnect the coax to the connector, and recheck the swr. You may have to readjust the tap a fraction of an inch.



Matching-stub detail. Stubs are tuned initially using a grid-dip oscillator, then pruned to correct length and soldered or welded to elements.

Now you can put 'er up as high as possible, and sit back and enjoy all the new signals you'll hear on the two-meter band.

references

1. *ARRL Handbook,* Headquarters Staff, American Radio Relay League, Newington, Connecticut.
2. R. L. Crawshaw, WA0NGV, "5/8 Wavelength Verticals," *73,* May, 1970, p. 36.

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