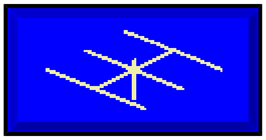

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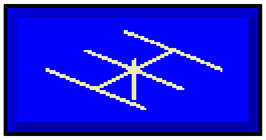
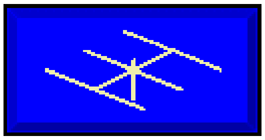


L. B. Cebik, W4RNL, 41159

In each issue of the ***10-10 News***, I try to clarify a significant cluster of ideas used in antenna work. My object is to help members make the best decisions about the antennas they buy or build without imposing my own prejudices on them. The more we understand, the better our choices will be.



No. 1: dB, dBi, and dBd

L. B. Cebik, W4RNL

A most convenient way to compare power is as a ratio between two powers. For this purpose, we have the decibel or dB. One dB = 10 log (P1/P2), where P1 and P2 are any two powers it is relevant to compare. A power ratio of 2 is 3 dB; a ratio of 4 is 6 dB; a ratio of 10 is 10 dB. These marker points will guide you to intermediate values. Your transceiver output is 100 watts. Your linear output is 800 watts. Hence, your power gain is 9 dB to the antenna.

Antennas measure their power gain in the favored direction in dB. Since gain requires 2 powers to make the ratio, where does the second power come from? It comes from a standard reference. For most theoretical studies, the most common reference is dBi, decibels over an isotropic radiator. An isotropic radiator is a geometric point in free space with no material losses that radiates equally well in all directions. My rotatable aluminum backyard dipole at 35 feet over soils with average losses has a gain of over 7.5 dBi.

A second standard is dBd, decibels over a dipole in free space made of lossless infinitely thin wire. This theoretic dipole has a gain of 2.15 dBi. Hence, my backyard real dipole has a gain of over 5.35 dBd.

For many, if not most of the decisions you will make about antennas, neither dBi nor dBd are the real references. Suppose you wish to buy a 3- element monoband Yagi for 10. What improvement can you really expect over your dipole? Now your own antenna--an aluminum tube (with losses) antenna at a certain height over soil (with certain losses)--becomes the standard. Unfortunately, manufacturers do not rate their antennas by testing them on your mast in your yard. How can you use your knowledge of dBi and dBd to estimate the improvement the prospective antenna will make?

One way is to make antenna comparisons theoretically and extrapolate to your yard. Table 1 shows the gain figures for 3 antennas: a pretty good 3-element Yagi, a pretty good 2-element Yagi, and a dipole, all in free space. The 2-element Yagi has a forward gain of about 4.3 dB over the dipole, while the 3-element Yagi adds another 1.8 dB, for a total of 6.1 dB over the dipole. In the favored direction and in front-to-back ratio for nulling out QRM, you can expect similar performance from equivalent antennas mounted at the same height over the same terrain.

Table 1: Relative Antenna Gain using dBi and dBd and Antennas in Free Space

Antenna	Gain in dBi	Gain over dipole	Gain over 2-element Yagi
Dipole	2.1	----	----
2-element Yagi	6.4	4.3 dB	----

3-element Yagi	8.2	6.1 dB	1.8 dB

Antenna	Gain in dBd	Gain over dipole	Gain over 2-element Yagi
Real Dipole	0.0	----	----
2-element Yagi	4.3	4.3 dB	----
3-element Yagi	6.1	6.1 dB	1.8 dB

Do not expect much more improvement than this, even if a manufacturer cites much higher numbers. The beams in this example can be tweaked for a little more gain or a little more front-to-back ratio, but not much and not both at once. And the ability of the antenna to hold its gain and front-to-back ratio over the entire 10-meter band will suffer.

As you might expect, it does not matter whether you make the gain comparison starting with figures in dBi or figures in dBd. You will get the same result. The only requirement is that you use the same reference for all your comparison calculations.

Since we started with a dipole, the charts seem to prefer dBd. That is an illusion, since we might have as easily started with a quarter-wave vertical, a 2-element Yagi (as column 3 shows), or ZL-Special. Moreover, had we placed the models over real ground, the gain numbers would have been intrinsically higher, beginning with a dipole gain of over 7.5 dBi or 5.4 dBd, but the differences would have been very similar.

Fig. 1 shows the free space azimuth patterns for the three antennas. Their relative proportions are identical no matter whether they start with dBi or dBd.

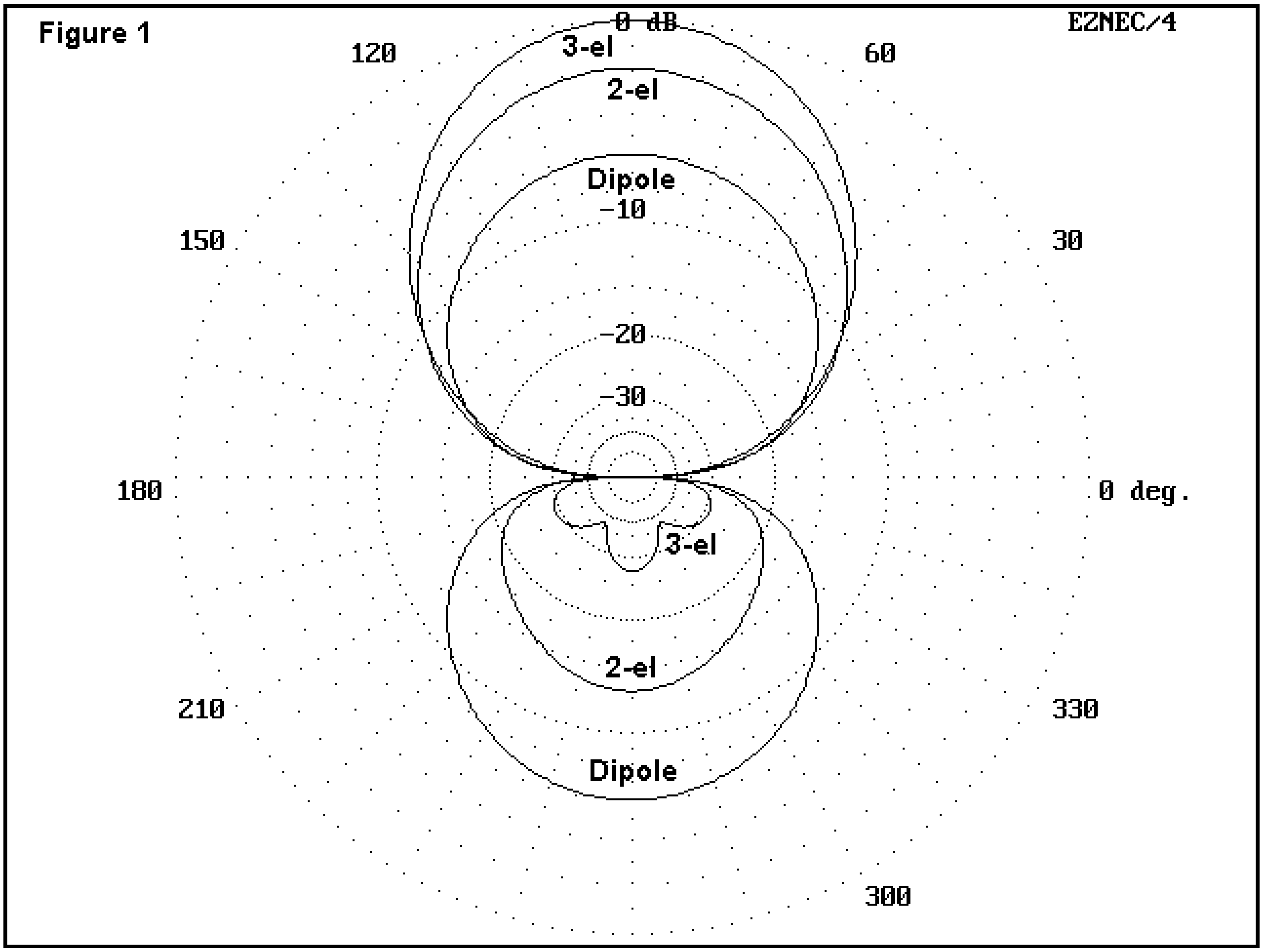


Figure 1

The relative gain of the 2-element Yagi over the dipole is evident, as is the relative gain of the 3-element Yagi over the dipole and the 2-element Yagi. That is what is crucial to know.

No. 2: Invisible and Hidden Antennas

L. B. Cebik, W4RNL

If you live in an apartment, condo, or development with antenna restrictions, you may need to hide or disguise your antenna. Here are some ideas to get you started. First, some general principles, then some basic antenna types.

Principles: The principles are few: 1. Safety: keep the antenna as far away from people as possible for their safety. 2. Propagation: put the antenna as high and in the clear as possible for maximum efficiency within the limits of needing to keep it out of sight. 3. Antenna tuner: with few exceptions, the hidden or invisible antenna will become a random length end-fed wire. Any of the T-matches (for example, MFJ's tuners) will do a good job matching the antenna to your rig. 4. Expectations: do not expect the performance of a long Yagi. Instead, expect to make a lot of great contacts.

Antenna Types: The basic hidden antenna types are four: 1. disguised verticals, 2. thin wires, 3. attic antennas, and 4. loading existing metal. There are dozens of variations on each theme. But, forget loading the bedsprings.

1. Disguised verticals: You can encase almost any type of vertical antenna in PVC, and call the outdoor structure a flag pole. For working dx from a development with restrictive covenants, this route is often useful, especially if you use a multiband vertical. Construction varies with the circumstances.

2. Thin wires: Wire as small as #28 enamel makes a good antenna for 100- watt transceiver use. It is often invisible enough to leave running from a second-story apartment window to a tree. Or, you can put it on a reel and wind it out and in as necessary. Alternatively, you can string it in the attic, turning corners wherever necessary. I have used it with success taped to the edges of a second story ceiling. How much wire? How much have you got? Just do not end up with tight coils; try for maximum length in each direction used.

Thin wire antennas, indoors or out, are random length wires fed at the end and need a transmatch. If possible, locate the transmatch where the wire leaves the building. Otherwise, try a piece of RG-213 from the tuner to the antenna wire. Ignore the coax losses. Try a sleeve balun (such as those sold by Radio Works) where the coax leaves the building. Ground the coax shield where the antenna begins and the tuner and every piece of equipment in the shack well--very well! The object is to do everything possible to keep the RF outside or away from the rig. Some combination of sleeve balun, ferrite cores, and the like will likely solve any RF-in-the- shack problems. Keep experimenting. And be willing to spend a few dollars on wide braid to use as grounding strap; it works well, as does a good, long ground rod (replaced every few years).

3. Attic antennas: Way up and away from everything is best, but attics are not usually as bad as you might think. The frame and roof shingles do not absorb too much RF, and the braces can help support an antenna. In the attic, you can usually find room for dipoles for many bands, even if you have to bend the ends down or to the side. Mount the dipole as high in the structure as you can, and away from any metal duct work, metallic duct insulation, or house and phone wiring. Feed an attic dipole just as you would an outdoor antenna (coax and 1:1 choke balun). Trim it to resonance or minimum SWR.

The attic may also hold a 2- or 3-element Yagi fixed on your favorite target. You can adjust element lengths for thinner wire elements and do away with the boom. If you use tubing, getting it into the attic may be a problem if the opening is small. First, build and test the antenna, then cut it into pieces that will fit the opening, developing couplings to reconstruct it on site. (Back before cable, I put a 12'-long TV log periodic in the attic just that way: I used wire on a wood frame, cut the wood into entry size pieces, and used linking pieces to reassemble the frame before restringing the wire. Great reception from Atlanta about 70 miles away.)

4. Loading existing structures: Perhaps the most obvious aluminum structure to load is the gutter and down spout. Treat the system like a thin wire antenna and use a tuner, driving a ground rod near the feed point. Be sure to securely bond the joints, since painted aluminum joints with pop rivets make a shaky electrical system. Expect changes in pattern and antenna tuner settings with water, snow, or leaves in the gutter.

You can also load patio umbrellas, existing aluminum flag poles, and other metal structures. You can shunt feed a grounded flag pole. Avoid iron and steel structures if an alternative is possible, since their losses are fairly high, but use them in a pinch. Even the frame of a sliding patio door will radiate and receive.

Anticipated results: Compared to a high and free outdoor antenna, these substitutes will likely disappoint you for local area point-to-point work on 10 meters. However, do not sell them short with skip. Their low height will give high take-off angles, but still produce very solid contacts, even in 10-10 contests. The idea is NOT to try to compete with the 1.5 kW linears feeding 7-element quads at 105' altitudes. Instead, find modes of operation to which the antenna is better suited: rag chewing, nets, and even informal contesting. Most of these hidden or invisible antennas will usually outperform loops and other tiny antennas (but they will also work in making contacts).

If your situation calls for these measures, develop an attitude: be on the lookout for better places (higher and bigger) for the next design. Most of these antennas are cheap, but do not skimp on quality coax, connectors, ground rods, baluns, and filtration. Use the same high quality components you would put into an outdoor tower and beam. Part of your attitude adjustment should be forgetting ultimate antenna efficiency, except when comparing two of your own models to see which one to keep.

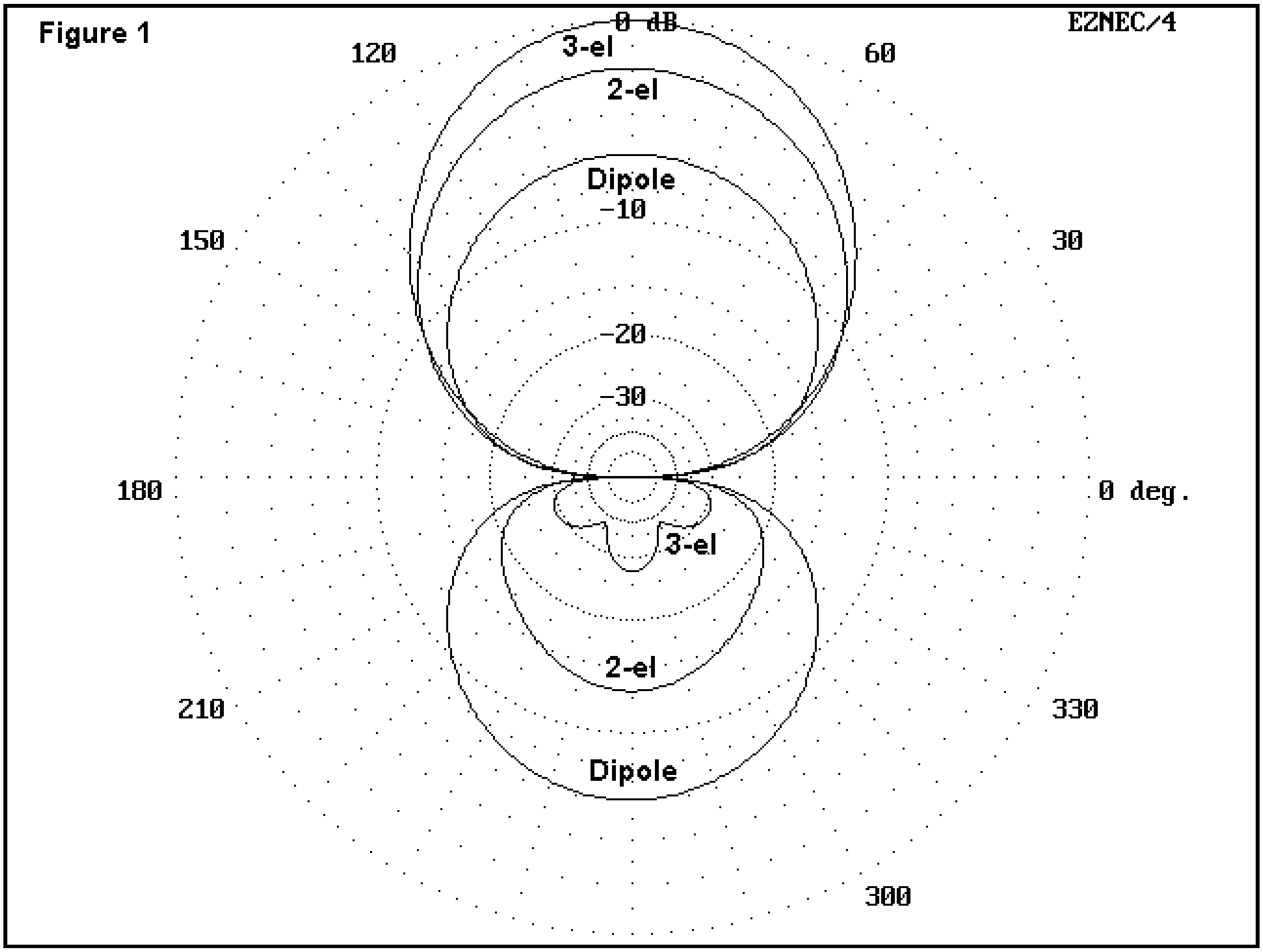
Last, be careful and considerate: keep RF out of the power lines and phone lines. It is often easier to try a different kind of hidden antenna than to filter or revise parts of the phone wiring.

No. 3: Where Does the Gain Come From?

L. B. Cebik, W4RNL

Earlier, we looked at 3 antennas modeled in free space: a dipole, a 2- element Yagi, and a 3-element Yagi. All were made from aluminum tubing and all were monoband antennas with no traps or other lossy components. The patterns we showed made it clear that the 3-element Yagi had the most gain and the highest front-to-back ratio. But that does not make it very clear from where the gain comes, given a constant transmitter output.

Fig. 1 repeats the azimuth patterns to refresh our memory. An azimuth pattern is like standing over the antenna and seeing its radiation. For free space patterns, we use 0ï¿½ elevation, since the pattern is strongest straight on.



The azimuth pattern does not give a whole picture of where the power is going. It does show that the beams project more power in the forward direction than the dipole, while "robbing" power from the rear. In reception terms, signals from straight ahead are strongest and weaker to the rear. However, they are weakest off the sides of the antennas.

To accurately see the power pattern of an antenna, we must also look at it from the side in an elevation pattern. An elevation pattern is like standing beside the antenna and looking through the aluminum tubes, while seeing the radiation. Fig. 2 gives an elevation pattern in free space for the same 3 antennas (3-element, 2-element, and dipole). Notice the displacement of the beam antenna patterns to the right, which corresponds to the forward lobe of the beam antenna azimuth patterns.

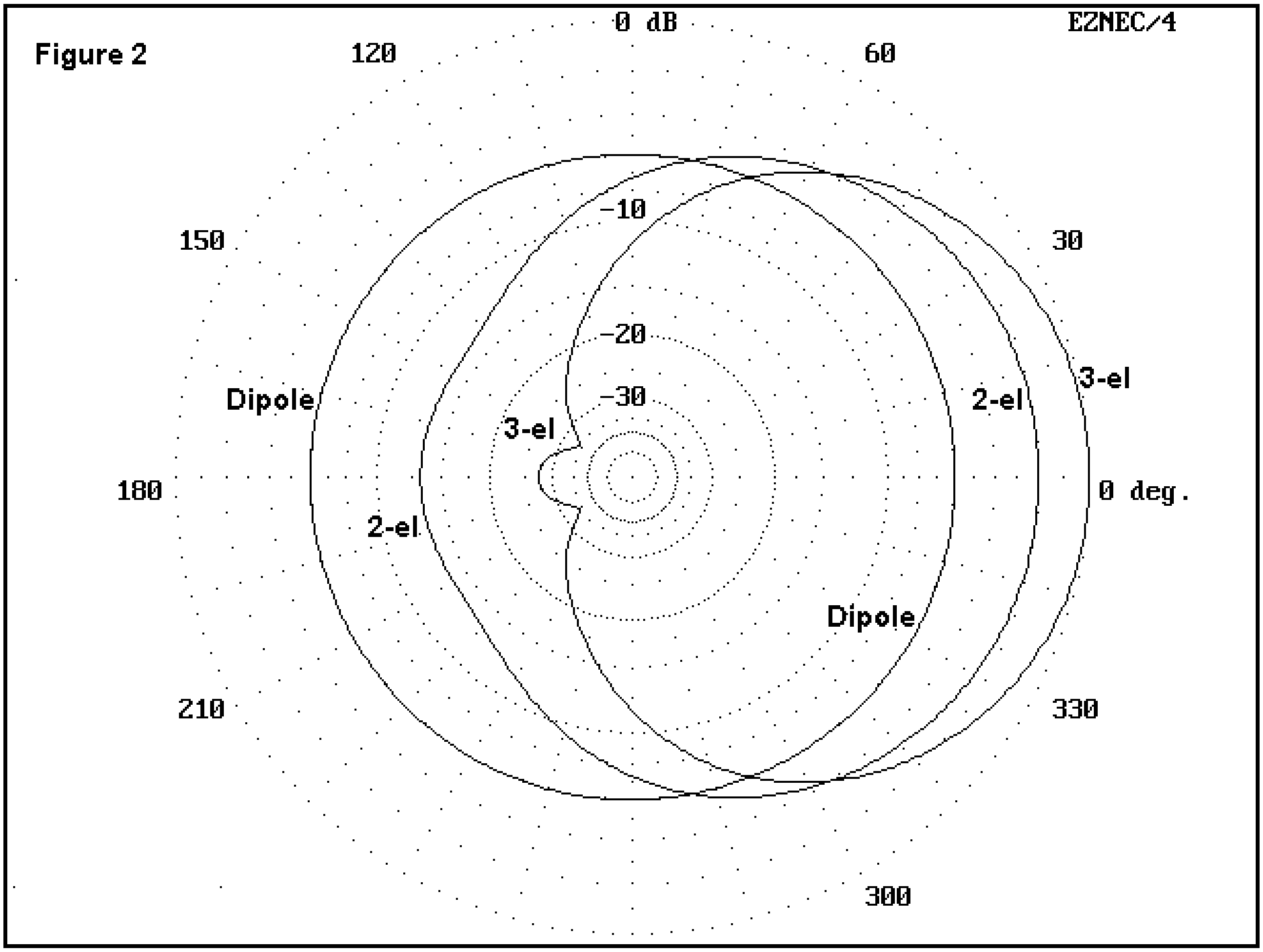
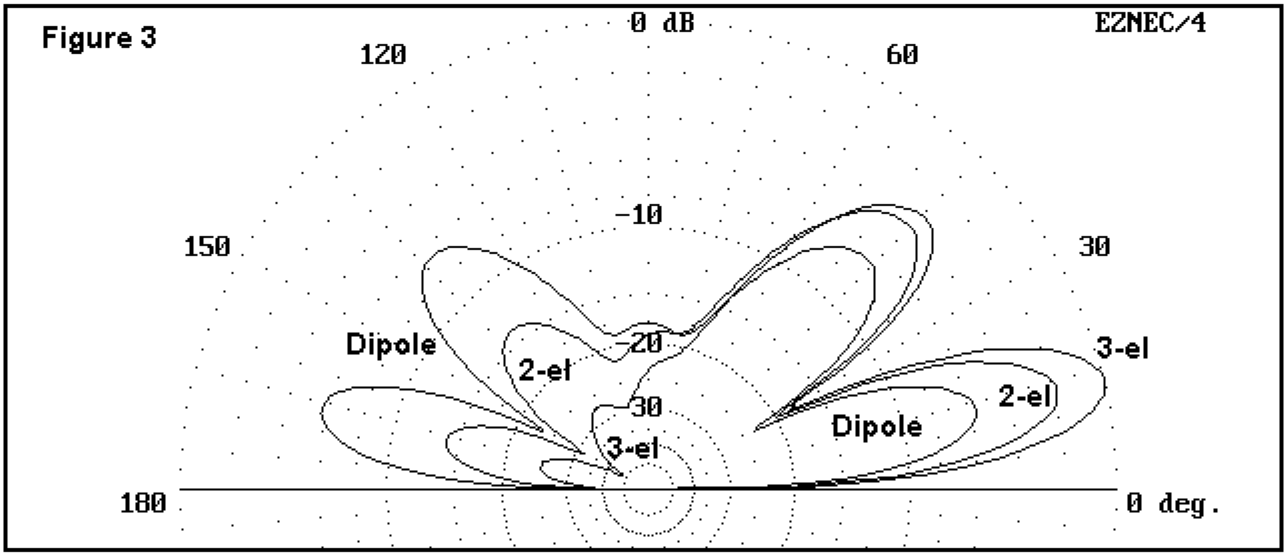


Figure 2

Only an astronaut can have a pattern radiating below the antenna site. Antenna gain over real ground also makes use of radiation reflected from the ground. Fig. 3 shows elevation patterns for the three antennas over real ground at 35' feet, about 1 wavelength above ground. The azimuth patterns would resemble those of Fig. 1, but they would not be taken at horizon level. Instead, they would use the angle of maximum power, sometimes called the take-off angle. The elevation patterns display this angle clearly and show that horizontal antennas above a real ground have a number of higher angle lobes as well as the main lobe. The complex pattern results from adding and subtracting reflected radiation from the above- ground pattern, depending on its relative phase.



Comparing Fig. 2 to Fig. 3 can lead to a misunderstanding, since the apparent radiation pattern is the same size; that is, the radiation just reaches the outer ring. However, that way of styling our drawings is just a convenience for making comparisons within each drawing. In actuality, the power in the lowest lobe of Fig. 3 for each type of antenna is much greater than the power in just the horizontal direction of Fig. 2. Expressed another way, all of the power represented by the spheres or near- spheres in Fig. 2 is flattened, thus putting greater power into the lobes that extend horizontally. The total power in the lobes is a result of adding reflections to the main or incident power going that way. The net result is gain over free space and gain of one antenna over another. And since the gain can be both calculated and controlled by good antenna design, we can--within limits--achieve a good bit more success than early radio pioneers in making and maintaining radio communications.

No. 4: Antennas and Low Sun Spot Counts

L. B. Cebik, W4RNL

As much as we hate to admit it, 10 meter conditions have been rotten. Instead of sunrise to sunset contacts across the ponds east to west, we hear only some weak north-south dx and a few weaker U.S. stations (from the U.S. perspective, of course). Occasionally during the day, the band will open a little for east-west skip. So, what kind of antenna is best for these conditions?

The answer depends on another big question: what kind of operating do you want to do? Let's look at three main answers: a. I want to work my local chapter and friends. b. I want to work those super weak signals, c. I'll take whatever I can get whenever I can get it. Each answer suggests some different antennas.

Local: Local chapters of 10-10 and other area communications are still wide open on 10 meters. That is because they are primarily point-to-point. (Note: we habitually call this ground wave, but usually it is not. Ground waves (or "surface" waves, as some call them) peter out on 10 very quickly. Just as on VHF, our elevated antennas look directly at each other: that is point-to-point.) Since most established hams have horizontal antennas, a vertical can be a disadvantage unless everyone is very close. Up to half the signal gets lost due to cross polarization.

The basic local antenna is still the dipole. If possible, make it rotatable, even if by hand, and as high as you can get it. Aluminum rod or tubing about 16' long, fed with coax at the center on a single mast works quite well.

If you live on the fringe of your local group, consider a simple 2-element beam, either fixed to point at the group or rotatable. The commercial HF5B is a typical compact multi-band design with a wide forward lobe (to catch everybody in the group) and modest front-to-back ratio. Since there is little trouble from QRM, the modest F-B ratio actually lets you hear someone off the back of the beam better than a station with a large beam designed to suppress virtually everything off the backside.

You can build a 2-element Yagi from supply store parts. If you are into building antennas, you might want to consider other designs for the fun of it. The Moxon rectangle, a wire beam, has about the broadest forward lobe and excellent rear suppression, but a little less gain. The X-beam is a bit tricky to set up, but is quite compact (a square under 10' on a side). Linear loaded Yagis can cut the element length from 16 to 12 feet. And the ZL-special can be built from 300-ohm parallel line (TV ribbon) on a light frame or suspended at its ends and fed with coax. If any readers are interested in these designs, I'll present some details in future columns. Meanwhile, look at any of the antenna books to gather some basic ideas.

Weak Signal Work: Much of the weak signal work done on 10 during sun spot lows is via backscatter, that is, by bouncing signals off the edge of the ionized layer, as weak as it is. That same layer, weakly hovering over the tropics, is responsible for the north-south skip that appears while the east-west path is too weak to support communications. So many 10-10ers point their beams south (or, if in the southern hemisphere, north) and listen carefully.

For the best results on backscatter and very weak skip, an antenna with the maximum forward gain is best. Again, the front-to-back ratio is unimportant, since there is no QRM. (However, few hams want the antenna just for sun spot lows, so they do pay attention to front-to-back ratio.) A long Yagi is perhaps best among the aluminum antennas. If designs are optimized, the gain depends on the boom length, so the longer the better (if you can support it).

Some wire antennas are capable of excellent gain, even if bidirectional. The extended double Zepp is over twice as long as a dipole, but narrows the beam width and has gain over the dipole. Dipoles (that is, antennas fed in the center) of a full wavelength can be set about a quarter wavelength apart and fed 180 degrees out of phase for additional gain. So too can EDZ dipoles (1.25 wavelengths long). These antennas usually (but not always) require parallel feeders and an antenna tuner. But the materials are cheap. Run the wires east to west for north and south lobes. For sun spot low backscatter and transequatorial skip, a fixed wire beam is not a bad choice. Again, if there is any reader interest, I'll provide more details in future columns.

Anything I Can Get: For general operation, use what you have and be patient. First, learn the band's habits. When do the openings occur? In what directions? How long do they last? Then plan your operating accordingly. Second, be sure your receiver is quiet so you can hear what there is. Early synthesized rigs are noisier internally than the preceding generation of crystal-mixing rigs. Direct-digital synthesis in today's rigs still leaves some noise on 10. That's why Ten-Tec offers both synthesized and crystal-mixing rigs and why some hams hang onto their old Drakes, TS-520s, and so on. The antenna is part of a system, not a solution to everything.

Third, plan your antenna for long term use, not just for the present lull in apparent activity. If you have room for antennas and like to build, have fun with experimental designs. But also plan the main system for the day when the sun spots return. (And, although we 10-10ers hate to admit it, that planning may involve operation on other bands, too.)

Finally, use your antenna! Very often a band is only as dead as the operators sitting around complaining about it. Listen to 10 on contest weekends to discover its true potential. Contesters (inadvertently) QRM each other on a supposedly dead band. Vertical or horizontal, your antenna will do you no good if everyone thinks the band is dead without checking. Find net frequencies, especially the daily 10-10 nets, and listen. If you cannot hear the NCS, request a relay check-in to find out if anyone is in the right place to hear you. Try some "CQs" near frequencies that used to be active. Make your presence known. . .of course, within the boundaries of good operating practice. 10 meters is more open than you think.

No. 5: What Difference Does Height Make?

L. B. Cebik, W4RNL

The general rule for antennas that we always hear is "The higher, the better." Is this true? Generally speaking, and for 10 meters, the answer is "Yes" in terms of antenna performance. (The answer may be "No" in terms of tower, rotator, antenna, and cable maintenance.) Why?

"Why" always takes more time and space to answer, but the general principle is this: the higher the antenna, the lower the take-off angle. We can get a hold of the idea of "take-off angle" by looking at Fig. 1. It shows one antenna, a three element Yagi, at heights of 22, 35, and 52 feet. These correspond to heights of 5/8 wavelength, 1 wavelength, and 1 1/2 wavelength respectively. If you extrapolate these ideas to other bands, remember that the principles apply in terms of height in wavelengths or fractions thereof.

We are interested in the lowest forward lobe to the right, the direction in which the beam is pointed. That is the main lobe, where the power is greatest (or the receiving gain is greatest). The angle of maximum radiation or gain is the take-off angle. At 22 feet, the angle for this antenna is 21 degrees; for 35 feet the angle is 14 degrees, and for 52 feet the angle is 9 degrees.

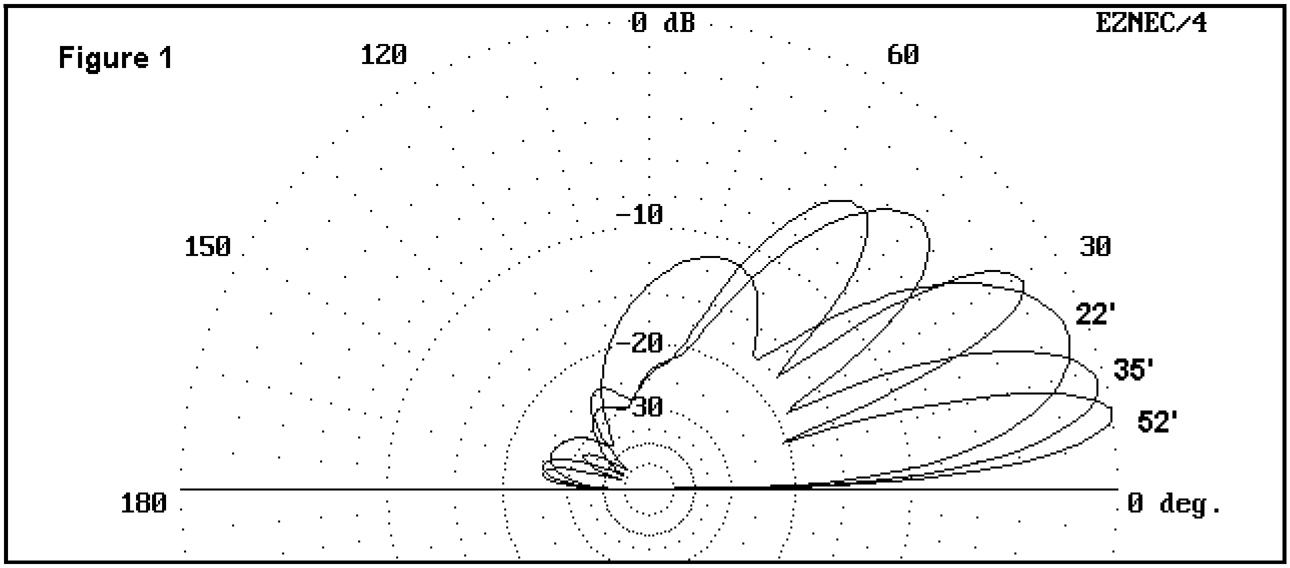


Fig. 1: Elevation plot for a beam at 22', 35', and 52'

There is a second principle to consider. Most of the time, the longer the path to a distant station, the lower the angle at which the signal bounces between the antenna and the ionospheric (skip) layer. On 10 meters, many dx stations require an angle under 10 degrees, especially during marginal conditions.

The test antenna at all three heights has some power radiated under the 10 degree angle, but obviously that power increases at this angle as we raise the antenna height. When the band is wide open, that is, when skip is very strong, the differences may make no difference in the ability to make long distance contacts. The differences begin to show up under marginal conditions or in competitive situations, such as contests and dx pile-ups. Many dxers favor heights above 100 feet, especially for their 20 meter antennas (that is, about 1 1/2 wavelengths at 20, 3 wavelengths at 10).

These principles are not absolutes. Skip conditions have many variables that can alter situations. Moreover, in some applications, we may want power in the high angle lobes. State-wide 75-meter SSB coverage conveniently calls for low antennas with high skip angles, and few of us can get a 75-meter dipole very high in terms of a wavelength. On 10, the secondary lobes of the beams are useful for using shorter skip paths.

Take-off angles do not vary much among horizontal antenna types. At very low heights (about 1/2 wavelength), 3-element Yagis and quads have a couple of degrees advantage over dipoles and 2-element Yagis, but the difference in take-off angles washes out at 1 wavelength antenna heights. Hence, a dipole at 100' might outperform a 4-element Yagi at 25' for some dx paths.

Height, especially at levels below 2 wavelengths, can make some subtle differences in performance as well. The gain, front-to-back ratio, and feedpoint impedance of an antenna are not constant as we raise it. Rather, for dipoles and Yagis, gain peaks at about 5/8 wavelength and again at 1 1/4 wavelength, 10 meter heights of about 22 and 44 feet. Gain dips at 7/8 wavelength, about 30 feet up. In some antenna designs, the dip may be almost a full dB below the maximum gain at favorable heights. Of course, if you have a multiband antenna, one band's maxima may be another band's minima, so some sort of compromise is in order. These subtler differences in antenna performance also complicate antenna comparisons.

Front-to-back ratios in 2-element beams show a variable pattern of change, but director designs peak just where reflector designs dip and vice versa. Curves are smoother for 3-element Yagis. The ups and downs in gain and front-to-back ratio that parasitic beams show demonstrate the complex interactions not only directly among the elements, but also with ground reflected power that plays such an important role in real antennas. The exact phase difference between the radiated power and the ground reflected power adds or subtracts from the antenna's total in both calculable and measurable ways. How the ground reflections add or subtract varies from one kind of antenna to another.

Antennas composed of 2 elements about 1/4 wavelength apart and fed 180- degrees out of phase show a bidirectional pattern with very significant gain over a dipole. They also display an immunity to some of the effects of height, general showing a smooth curve of gain increase with height. Another feature of these antennas is that they have a strong vertical null, that is, negligible radiation straight up. Hence, the interactions of ground reflected power with the antenna are largely confined to increasing the strength of the main lobes.

These subtler interactions, of course, do not negate the first principle of antennas. Get the thing as high as you can legally, safely, and economically maintain. Then start operating.

No. 6 The Simplest 2-Element Yagi?

L. B. Cebik, W4RNL

Building a beam is not as difficult as it may seem. Of course, a many- element, multi-band Yagi is an advanced exercise in design and construction. However, a 2-element Yagi for 10 meters is entirely manageable for the novice builder. Parts are available from almost any large home supply warehouse. About $50 for all new materials will produce a very usable beam. Mast and rotator, of course, are extra, but a TV rotator and well-guyed mast will easily support a 10-meter 2-element Yagi.

Fig. 1 shows the general outline of one of two forms of a 2-element Yagi. Some designs use a driven element and a director. The design in Fig. 1 uses a driven element and a reflector. The circle across the Y-axis line (the direction of forward gain) indicates the feedpoint.

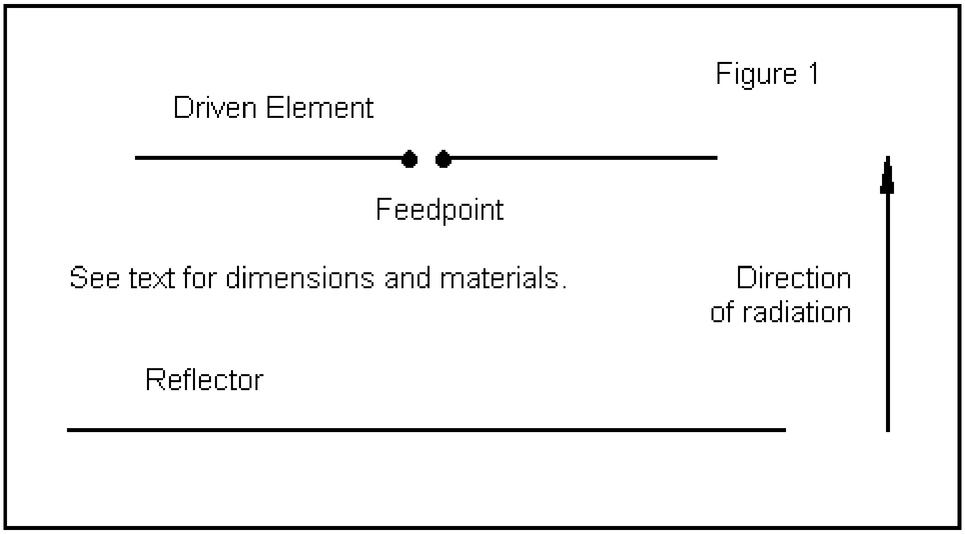


Fig. 1. General outline of a 2-element Yagi.

In the December, 1990, issue of *CQ*, Bill Orr, W6SAI, presented "A Compact 2-Element Yagi for 10 Meters" (pp. 83-84). His design used a combination of 1" and 7/8" diameter aluminum tubing, along with a gamma match for the 30-ohm feedpoint impedance. His beam was remarkably well-behaved. The gain varied from 6.86 dBi down to 6.08 dBi from 28 to 29 MHz, while the front-to-back ratio varied from a low of 9.09 dB to a peak of 11.29 dB. The beam was 17.5' at its widest with the elements separated 4.25'. Fig. 2 shows the beam's pattern at the design center frequency (28.5 MHz). It offers neither the highest gain nor the highest front-to-back ratio obtainable with two elements, but it gives consistent performance over a wide bandwidth.

It is possible to simplify Orr's construction, using either 1" or 0.75" diameter tubing available from hardware outlets. Moreover, by separating the elements 6', the feedpoint impedance increases to 50 ohms, allowing direct feed (with a 1:1 balun).

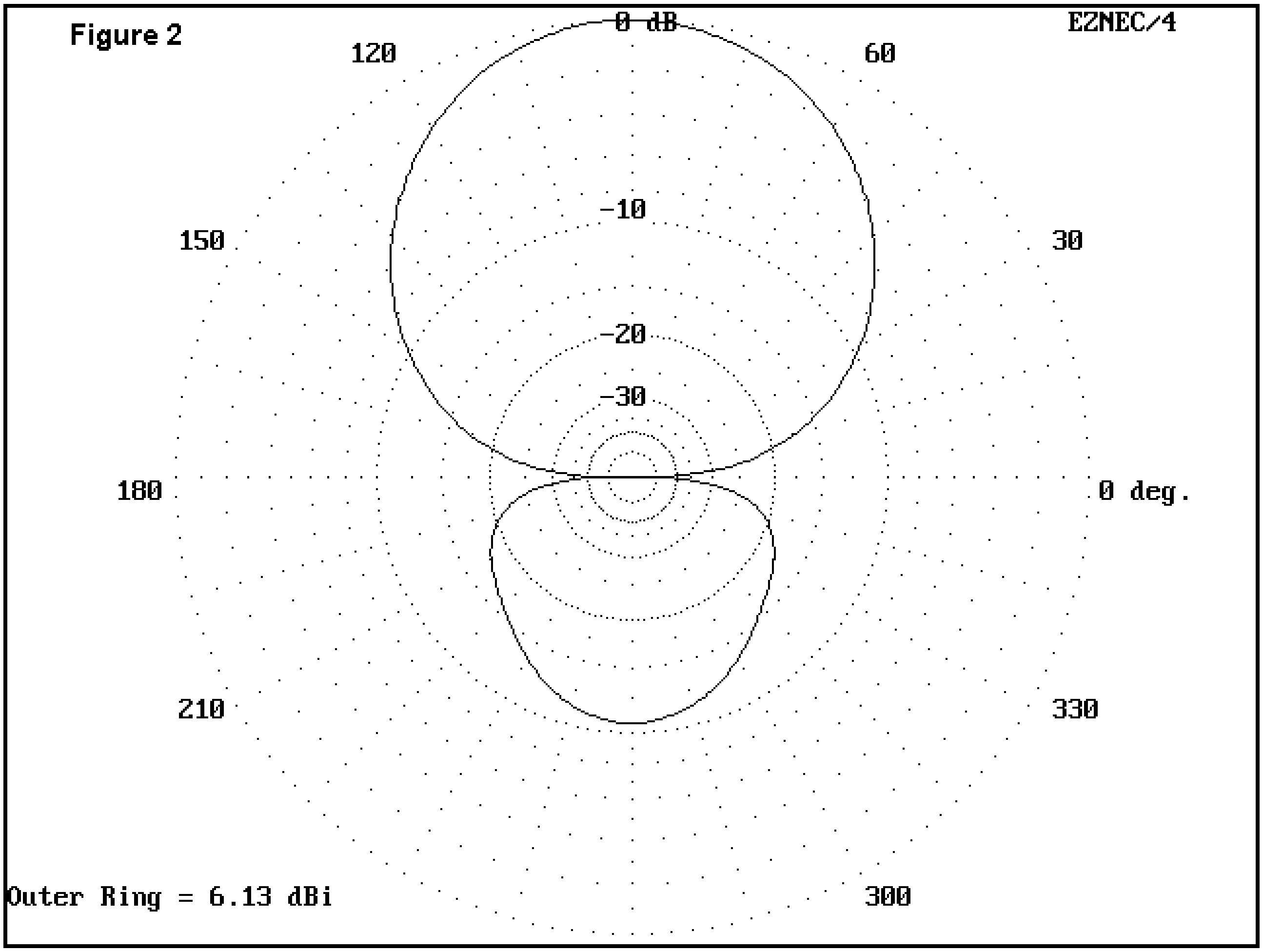


Fig. 2 Azimuth pattern in free space of a wide-band 2-element Yagi.

In fact, with 6' element separation and the dimensions shown below, SWR is less than 1.5:1 across the first MHz of 10 meters. We do lose some gain and front-to-back ratio, but less than 0.5 dB in each case, and the front- to-back ratio is more consistent across the band, never dropping below 10 dB.

The dimensions for the elements are as follows:

```
1" diameter aluminum tubing, 6' element separation:
  Driven element:  15.9' (ï¿½7.95')  Reflector:  17.52' (ï¿½8.76')
0.75" diameter aluminum tubing, 6' element separation:
  Driven element:  15.98' (ï¿½7.99')  Reflector:  17.5' (ï¿½8.75')
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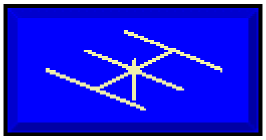
The driven element must be split at the center and fed like a standard dipole. To accommodate this, I mounted both elements on scrap plywood plates 3/8" thick, about 24" long and about 6" wide. Varnish or (better) fiberglass epoxy the plywood for weather protection. A pair of #10 stainless steel nuts and bolts (with both flat and lock washers) mount each half element to the plate. The bolts at the center make a good attachment point for a balun or for a coax connector to mate with another on a balun. Small U-bolts can be used for the outer fasteners.

The reflector is longer than a pair of 8' aluminum tubes. I used a 1.5' long piece of tubing as the center for my 1" diameter version of the reflector. Inside was a 3' section of 7/8" diameter tubing that supported the 8' lengths of reflector tubing. The #10 hardware at the center goes through the center 1" tube, while the outer #10 hardware goes through (or around, if U-bolts) the 8' extensions. All the #10 hardware goes through the 7/8" tube. Additional sheet metal screws (also stainless steel) clamp the extension tubes to the inner tube at its ends, cutting down on vibration.

For a boom, I used a 6.5' section of Schedule 40 PVC, 1.25" nominal diameter. A pair of 1.5" U-bolts holds each plate to the boom. Thick PVC tubing works well up to about this length, but much longer might produce too much sag. The plates go under the boom, and the elements are below the plates. Connections to the center of the driven element go to an extra set of lock washers and nuts on the element mounting hardware. The balun and coax are then taped to the boom and mast.

There are very few cautions to give for this beam. Check dimensions. Be sure all metal-to-metal contact is very good. Use stainless steel hardware to avoid rust or using protective spray sealers that work their way between contact points. (However, use flexible coax sealer over any screw-type coax connection.) As with any beam, check both mechanical and electrical connections every few months and after any severe storms.

Although the beam will perform well from a 20' mast, a 35' mast (or higher, of course) is even better. Expect some gain, almost 2 S-units of front-to- back ratio, and excellent rejection of signals off the side. This beam will not open 10 meters during the sunspot null, but it may let you work some of the weak backscatter signals on the band. In addition, it is useful in nets, since you can still hear locals off the rear while aimed at weaker signals. For versatility, the 2-element Yagi will certainly beat a fixed wire dipole hands down.



No. 7 The Poor Old ZL Special

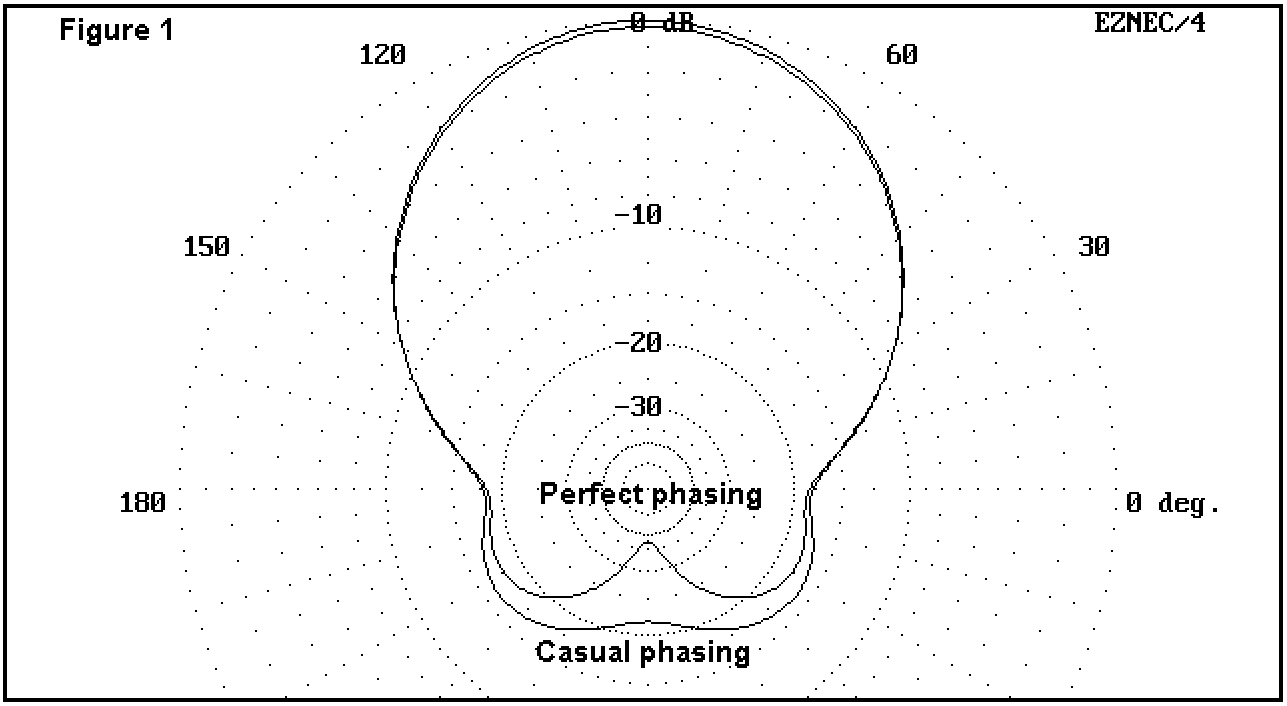
L. B. Cebik, W4RNL

Because the ZL Special is such a mechanically simple and cheap antenna, it has spent its nearly half century of life misunderstood. Rightly understood, it has a place in the 10-10 inventory of antennas. It will not cure the blues on a rainy day or make DX in the absence of sunspots, but it may make a very useful attic or field antenna.

ZL3MH (later ZL2OQ and recently a silent key) brought the antenna to ham attention in 1949, giving credit to W5LHI and W0GZR for basic information on the design. G2BCX, who has developed variations on the design from the earliest days to the present, dubbed it the "ZL Special," and the name stuck.

The basic idea is deceptively simple: take a driven element and a slightly longer reflector and space them between a tenth and an eighth wavelength apart. Next, connect the elements with an eighth wavelength of transmission line (adjusted for velocity factor of the line) with a half twist, and feed the former driven element with ladder line to an antenna tuner. The result is a 135ï¿½ phased array. In the early 1950s when hams had difficulties building Yagis at home, the antenna seemed to outperform 3-element Yagis and give almost miraculous front-to-back ratios. The claims are almost embarrassing today.

First, the ZL Special, in any form, will have the gain of a 2-element Yagi at best. In fact, most decent designs show about 6.1 dBi forward gain in free space, about the same as the broadband Yagi described in the last column and about 4 dB better than a similar sized and placed dipole.



Second, the front-to-back ratio can range from great to mediocre depending upon design care, luck, and Murphy. Figure 1 shows two patterns of the version we shall physically describe below. They are taken over real medium earth at a height of 20' (for reasons we shall also note below). Casual building can achieve the broader pattern, while extensive design and experimental work might approach the "perfect" pattern.

The perfect pattern might not be more especially useful than the casual pattern, since it is so pinched. Any rear QRM just off center line will not feel the effects of the high front-to-back ratio, since it will fall within the off-center lobes. The casual pattern is only slightly worse than the lobes of the perfect pattern. Looking at the entire rear sector of an azimuth pattern is sometimes called analyzing the "front-to- rear" ratio.

The casual pattern is still useful for certain kinds of applications. It provides a better than 15 dB front-to-rear ratio across the entire backside. If the mechanical features of the antenna fit your building needs, then it may pay to try a ZL Special.

Most of ZL3MH's designs used unequal elements. A few years back, W7EL published a Field Day Special version of the antenna using equal length elements. Hence, I tend to call unequal element versions ZL Specials and equal element versions FD Specials. W7EL's antenna is made (like some predecessors) from 300-ohm good quality TV feedline. The general configuration appears in Fig. 2., scaled for 10-meter use.

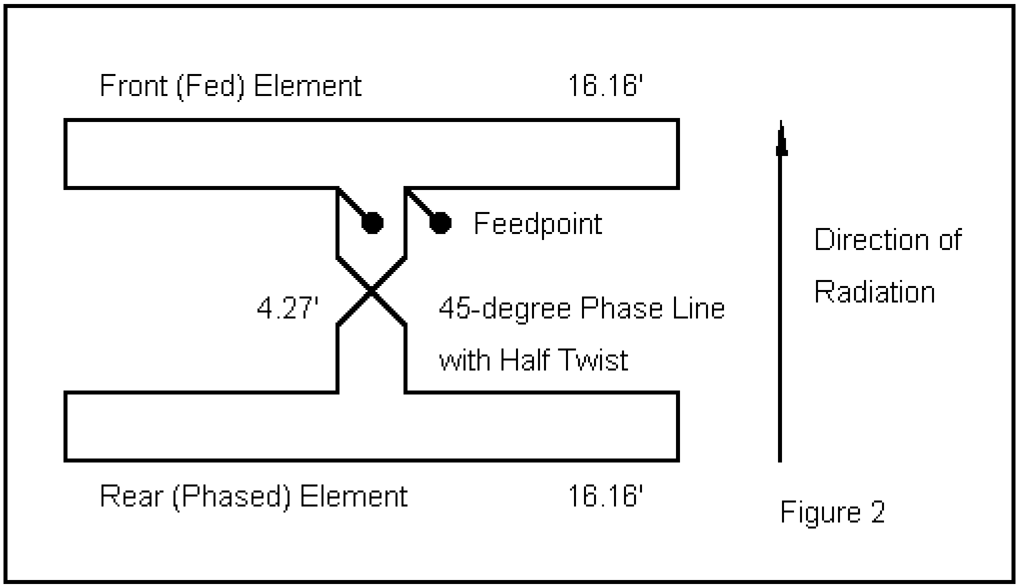


Figure 2

The elements are folded dipoles 16'2" long. The 300-ohm phasing section is 4'3ï¿½" long with a half twist between the front and rear elements. The phase line here is designed to be the same length as the distance between elements, thus producing a taut assembly.

You can feed the antenna in two basic ways. One way is to place capacitors in series with each feedpoint to compensate for some remaining inductive reactance at the feedpoint. Then a 1:1 choke balun links the feedpoint to regular coaxial cable. If finding the right amount of capacity to place at the feedpoint is a bit too much trouble, then feed the antenna with more 300-ohm ribbon brought to an antenna tuner. The feedpoint compensation will have no bearing on the basic properties of the antenna.

Heavy plastic squares with stress-relief slots and small machine screws as tie-point anchors should make easy work of the mechanical connections, front and rear. You can tape the antenna to bamboo and simulate a Yagi, but that is probably not the best use of the antenna. Better applications are as an attic antenna or an antenna strung between trees on Field Day and similar operations. A spacer bar at each end of the antenna and some rope ties will hold the antenna in place. These applications prompted the 20' height patterns, since they rarely permit very high antennas.

W7EL also noted a convenience: he attached half-wavelength sections of twin lead dangling from both the front and rear junctions. One just dangles (without touching the ground) while the other is connected either to the antenna tuner or the coax feedline. Swapping leads reverses the direction of the array. The dangling open-end half-wavelength line acts like a very high impedance, which affects antenna performance very little, if at all. Adjust these lines for the velocity factor of the ribbon cable, about .8 for most common 300-ohm twinlead.

Sounds simple, doesn't it? Mechanically, it is simple, but electronically, things get a little more complex. Some call the ZL Special a 135ï¿½ phased array because they think of the rear element as 180ï¿½ minus the 45ï¿½ twisted phase line out of phase with the front element. This is true with respect to impedance values found at each element. However, it is current magnitude and phase which determine the performance of the array, and the target ballpark for that current is 315ï¿½ (which is also -45ï¿½) out of phase with the front element. The half twist of the phase line is equivalent to twisting the element itself 180ï¿½ with respect to the front element, with an added 45ï¿½ phase line between them.

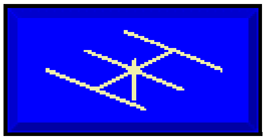
Now let's make it a little more complicated: for any 2-element horizontal antenna, there is an optimum current magnitude and phase angle for the center of the rear element to give the maximum front-to-back ratio. If the elements are about an eighth-wavelength apart, the current magnitude is near the value on the front element and the current phase angle is nearly -45ï¿½ relative to the front element. But, the antenna element lengths are also part of the overall geometry, and so the exact values for maximum front-to-back ratio are rarely these ideals. If you radically alter the geometry, like bending the elements toward each other at the ends, the natural values (or parasitic values, if you like to think in Yagi terms) change considerably from those found with straight elements at the same spacing.

Finding the exact dimensions for a perfectly phased ZL Special can be daunting and unrewarding, especially since the values also change with the antenna height above ground. (The "perfect" pattern in Fig. 1 required a modeled rear element current of 1.01 times the current on the forward element and a phase angle of -40.8ï¿½ and those values differ from the free space model values.) ZL1LE has developed a "lumped constant" matching network that permits him to tune his antenna to the deepest rear nulls as he feeds both junction points with half-wavelength feedlines.

However, there is a big difference between a usable antenna and a perfect antenna. Most ZL Special designs will show little loss in gain and at least 15 dB front-to-back ratio up to 5% above or below the optimal current level and up to 8 or 10 degrees off optimal phasing. Hence, even casual ZL Special designs get the job done, even if they are not perfect. That is why most antenna analysts (who are usually perfectionists) tend to hate the ZL Special, while many a poverty-level or teenage ham has learned to love the antenna.

Like the hams of the 50s, I prefer to use an antenna tuner with the ZL Special because I do not have to recompensate the feedpoint every time I move the antenna. And tuning one up to acceptable performance is a matter of adjusting the length of the phasing line, usually making it longer and a bit more saggy than most of the magazine designs show. Twin lead is cheap enough to experiment with almost endlessly--or at least until the sunspots return.

If your needs fit the mechanics of this antenna, try one. If you love it, you will love it even more for the savings. If you hate it, at least you won't be out much money, and the twinlead is reusable.



No. 8 Raiding the Hardware Store

L. B. Cebik, W4RNL

Home-made antennas have no warranties. We build them, modify them, fix them, and then use the pieces for another project. We move them from the roof to a mast, and from there to the attic. We fold, bend, staple, and mutilate them with great regularity. We do not have to think like manufacturers when we look for materials for small, experimental antennas. The hardware store will do just fine for 10-meter antennas (except for stock items like coax, ladder line, baluns, connectors, and #14 stranded copper wire).

Think hardware store if you build any of the following: attic antennas, portable or field antennas, experimental or short-term antennas, hidden antennas, "hurry-up-and-get-it-in-the-air-because-the-contest-is-about-to-start" antennas. By hardware store, I mean anything from the traditional shop to the giant home improvement depots.

The rule of thumb is this: if it is copper or aluminum, then it may be an antenna element; and if it is plastic--especially PVC or its offshoots--then it may be an insulator.

Here are a few examples to get your creative juices flowing.

1. Why tubing? Manufacturers use tubing for at least two good reasons. First, it is relatively strong among available antenna element materials. Secondly, it slips the wind better than most other economically feasible shapes. However, without a good shop, working with tubing is inconvenient. Lining up holes for connectors is a bear if we only have hand tools. We often crush it with both regular bolts and U-bolts. So, for experimental and field antennas, why not use something else.

Angle aluminum is available in a wide variety of sizes. We can choose 1/16 or 1/8" thickness in half-inch or three-quarter-inch widths. I prefer the 1/16" thickness for its lightness and the 3/4" width because I can mount a coax connector right on the element (after grinding off two of the corners).

Some years ago, I put together a collapsible square quad loop made from a combination of angle aluminum for the horizontal members and wire for the vertical. Construction and field assembly were a breeze because all the nuts and bolts went through flat surfaces. Any difference between the radiation of a tube and a complex angled surface was washed out in practice.

Hardware stores also have flat aluminum bar and often you can find aluminum rods. The bar would flap too much as an antenna element, but it makes good connector straps in short lengths. If you can thread aluminum rod, you can link pieces, as I did some time back with a collapsible dipole.

While you are thinking about alternatives to tubing and #14 wire, consider both 300-ohm twinlead and 450-ohm ladder line. You do not have to make folded dipoles out of them. Instead, just connect the wires together at the ends of an element to simulate a fatter wire for a slightly greater bandwidth than you can usually achieve with a single wire. For attic and field antennas, the slight weight difference may be offset by the wider QSY possibilities.

The usual steel mast and steel or aluminum tower is a marvel of engineering, and most handbooks show metal plates using metal hardware to mount a metal mast to a metal boom to metal elements. The operative ideas are durability and lightning protection. For many indoor, experimental, and field operations, these ideas are secondary, at best.

Schedule 40 PVC makes a good partial substitute for steel masting in short lengths. It works easily with hand tools. I have experienced no RF difficulties with it at 10 meters. I have used 1/2" to 1 1/2" diameters for various element support, mast, and boom exercises. The 2-element Yagi in a past episode used a PVC boom under 6' long, well within the sag limits of the tube.

Schedule 40 PVC gives "nominal" or minimum diameters: the actual inside diameters are greater. 1.25" PVC has closer to a 1 3/8" inside diameter and a 1 11/16" outside diameter. 1" nominal will nest inside 1 1/4" nominal, but not tightly. However, most other sizes will not nest well or at all.

Consider the following portable dipole. The elements on each side of center are 3/4" and 5/8" aluminum tubes that slide into each other for carrying. The center insulator is a 2' to 2.5' piece of 5/8" dowel--a foot or so of antenna element over each end of the dowel. The dowel slides into a hole through the near top of a 2' piece of 1" nominal PVC. The PVC slides over the end of a section of TV masting. 5' sections of the mast put the antenna as high as safe and feasible, with rope guying. The dipole is turnable by hand over 90ï¿½ for nulling QRM into the element ends. Wherever the tubing fit is too loose, some electrical tape on the inner tube tightens the grip without gluing the assembly together. It all breaks down into a collection of tubes no longer than 5' maximum. Nest what you can; then lash the bundle together with the guy ropes for transport. It is possible to drill a hole and fasten a coax connector to the PVC top mast section, or you can make up a little plate for it from some scrap aluminum.

For wire antenna element spacers, portable quad element supports, and similar light duty functions, try some of the lighter-weight tubing available. Half and three-quarter inch CPVC tubing is available, as is Schedule 315. For both 90ï¿½ and 45ï¿½ corners, as well as for section couplings, there are fittings that glue together so permanently that I have never had one fail yet.

3. Flat and angled insulators: Sturdy plastic insulating plates are easy to fashion from thick freezer containers. They are temperature impervious for normal use lifetimes. The sides are either straight up or slightly angled, making good mounting lips. A hacksaw cuts these 4" square containers into handy sizes, and a 5/8" hole saw for wood cuts a perfect coax connector hole. The uses are limitless, but the first use that comes to mind is as a center insulator for either straight wire or folded dipoles.

However, do not overlook round and "squared" plastic bottles for special uses. The semi-rectangular bottles used for some liquids have rounded 90ï¿½ corners. Cut a pair of round holes (to match a boom, a mast, or an antenna element), one on each surface of a corner section. Squeeze the corner together and slip it over the mast, boom, or tube. Let go, and the corner grips well enough to withstand small loads and winds up to 45 mph. You can use this scheme to space feedline from a boom or mast or to suspend linear loading elements beneath a main element.

4. Wood and the "auto" section: For most experimental, indoor, and field antennas, metal mast-to-boom and boom-to-element plates are not necessary (unless you just happen to have a stock of 3/16 to 1/4" thick aluminum). 3/8" or 1/2" plywood will do as well.

Put away the varnish, because it will not last long in the weather. Instead, look in the auto supply part of any of the X-mart stores for a can of auto body work fiberglass resin liquid. Spread it liberally over the plywood piece (already cut and drilled). Give special care to the edges, where plywood is very porous. Once dry, recheck the hole sizes for easy hardware passage and redrill as needed. If your wood plate is lumpy, sand the surface flat, but not down to wood again. If you slip up, retouch the area. Now your plate is sealed against weather much more perfectly than any varnish I have found.

The one exception is epoxy paint made to seal concrete and similar benches, tables, etc. It does much the same work about as well, but is not always readily available.

Note that I do not use the fiberglass cloth in this process. It is unnecessary for this application.

5. Hardware: For antenna work, use stainless steel hardware (nuts, bolts, washers, hose clamps, etc.) wherever possible. Stock sizes are now readily available in the depot-type stores, and there are in many medium to large cities specialty suppliers of stainless steel hardware. If it is rustable, do not use it for an electrical connection out of doors. Beware, for example, of those little wire-end rings: most turn to rust in a few months.

For hardware that does only mechanical, but not electrical work, clear sprays can extend their useful lifetimes. Of course, such coatings take the hardware out of the secure grounding system. So if you need a ground lead from your antenna boom to the rod in the earth, run a separate flat braid. Do not rely on coated or rustable hardware for this job.

This is just the start. If you like to play with experimental antennas, especially for 10 meters, just wander around a hardware depot. Buy a few fittings that look promising and cheap just to stare at in your leisure. I am sure you will find a use for some of them in your next project. Remember: antennas do not have to look like commercial versions to do the job you need them to do. They just have to be electrically and mechanically sound enough as antennas and convenient enough relative to your situation.

Now where was I? Ah, yes. This elbow joint just fit over the end of the tube for my bedspring helical J-pole antenna. . ..

No. 9 Fans and Bow Ties

L. B. Cebik, W4RNL

Can you use a simple antenna that has an SWR of less than 1.5:1 all the way from 28.0 MHz up to 29.7 MHz? Then you need something stylish in the way of a fan or a bow tie.

Fanning the ends of a dipole or spreading them into a bow about the middle of each side of the element is an old trick for increasing the SWR bandwidth of a dipole. The fatter the element, the broader the bandwidth of the antenna without any significant loss of performance. Ten-meter fans have been around a long time, but folks have almost forgotten them. Let's restore the memory. Remember that there is a good bit of activity at the upper end of 10, what with satellites, repeaters, HF packet and the like. An antenna that will let you work both the repeaters and the CW end of the band is worth remembering.

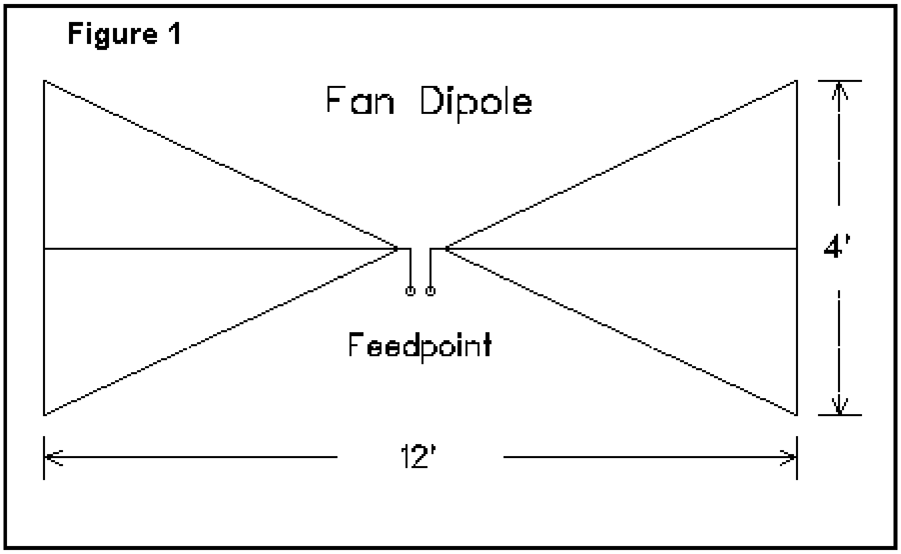


Figure 1. A fan dipole for 10 meters.

Figure 1 captures the essence and the dimensions of a fan dipole for 10 meters. It is a resonant dipole for 10 with a feedpoint impedance of just about 50 ohms resistive at resonance (about 28.75 MHz). A fan can be built with or without the center bar across the middle. However, if the middle bar is removed, the resonant point actually goes down in frequency to about 28.25 MHz with the dimensions given. So some shortening of the structure is in order.

The bandwidth of the antenna increases almost linearly as the vertical dimension is increased. Four feet is a good compromise between performance and ease of building the antenna. At this size, the gain is about the same as a wire or tube dipole having a narrower bandwidth. With the right construction, the antenna will slip the wind easily and be a very long-lasting antenna. It may even look odd enough to fool your neighbors into thinking it is not a ham antenna.

Building the fan begins with a centerplate: plywood with a coating of the epoxy used for fiberglass repairs works fine. Make the horizontal element 0.75" diameter aluminum from the hardware store. While you are there, pick up an 8' section of aluminum rod or tubing about 0.375" (3/8") diameter and cut it in two. These are the end verticals. You can drill a 3/8" hole in the end of the tube or use some other clamping system. I just slid the rod into the hole and locked its position with two tiny hose clamps, one above and one below the tube. A pair of bolts, with nuts on either side of the tube wall, press on the rod for electrical contact. Be sure to use lockwashers on the bolts for a good bite into the aluminum tube.

#14 stranded wire runs from the rod ends to the center of the dipole. Another set of hose clamps locks the wire in place at each end. Mount the plate on a mast, turn it by motor or hand, and the job is complete.

Be sure to use stainless steel hose clamps and hardware. A little conductive "butter" helps preserve contacts, especially where the metals are dissimilar.

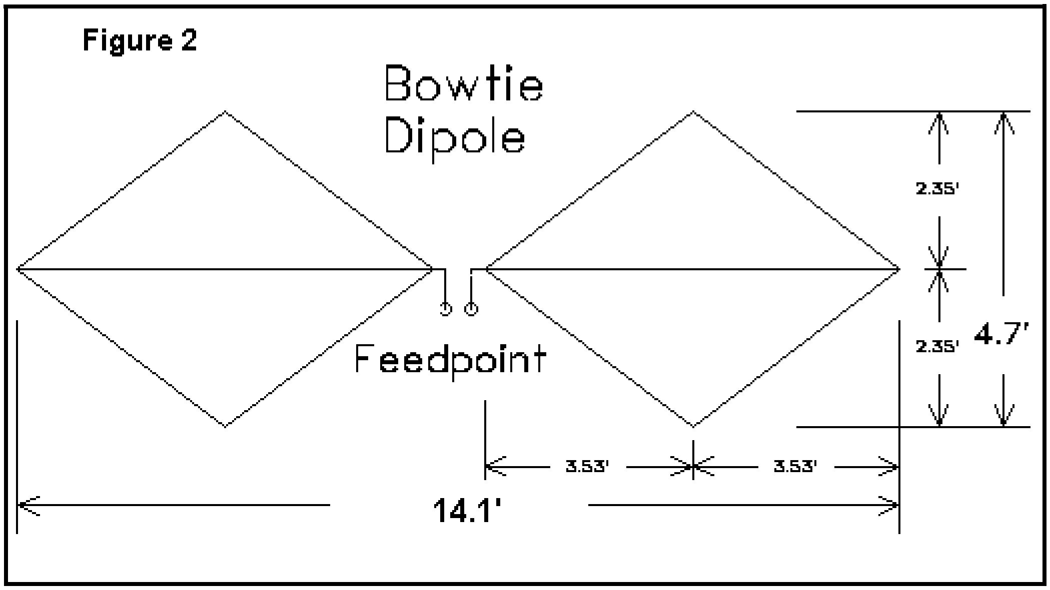


Figure 2. A 10-meter bow tie antenna.

An alternative to the fan dipole is the bow tie. Instead of spreading the antenna at the ends, we spread it in the middle of each half of the dipole. For the same bandwidth, we must have a longer antenna, spread a bit wider at maximum. However, the ends come back to the center tube, which makes construction a bit simpler for some folks. The same principles apply. However, notice that no vertical element is showing in the diagram. Use something nonconductive for this spreader. A length of Schedule 315 PVC (thinner wall) may do the job. The wire tension will keep the tubing from bowing, and a simple set of brackets will hold it to the center tube.

The SWR bandwidth of the bow tie is just as good as it is with the fan. If you think you can hear the difference made by 1/10th of a dB gain, then computer models say the bow tie is that much better than the fan. (Before you get caught up in the idea, forget trying to hear a 0.1 dB difference in anything; you cannot do it.) So the difference comes down to this: which antenna is easier for you to build.

Fans and bow ties used to be built from bent tubing, getting rid of the center horizontal tube. Personally, I do not recommend this construction. Even if you are an expert tubing bender and do not weaken the tubing by crimping it, the wind will transform your fan or bow tie into a crumpled scarf in very little time. Some modification of the suggested construction method, adapted to what you have in your shop, makes the strongest assembly.

Fans and bow ties, especially fans, lend themselves to 2-element beams quite readily. Ask the folks at Butternut, where they make a multi-band beam from 2 fans slightly larger than the dipole described above. They call it a "Butterfly" beam, so if you make a beam from two bow ties, you can call it a dragonfly beam.

Actually, a monoband beam for ten is not too difficult to build. With the basic fan dipole as a guide, you will have to lengthen the back element by about 5% or load it with a coil at the center. The driven element will be long, just about long enough to add the right inductive reactance for creating a beta match with a capacitor across the feedpoint terminals. You can experiment with a variable capacitor and then replace it with a fixed capacitor of the right value. About an eighth wavelength of spacing (about 4.3') will give the same performance as a "full size" 2-element Yagi, such as the "simplest" Yagi described in an earlier column.

While 10 is so marginal for everyday activity, I suppose I will not break any taboos by mentioning the fact that you can apply the same fan principle to wire antennas for the lower bands. With all the variables that go into wire antennas for 80, 40, and 30 meters, it likely makes no great difference if you connect the ends of the fan together or leave them separate. If you add a fan wire to an existing antenna, be prepared to shorten the antenna, since the spread wire will act like a thickening agent. Some hams have strung wires cut for the low end of the 80-meter CW band, the Novice portion of the band, and for 75 meters, all with one feed. However, 80 is so wide a band (as a percentage of the frequency), that these wires tend to act like 3 independent antennas with a common feed. So you can expect to see ups and downs in the SWR pattern rather than one single low point.

The fan and the bow tie are distant relatives to the cage antenna, a series of wires spaced apart along their entire length by special nonconductive spacers. The original theory was that the radiation from each added up, but actually, the only benefit was getting the equivalent of a fat wire from thin ones. You do not have to go that complex route to get a wide-band dipole for 10. The fan and the bow tie will do the job, and they are much easier to rotate the 90 degrees it takes to put a maximum face on the station you want to work.

No. 10 Notes on 10-Meter Antenna Tuners

L. B. Cebik, W4RNL

There are many excellent antenna tuners (ATUs) on the market that will match at 80 or 160 meters. On 10, the match may be more of an illusion than an effective reality with some designs. If you are a dyed-in-the-wool 10-meter operator and use an antenna system that calls for an antenna tuner, you may be better off building your own.

So what is wrong with the commercial tuners? (Remember, not all of them are wrong. Compare the points made here with the features you see when you think about buying one.) A number of things go wrong in designs aimed at covering 160-10 meters.

1. The basic design: Most ATUs use a T-network with series capacitors and a shunt inductor, as schematically shown in Figure 1.

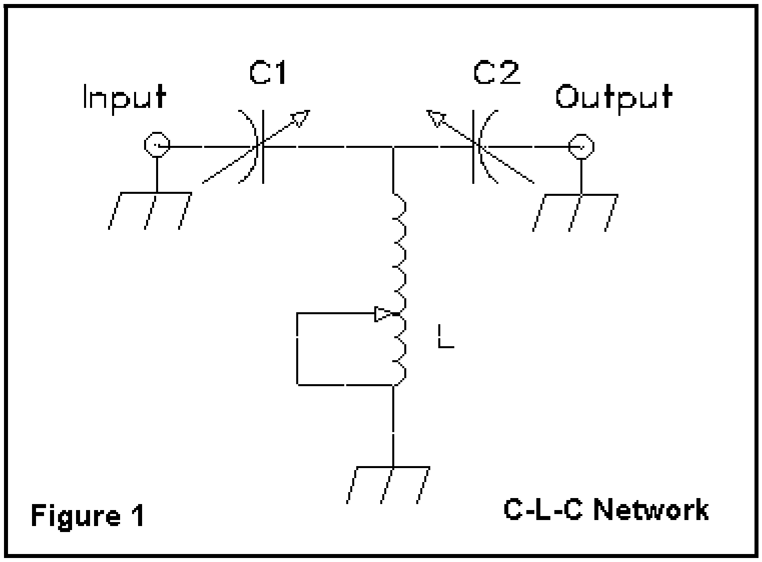


Figure 1. Typical Series-C T circuit.

This design is a high-pass filter and provides little, if any, suppression of harmonic energy. One can argue that we should not rely on the ATU to do the job our rig's output circuitry should be doing. That argument is sound, but if there is a design that will also provide some harmonic energy suppression, it may be preferable. Two designs fill the bill.

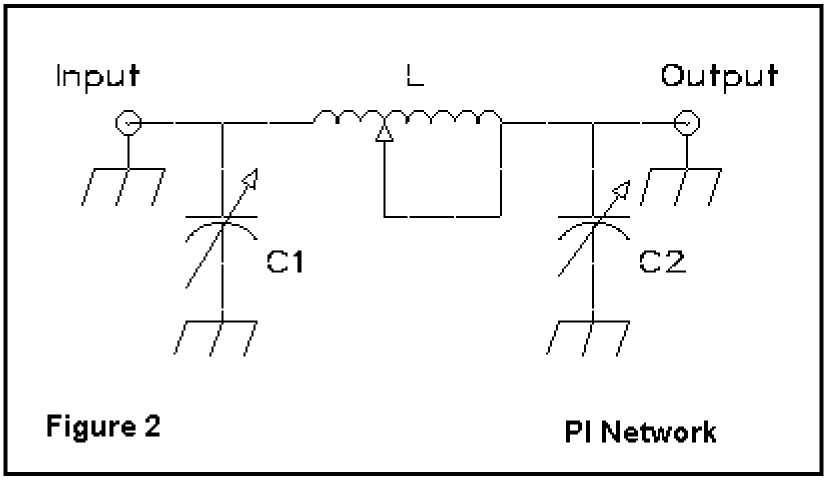


Figure 2. Typical PI network.

Figure 2 shows a PI network with shunt capacitors and a series inductor. It is inherently a low-pass filter.

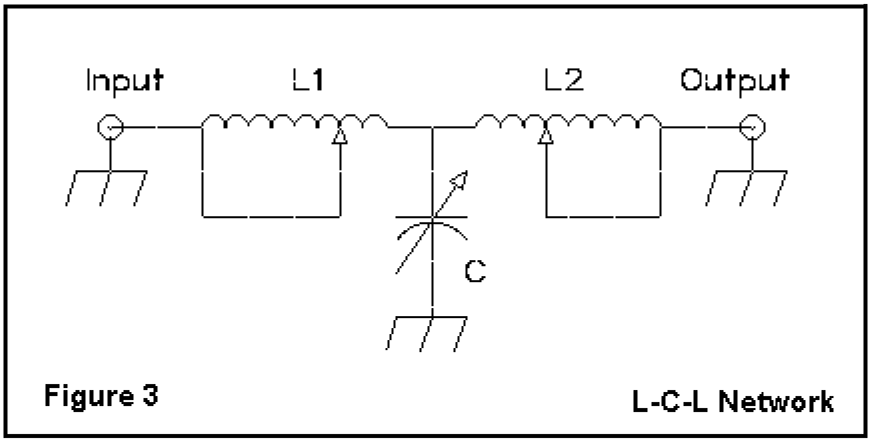


Figure 3. Typical Series-L T circuit.

The circuit in Figure 3 is also a high-pass filter: it is a T-circuit with series inductors and a shunt capacitor.

The reasons for using a series-C T are cost and size. The components for it are smaller for a given power level, since we can fit a 20+ microH coil (rotary or tapped) alongside a pair of 250 pF variable capacitors in a compact case. By contrast, the inductors for the other circuits may require up to and over 30 microH, and the capacitor for the series-L T may need values up to 1000 pF. That is, if you want to tune 80 or 160.

If you only want 10 meters, then the values drop. A 5 microH inductor (or 2) and a 250 pF air variable (or 2) give all the range anyone should need for 10.

2. Tapped inductors: A tapped inductor may do the job you require, but for some antenna situations, you may not be able to find the 1:1 SWR point. That is not fatal if you can find a point under 2:1. However, a good rotary inductor (or 2 in the series-L T circuit) is superior, since there is no required setting that is unavailable to you. You can find some good near bargains in rotary inductors at hamfests. The same applies to capacitors.

3. High-value components: The higher the highest value of a capacitor or coil, the higher the lowest value. The large frames of high-value rotary inductors may limit the lowest value to well over 1 microH. Capacitors are even worse, because the high maximum value does not tell the whole story. Usually, capacitors follow the rule, but you also have to watch out for construction. I have an old military capacitor with a maximum value of 35 pF. Unfortunately, its lowest value is 17 pF. It is built within a set of frame plates that surround the stators and limit how low it can go. By contrast, a 100 pF old E. F. Johnson capacitor in one of my units has a minimum value of about 10 pF. Its supporting metal work consists of two small plates on either end of the unit. If you roll your own, look for the capacitor's minimum value as well as its maximum value.

4. Closed tight cases: On ten meters, some commercial ATUs achieve a match more with stray capacitance and inductance than with the higher Q variable components that are supposed to do the work. Steel cases that cut the inductive fields of coils and provide several pF of shunt capacitance to the other components complicate and usually hinder the basic work of the matching network. A spacious case, however much against the grain of today's stylistic fetish of ultacompactness, is a plus for an ATU.

5. Poor ground paths: Ideally, there should be one good ground point for the ATU network. With large components, this condition is often impossible to attain. However, grounding should be as direct and compact as possible--and as near to the ground lugs of the coax sockets as possible. It should not rely on the bite of a lock washer through a painted surface. A rivet used as a ground connector is a prelude to malfunction. There are no shortcuts to good, short, wide ground paths and good mechanical and electrical connections. They are not expensive, but they do take care.

This list of difficulties is not an indictment of all ATUs. Many units have taken the trouble to be the best they can be as 80 or 160 through 10 meter units. However, you can probably do better yourself. For 10 (or realistically, 10-20 meters), a PI or series-L T circuit is achievable with parts you can obtain from hamfests. A PI might use a 5 to 10 microH inductor with a pair of 250 pF air variable capacitors of good power rating. A series-L T circuit might use a pair of 5 or 10 microH rotary inductors and a couple of 250 or 300 pF variable capacitors, with a switch to bring them into play either one or both at a time. A surplus or home brew case with plenty of room helps ensure that strays are minimized, as do well-planned ground paths. Consider a plexiglass case for the ultimate in avoidance of strays.

Remember, multiband is not always the most efficient, even if it is the most compact. The bands that take the beating are the ones at the high and low ends of the multiband range. Ten meters, unfortunately, is one of those ends. Hence, if you use a 10-meter antenna system calling for an ATU, consider building yourself a customized unit with all the advantages and none of the difficulties.

No. 11 Mobile Antennas for 10 Meters

L. B. Cebik, W4RNL

I was asked to do a column on mobiles. While I claim no serious expertise on mobile antennas, there are some ideas worth considering, some information worth getting, and some safety thoughts worth taking very seriously.

Mobile in motion

Inherently, a mobile-in-motion antenna system, consisting typically of a shortened, loaded vertical antenna, is a very lossy system. Most of your power goes nowhere. However, do not let that discourage you, since some truly amazing hamming has been done mobile. Let the problem be your challenge. How can you minimize the losses?

The first step is to ensure that a mobile rig in your car will not do bad things to your car's computer and equally bad things to your car's warranty. ARRL has published some contacts with automakers and distributors where you can get some (but probably not all) of the answers.

The second step is to prepare your car for a mobile antenna system. This involves close attention to power cabling, ground cabling, and decoupling RF from the battery and other auto electrical components. Use coax that can handle the automobile's hot and cold and greasy and dirty environment. Avoid foam insulated coax cables, as well as those like RG-8 and RG-58 with older types of jackets. RG-213 generally meets the needs of the mobile environment. The very best book I know of on the subject of mobiling is Don Johnson's (W6AAQ) ***40+5 Years of HF Mobiling***, which is from World Radio. Please do not just slap a rig in the car, mount an antenna on the roof, trunk lip, or plastic bumper, and try operating. Read Don's advise and carefully prepare your vehicle for a mobile set-up.

The third step is choosing an antenna. According to various sources, the bugcatchers (either Texas or California style) and the DKs (antennas that follow Don Johnson's design) appear to do the most consistent job across the ham bands. However, for 10, you can consider the Hamstick types or even an old fashioned quarter-wave whip with no loading.

Mounting brackets come in every conceivable size and shape. Brackets used by truckers for CB antennas will attach the antenna almost anywhere on the vehicle. The big question is this: where?

Since the vehicle serves as a ground plane for most mobile antennas, the best place is in the middle of the roof, which is often a bad place physically. The antenna hits every overpass (until it breaks, of course), and you have to put a hole in your new $15,000 to $30,000 car, an act to which warranty servers may not take kindly, especially if you lease your car.

Since trunks are making a comeback after a decade of hatchbacks, the trunk lip is a possibility. However, do not rely on the set screws of the trunk lip mount for a ground to vehicle metal. Add a short, wide strap from the ground of the base to a good bolt in the car metal.

Increasingly, you can find a metal bumper only on trucks and vans. However secure, the antenna base, where the highest current resides and creates the most intense part of the radiation field, is very close to ground without much of a ground plane below it.

Trucks and vans are becoming more popular as wheels for mobiles, and folks seem less fearful about making holes in them. Side-mounting mobile antennas well up the van wall or cab side is considered an acceptable alternative to roof mounting, and it lowers the tip of the antenna by a foot or so. Bumpers are strong on many of these vehicles: consider a sturdy extension to the antenna base to raise the entire assembly.

Once everything is in place, including the rig, do not just hit the road chatting away. If you have not watched a weaving car with a cellular phone in the driver's hands, you have not been paying attention. While some ham-drivers can learn to drive and talk and twiddle knobs all at once, many others are high-speed unguided missiles. Unless you are certain that you are safe, let your passenger do the operating. I learned that the semi-hard way--from a close call rather than from an accident. It was inches from being the other way around.

Mobile not in motion

The safest way for the driver to operate mobile is to stop the vehicle and operate a while. Here, the driver can select a potentially good site to maximize radiation in useful directions, as well as operate safely. Parking lots, open fields, and hilltops are all likely operating points.

Once you stop your car, you should instantly realize that your antenna options increase dramatically. You can take a modified mag mount CB antenna, resonated for 10, and slap it on top of the vehicle so you can monitor the band while you assemble and raise some kind of antenna less dependent on the car for its ground plane.

With careful planning, you can create a dipole or a 2-element beam that breaks down into sections that store within the trunk or a similar storage space. A little tool kit with pliers, screwdrivers, and nut drivers can have a permanent place in the trunk. Here are a few tips for such antennas:

- 1. Avoid sheet metal screws as element length connectors. Their holes will wear out just when the band opens to Asia. Use hose clamps with a nut driver (usually faster and more sure-footed than a screwdriver).
- 2. Protect the elements and the center connectors when not in use. A cheap golf-club bag (are there any such things any more?) or something similar is a good protective carrier.
- 3. Store any loose hardware in a bag with a seal inside a plastic box with a clasp. Finding all but one absolutely necessary screw is Murphy's favorite joke on you. Better yet, have no loose hardware--keep it attached to one or the other of the pieces separated for storage. Then, keep a few EXTRA pieces in that bag in a box.
- 4. Keep the antenna sturdy enough to store well, but as light as possible for easy assembly and raising. Remember, the antenna does not have to withstand gale-force winds in this application. Smaller diameter, thinner wall tubing will do a good job and prevent back pain.

The mast can be as simple as 4 5' sections of TV mast. There are also a number of extendable aluminum poles, most never intended as masts, that will support a light antenna in very small breezes. The search for the perfect stationary-mobile mast is endless.

Guying the mast, even for a brief stop is a good safety measure. One workable system requires a little 3/16 or 1/4 inch rope and a single concrete block. The mast slips into one of the block's holes, which generally is enough to prevent the end from skidding. A side bracket attached both to the door frame (of a car and perhaps the side rail of a pickup) holds the mast a few feet up. The guy ropes go from near the top of the mast to the other side of the car and are tied to the fore and aft bumper frames with a slight tension that holds the mast in place, but still lets you turn it.

You can also make up a tubular bracket a few feet long and attach it firmly to a pickup's rear bumper. The mast slides into it and is self-supporting.

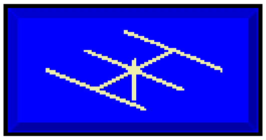
Most studies show that over flat land, low horizontal antennas do best at a 5/8 wavelength height, which is just about 20' on 10 meters. Although the take-off angle is high (above 20 degrees ordinarily), short skip operation is quite good, and dx is often only about 2 S-units down from elevations above 1 wavelength (35'). Even though the take-off angle decreases with each increment in antenna height, try to avoid heights between 3/4 and 7/8 wavelength, since ground reflections tend to cancel some of the radiation in the lowest lobe, which is the most useful lobe for skip. If the land is not flat, diffraction effects can wash out some of these phenomena.

However, a 20' mast is the most many hams can handle mechanically in the field. Those who can get above 30' up need to ensure both personal safety and the safety of passengers. Not to mention saving that big wheeled investment from damage by a $10 homebrew antenna.

Of course, nothing says you cannot use a well-installed regular mobile antenna. When the band is open, antenna efficiency only makes a difference in pileups (station pileups, not vehicle pileups).

This style of mobile operation is more leisurely than mobile on the fly. It is also safer for everyone.

Drive safely. The life you save may be mine.



No. 12 Multiband vs. 10-Meter Dipoles

L. B. Cebik, W4RNL

If we had unlimited money and space, we could ask the following question sensibly: What is the best 10-meter antenna? The answer might be about 4 stacked long-boom, many-element Yagis from about 70' on up on a rotatable tower on a one-hill island surrounded by ocean. Even that answer might get an argument. However, for most of us, the simple question of what the best 10-meter antenna might be is an exercise in irrelevancy.

A more sensible question is usually this one: which of two alternatives is the better antenna? Each alternative might fit our yard and bank account. However, no general answer is possible. Even if one antenna does outperform another, there are always a number of other factors that affect the final decision. Can I maintain this antenna? What will my neighbors say when they see it? Is it compatible with the rose garden?

With those qualifications in mind, let's compare two antennas on performance alone just because people have asked a certain question: which is better: a multiband wire antenna like a G5RV or a center-fed Zepp on the one hand, or a dipole cut for 10 meters on the other hand? And let's presume you have the room and supports for both antennas to make this a real comparison.

If you like to work all of the HF ham bands and are limited to a single antenna, then the multiband wire is certainly an antenna to consider. An "80-meter" 135' center-fed Zepp, a G5RV 102' dipole, and a "40-meter" 67' center-fed Zepp are all long doublets, center-fed with parallel transmission lines and differ only in length. All require an antenna tuner, although some antennas show a low impedance on some bands. The 135' Zepp obviously works better on 80, although the 102' center-fed antenna does quite well there, and all three antennas can show respectable performance from 40-10.

In fact, some folks praise these longer antennas because they show some gain over a 10-meter dipole on 10-10's favorite band. Unfortunately, that kind of claim is like preferring $10 bills over $5 dollar bills. I'll take the $5s if you give me enough more of them than the $10s. The bill size is not relevant until you know how many of each are at stake.

When comparing any of the longer multiband wires with a 10-meter dipole, the extra gain is not relevant until we answer the question of where it goes and, equally, where it does not go. A lot of variables go into the answer to the "where" question, but we can give a glimpse into the answer with Figures 1, 2, and 3. Each shows the azimuth pattern of 3 antennas (2 dipoles and one multiband antenna) modeled at a height of 35' (a typical amateur backyard installation) over real ground at a 14-degree angle of maximum radiation at 28.5 MHz.

Think of these patterns as looking down on the antenna from overhead. The dipoles are the simple figure-8 double loops. For the loops reaching out to 0 and 180 degrees, the antenna runs up and down the page through the center of the diagram. For the loops reaching maximum at the top and bottom of the diagram, the antenna runs left and right across the page. Each multiband antenna also runs left and right across the page.

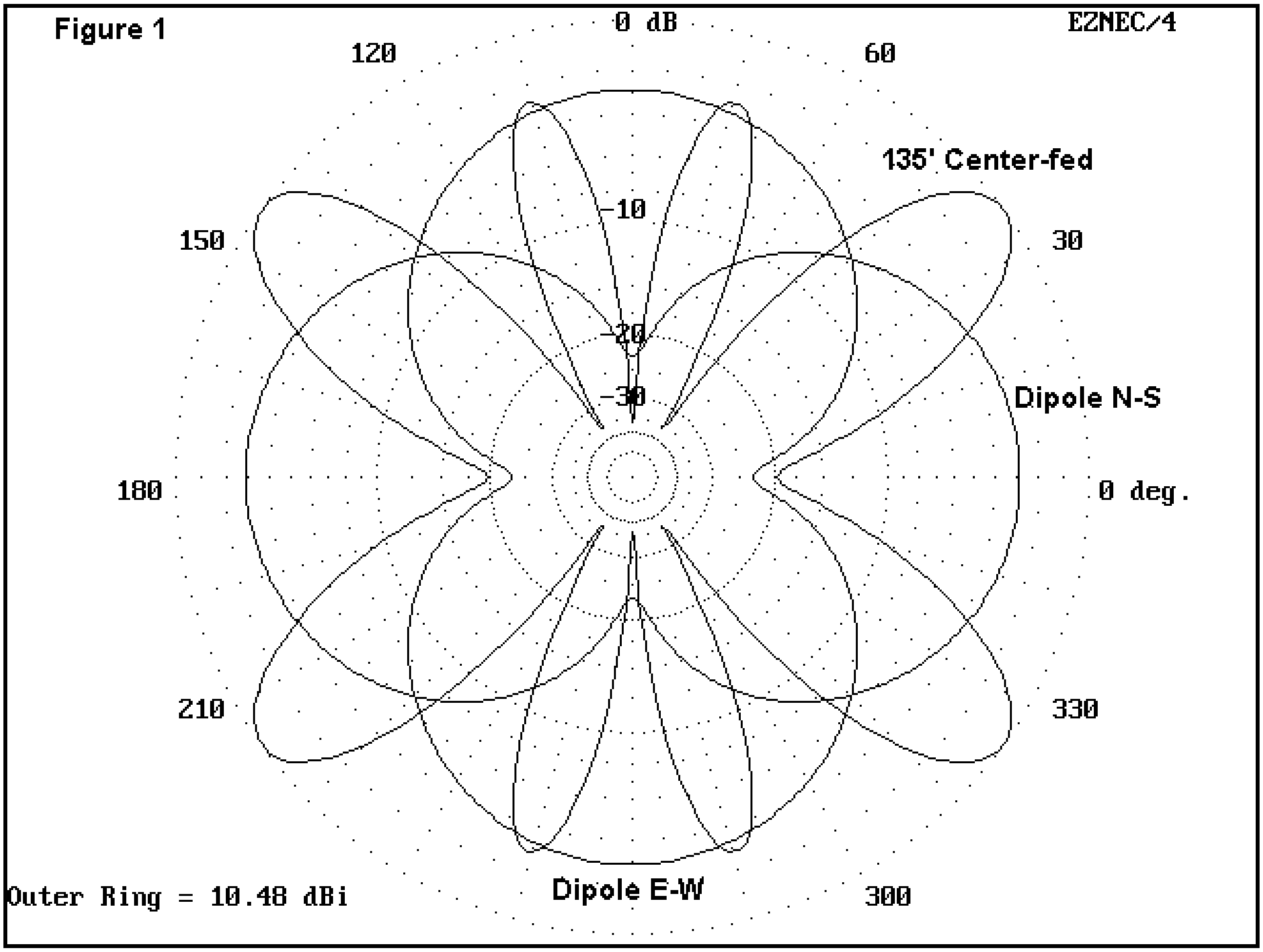


Figure 1 shows the 135' Zepp. It has four lobes that exceed the dipole limit by a good bit. However, notice how narrow they are. Notice also the nulls in the pattern. with some careful planning and some good luck in where your yard trees go, you might align the antenna so that one or more of the lobes points right where you find the stations you like to work most. Then again, you might end up aligning the antenna so that nulls point at your second and third favorite spots.

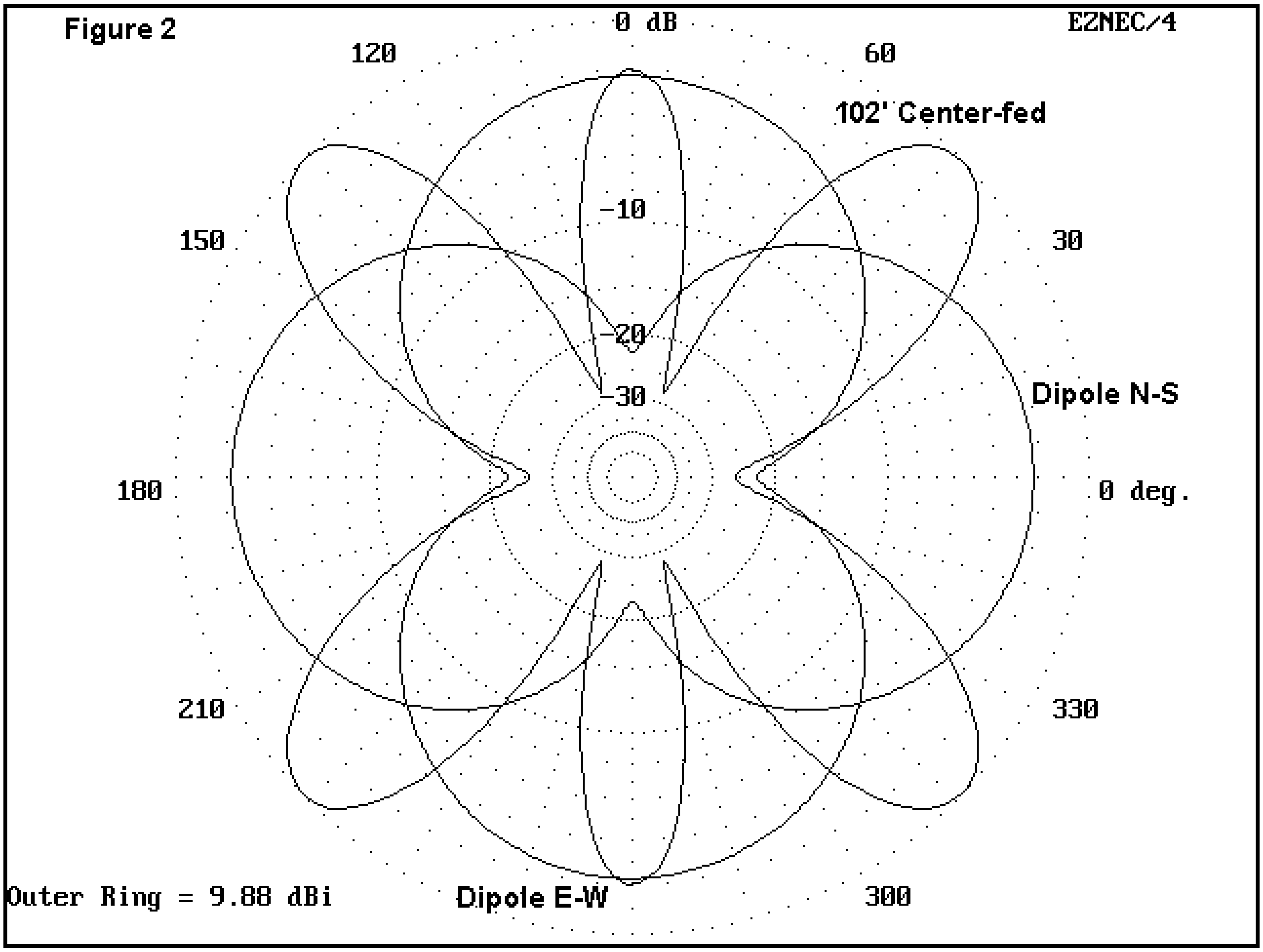


Figure 2 shows the dipoles with a G5RV. Again, there are higher-gain narrow lobes, but aimed more at the 45-degree point on the pattern. The shorter antenna creates fewer lobes. Again, you might use this information to hit one or more of your targets, and possibly miss a few desirable targets.

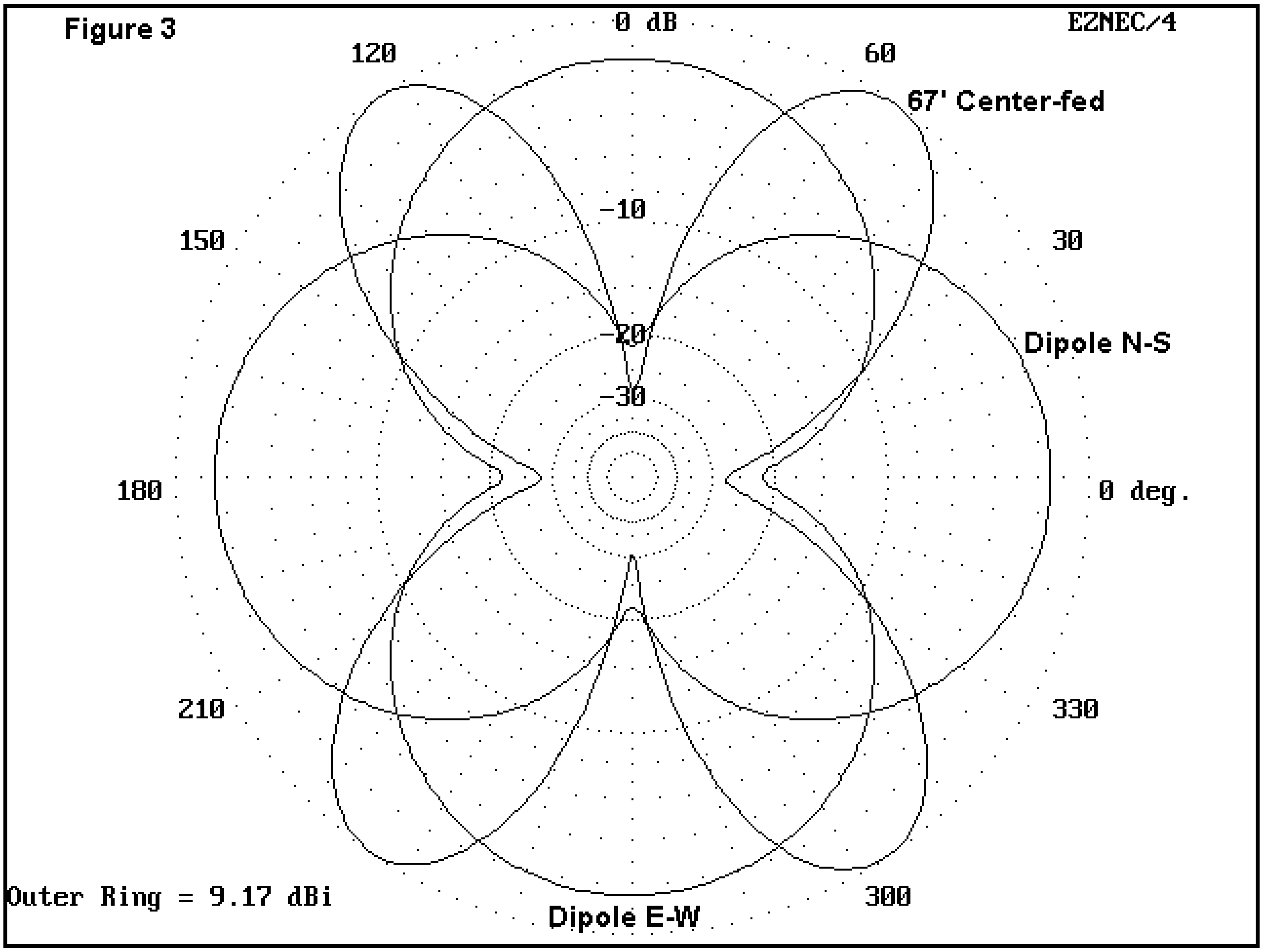


Figure 3 shows the same data for the 67' Zepp, about the length of a 40-meter dipole. There are only 4 lobes for this shorter antenna, but, of course, 4 nulls as well.

Each of these antennas has its place in some ham's yard, especially for working the lower HF bands (and each antenna will show a different pattern on each band). But is any really significantly better than a dipole on 10 meters? Gain is nice, but those nulls can drive you crazy.

Well, the dipole also has nulls off each side, so it too is limited. However, with an overall length of between 16' and 16.5' (depending on the element diameter), it is not too difficult to put up a rotatable dipole. You can hand-rotate the antenna mast or use a TV rotator. Then the nulls disappear. More correctly, they go where you put them, as you broadside the antenna to the desired signal. Hence, you only have to rotate a dipole less than 180 degrees to get full 360-degree coverage.

A stack of TV masting with a house clamp only roughly tight or guys in guy rings would permit you to hand turn the mast. You can attach a short level rod to the mast to make turning easier. Except in odd late afternoon shorter skip conditions, where signals seem to come from every direction, you will likely only have to change the antenna's orientation every few hours.

Am I "pushing" the rotatable dipole? Not really. Part of my point is that gain is not everything, especially if it does not point anywhere useful. Part of my point is that pointing is more simply done on 10 meters than many people believe, especially if they only look at monster 20-meter beams. Part of my point is that a multiband wire antenna is a very useful antenna for working all the bands. And part of my point is that, with a little ingenuity, a 10-meter dipole can do a lot of useful work for us without being unduly noticeable or expensive. Even if you already have that long wire, you might also consider adding a rotatable dipole to the antenna "farm." Now, if it is simple enough, you might even take it apart, toss it in the truck or trunk, and go portable with it--and put it back up when you get home.

No. 14 EDZs: Stacked and Unstacked

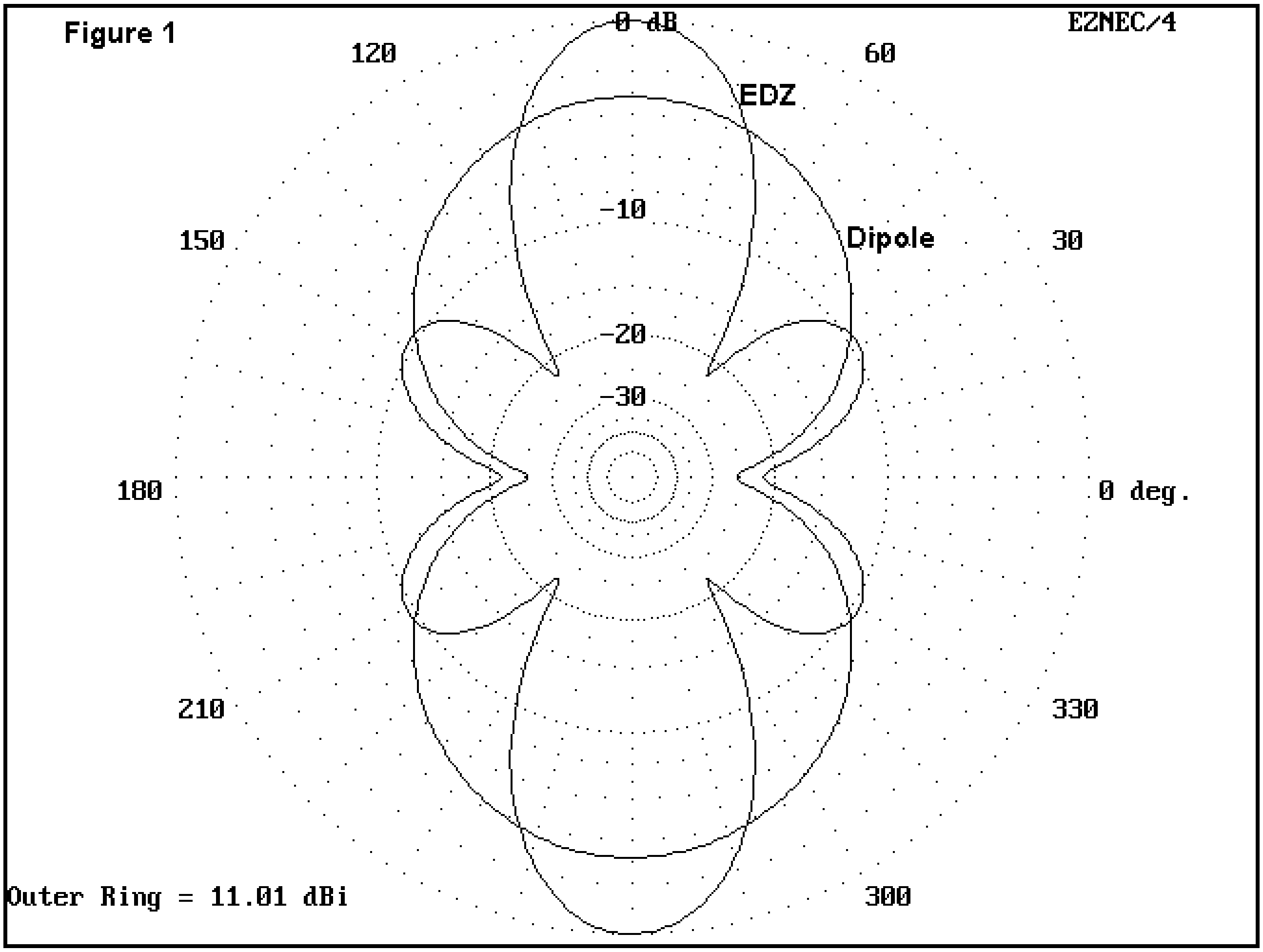
L. B. Cebik, W4RNL

After an article on EDZs (extended double Zepps) appeared in ***Communications Quarterly*** in Fall, 1995, I received some mail and phone calls on a version of the antenna I had not covered. So I thought I would bring it to your attention. The EDZ is a good fixed wire antenna for those who do not wish to fool with towers and rotators, but do wish to work some DX when the band fully reopens. It helps to have high trees or other tall poles to support the ends, and you have to like ATUs (antenna tuning units or transmatches). Even if you do not like these things, read on--they can grow on you.

The Basic EDZ

The basic EDZ is a 1.25-wavelength wire antenna fed at the center. Unlike a dipole, precision wire cutting is not required. A 10-meter EDZ needs about 44 feet of copper wire. The feedpoint impedance will be about 130 ohms with about 680 ohms of capacitive reactance. I recommend you use 450-ohm parallel feedline to an ATU. Although you can match the EDZ to 50- ohm coax at the antenna feedpoint, you would lose the ability to use the antenna on other bands. For every band 20-meters and up, the antenna is longer than a dipole and thus shows a little gain above a dipole.

At 10-meters, an EDZ up 40' in the air shows about 3.5 dB gain over a dipole. Of course, both antennas are bidirectional. The EDZ gets its gain by shrinking the side-to-side beamwidth of its two main lobes. The dipole has a half-power beamwidth of about 78ï¿½ while the EDZ cuts that to about 30ï¿½ with two small side lobes in each direction. See Figure 1



Some folks view the sidelobes as QRM producers. If you agree, see the ***ARRL Antenna Compendium***, Vol. 4 for an EDZ with capacitors in the elements to eliminate them. However, you may lose some performance of the antenna on other bands.

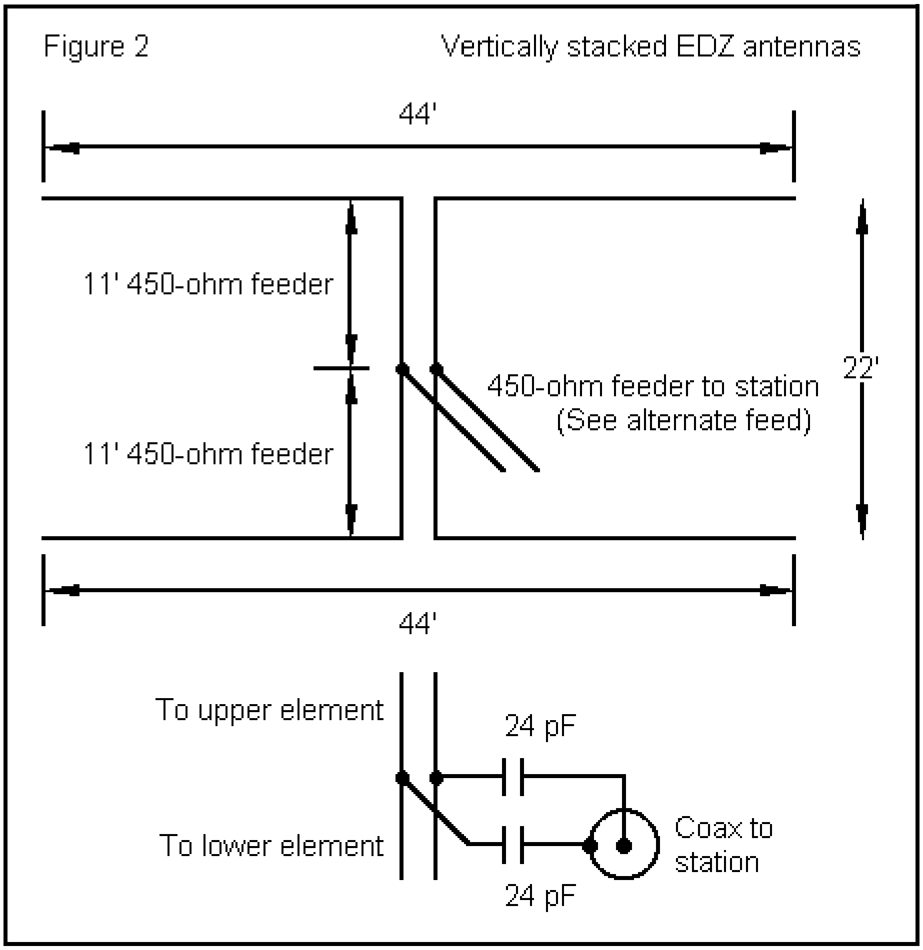
Almost any wire antenna for 10 up in the air 40' has a take-off angle of 12ï¿½ above the horizon. Take-off angle means the elevation of the lobe with the most power in it. The half-power points are ï¿½6ï¿½ around that angle, so there is plenty of power in the low angles needed for efficient DXing. But perhaps we can do a little better.

Stacked EDZs

Stacking any two antennas will do two important things for you: 1. It will increase the system gain a bit and 2. it will lower the take-off angle a bit. Both those advantages are DXer delights. So let's get crackin' and stackin'. The system I shall show you derives from an article in the November, 1968, *CQ* by John Schultz, W2EEY called "The Expanded Lazy-H Antenna." (My thanks to Henry Pollock, WB4HFL, for sending me a copy of the article.)

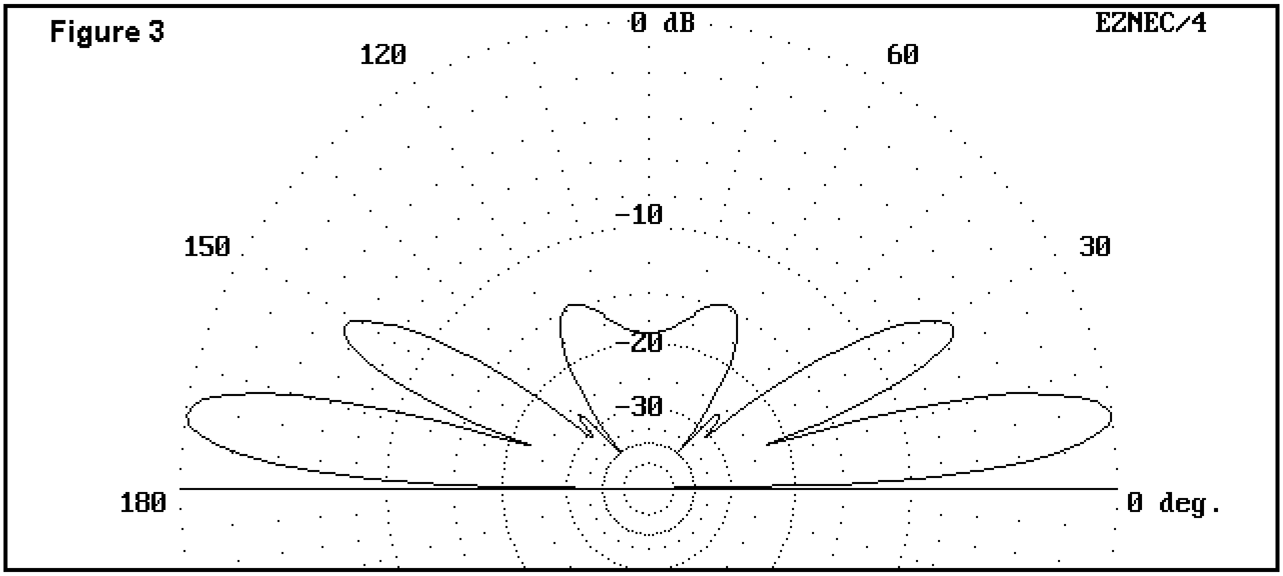
A vertical spacing of 5/8ths of a wavelength is about the most efficient gain producer when stacking antennas. This applies to Yagis and other arrays as well as EDZs. At 10 meters, this means a spacing of about 22' or so. Again, this number is not critical ï¿½a foot. Figure 2 shows the general scheme. Assuming you have the side supports, there are only a few questions to ask about stacked EDZs.

Figure 2



1. What do I get for my trouble? First, you get 3 to 4 dB additional gain in both directions, depending upon which wire you set at the 40' level, where we placed our one-wire EDZ. If you can put the second wire at about 60' or so, you will get the higher gain, plus a lower take-off angle of 9ï¿½. That puts the bulk of your power in the 10-meter far-DX zone. Figure 3 also shows a secondary lobe at about 28ï¿½ for shorter paths. If you place the lower wire at about 20' up, you will get the lower gain and a basic take-off angle of 14ï¿½. That is still worth while.

Figure 3



2. How do I aim single and stacked EDZs? With care, since they are fixed. In much of the US, the NE-SW corridor gets you both Europe and VK- ZL-land. Or you can broadside N-S for South America and over-the-pole and back scatter. Or, you can broadside to Asia. Finally, if you have lots of trees or poles, you can build 3 EDZ stacks and switch among them (a nice wiry dream).

3. How do I feed the beast? The easiest feed system is to run 450- ohm parallel feeders from each feedpoint to a common center. At that point, you will see something like 75 ohms resistive and about 460 ohms inductive impedance. This situation gives us a choice.

a. If you wish to use the antenna on 10 meters only, you can insert on each side of the line junction a 24 pF capacitor. This is a series connection on each side, with the ends then connected to each side of a coax connector. The capacitors cancel out the inductive reactance, leaving only about the same mismatch you would get with a dipole--and that's manageable.

b. If you wish to use the antenna on all bands from 20 meters on up, just connect more 450-ohm parallel feeder and bring it to the shack and ATU. On 20 you will get dipole gain or better, with more gain on the other bands between 20 and 10.

4. What does it cost? Well, #14 wire runs about 7 to 12 cents a foot, depending on its nature, and 88' of wire is in the $8.00 range. Add some insulators and rope for supports. Then add the 450-ohm parallel feeder, which is cheaper than coax. Even if you have to erect some supports (4 sections of 10' TV mast per side, plus rope guys and tie-down ring-screws in the ground), you might run the bill to $75 to $100. That will barely buy the TV rotator, let along the tower and very light beam that goes with it.

Note that, as in all antenna work, we must compromise. The stacked EDZ requires supports and fixes your general directions to two, but saves you many dollars, pounds, yen, francs, marks, or lire. The long Yagi with the same gain gives you freedom of direction, but empties your pockets and requires constant maintenance. (Remember, Murphy's law says that when the rotator goes bad, it is always stuck in a direction with no hams in sight.) So the EDZ and the stacked EDZ array are suitable only for some people. But perhaps you are one of them.

No. 15 Coax: The Short Story

L. B. Cebik, W4RNL

One good way to think about antennas is as a system: the antenna system. The antenna system consists of all components that get power from the rig (or, on reception, to the rig) into the transducer (that is the antenna proper) that converts the electrical energy (the energy that shocks) into electro-magnetic radiation (the energy form that lets your signal bounce off the ionosphere to all that good DX). Some of those components are inside your rig: the filtering and impedance matching components that establish a 50-ohm impedance at the coax connector.

The remainder of the components are external: the antenna proper, the transmission line, the transmatch or antenna tuning unit (2 names for the same item, and it may also be in your rig's case), and any matching components at the antenna terminals (such as a beta or gamma match for a Yagi). All of these have to be working well to ensure maximum efficiency of energy conversion into RF radiation.

The weak link in the system is often the transmission line, and just because it is a simple, no-adjustment component. It does not start off as the weak link: it just gets that way because we ignore it. Most 10-10ers use coax to feed their antennas, so let's confine our discussion to coaxial cables as transmission lines.

Some Coax Basics

Everyone knows what coax looks like. There is a center wire, which may be solid or stranded. Surrounding the center wire is some insulating material: it may be a solid, translucent plastic or a white softer foam. Around the insulation is a layer of conductors: these may be a mesh or braid of copper, or in recent cables, the conductor may consist of a foil with a mesh around it. Over these layers is a coating--usually a black jacket on ham wires, but sometimes gray or even white for special purpose cables.

For the moment, forget the outer cover. The center wire, the insulating material, and the wire mesh that determine the characteristics of the cable as a transmission line. We can be a little more precise by remembering that alternating currents at HF frequencies travel at the surface of the wires. Hence, we are concerned with the outer surface of the center wire and the inner surface of the wire mesh: these two surfaces determine what the characteristic impedance of the cable will be. Of course, most of us use 50-ohm cables. Since getting a 50-ohm impedance depends on the ratio of the diameter of the center wire and the circle made by the wire mesh, we can make many different sizes of 50-ohm coax.

Here is a table of the most common 50-ohm coaxial cables we hams use:

Cable #	**Outer**	**50 MHz**	**Maximum**	**Velocity**

	Diameter*	Loss**	Voltage***	Factor****
RG-174	0.1"	5.7 dB	1100	.66
RG-58	0.195"	3.1 dB	1400	.66
RG-58 Foam	0.195"	3.3 dB	1400	.79
RG-8X Foam	0.242"	2.1 dB	2000	.75
RG-213	0.405"	1.3 dB	3700	.66

* Outer diameter includes insulating jacket.
** Losses at 10 meters will be about 2/3rds this figure; losses are approximate and vary somewhat from one listing to another.
*** Maximum operating voltages (rms) also vary from one list to another.
**** Velocity factors on foam cables vary from one listing to another.

What can we learn from the table? Actually, several things.

1. The fatter the cable, the lower the losses in the cable. So, use the fattest cable you can afford and handle in your situation.

2. The fatter the cable, the higher the power handling capability (as roughly indicated by the operating voltage). So if you use an amplifier, use RG-213 or better.

3. The outer diameter of the cable determines what coax connectors to use. RG-213 requires regular PL-259 plugs. RG-8X, being the same size as RG-59 (a 70-ohm cable) requires UG-176 adapters. RG-58 requires a UG-175 adaptor. Do NOT forget the adapters for the smaller cables: they relieve stress on the wires for longer-lasting connections.

4. The velocity factors tell us how long a cable wavelength is relative to that same wavelength in free space. The cables with solid insulation will be an electrical wavelength long at only 2/3rds the length of the wave in free space. Notice that the foam insulations have higher velocity factors than the solid insulation types. For all foam and for cables with new numbers, be sure to check the velocity factor just in case you have to make up a cable that is a specific fraction of a wavelength long.

In addition to these basic cables, there are a number of new cables. Beldon and others make a very low-loss version of RG-213 under company stock numbers. It is for VHF or for very long (100' +) runs of coax. And it costs more. There are also marine cables with jackets that resist sun, salt water, acids in the air, and almost any other contaminant. They also cost more.

What Cable to Use

Determining the best cable for an application is a combination of cable characteristics and practical realities. While no absolute rules are possible, here are some scenarios and recommendations.

1. Mobile or portable: Since power with likely be no more than 100 watts and cable runs will be under 35' in most cases, RG-58 should do the job.

2. High power contesting: Use RG-213 or better cable to handle the power and the longer cable runs to permanent antennas. One of the low loss cables may be in order if you use very high towers or antenna supports.

3. Moderate power, but over 65 years old: Consider RG-8X. It is lighter and easier to handle than RG-213, but has more power handling ability and lower loss than RG-58. (For every tens years of age over 40, also

consider lowering your tower by 10' to a height you can climb.)

4. Coast-line or industrial area installations: consider some of the marine cables with their extra protection.

5. Buried cable installation: RG-213 (an improved version of the old RG-8) should work fine, but for minimum maintenance, consider one of the cables with greater resistance to chemical and abrasive wear.

Check at hamfests: sometimes a dealer will run a special on one of the marine or low-loss cables, bringing the price down to nearly the same as RG-213. I tend to avoid preassembled cables, since the crimped connectors are not as well-connected to the cables as carefully assembled regular connectors. However, I do use them for quick tests and for portable work. After a while, I end up replacing the connectors with soldered versions.

The UG series of connectors was made to be taken on and off with ease, and to some degree, they depend on the abrasive effects of connecting and disconnecting to keep the center pin and the threads clean. If you use them at the antenna terminals, be prepared to disassemble and clean the connectors at least once a year, even if you use plenty of coax sealant to weather protect the connection.

Coax Problems

There are two types of coax problems: mechanical and electrical.

Mechanical problems and maintenance: Nothing lasts forever (except love). Inspect your coax and connectors at least once per year or whenever you have any signal strength problems. Clean the connections and reseal them, if outdoors. Wipe down the coax to remove dirt and chemical build- up. Try to install your coax as much in the shade as possible to reduce the rate of sun deterioration of the outer jacket. For buried installations, check for standing water around the cable and improve drainage if necessary. Be certain that you use plenty of support on vertical runs (for example, up the leg of a tower). Avoid long, unsupported horizontal runs: use a support rope to which the coax is taped at small intervals. Coax was not made even to support its own weight. Avoid tight corners: the fatter the coax, the larger the radius of a corner. (This also prevents deformation of the cable, which can change its electrical characteristics.)

After five years of outdoor use, replace your coax. It may have some good life in it, but the odds are that your signal strength on both transmission and reception have dropped as the aging cable ate more of the signal power. If you want to use the old cable, cut away and discard a few feet from each end, along with any segments with visible jacket damage. Then use the remaining cable for those shorter noncritical indoor runs of a few feet each. Or remove the jacket and extract the braid as a grounding strap. But keep your outdoor coax fresh.

Electrical problems and maintenance: Remember that the transmission line characteristics of the coax involved only the outer surface of the center wire and the inner surface of the wire mesh. The wire mesh also has an outer surface perfectly capable of conducting HF electrical energy. In fact, it can act just like an antenna in parallel with your "real" antenna. That phenomenon can ruin the performance of your system (unless it is designed into the system, as in some wire antenna schemes). Hence, you need something to isolate the outer surface of the coax from the antenna currents. Many beam manufacturers already provide a "balun" or "line isolator" to take care of that potential problem. If your system does not have one, consider purchasing a 1:1 current balun or W2DU-type choke balun to install between the antenna terminals and the coax run.

I also take one other precaution. Instead of running one piece of coax from the antenna terminals to the rig, I use several. The first goes from the beam terminals (actually, the choke balun) to the mast, around the rotator with a large strain-relief loop, and down abut 8 feet along a tower leg. I have grounded my tower legs as best I can, and I have a plate on the leg with a bulkhead (double female) coax connector. The first length of coax ends here and the second begins. electrically, the tower and the outer coax braid surface are at the same potential. The second coax length goes to another plate installed where the coax enters my home. At this weather protected point, when weather threatens, I can move the coax from the house run to a plate with coax connectors and a long pipe into the soil. Keeping heavy charges outdoors is my goal, especially when I am on vacation. This measure protects my home. A third run goes from the home- entry plate to a plate at the edge of my operating table. Routinely, whenever I am not on the air, the coax, ground strap, computer connector, and AC cord to the station are all completely disconnected, so that the station is isolated from any electrical dangers. This measure protects my rig. Finally, short lengths from the plate to my antenna tuners and rigs complete the connections.

Do I get some losses from having so many coax connectors? Probably a little. But so far, in 40+ years of operating, I have had no problem with static charge build-up on the antenna, power line surges, ground surges, or other weather- and thunderstorm-related problems.

Coax makes a very effective transmission line, but its effectiveness depends on sensible selection, thoughtful installation, regular maintenance, and timely replacement. You might want to check out your transmission lines before the sunspots numbers take your mind off everything except operating.

No. 16 Antenna Noise

L. B. Cebik, W4RNL

We often hear reference to "noise" in antenna work, but often we are not sure what kind of noise is being talked about. So let's talk about noise and antennas. "Noise" comes in a wide variety of styles, but here is one way to divide the group into usefully smaller chunks:

1. Man-made noise: This category includes the usual machinery sparking, faulty signs, auto engine sparking, etc. As you can see from thinking about the sources, it largely derives from spark generation and hence produces useless RF over a wide frequency range. Most human-made noise is vertically polarized and of ground wave propagation. Hence, ground-mounted verticals are most susceptible to this category of noise. A horizontal antenna generally shows an immediate 3 dB reduction. Additionally, antenna elevation also helps reduce the noise level. Finally, a narrow-band antenna also reduces the total amount of noise energy in this category from reaching the receiver. A parallel feedline-ATU arrangement sometimes shows improvement over the same antenna fed with coax by filtration action, i.e., narrowing the bandwidth of the energy allowed to reach the receiver.

One technique that has been the subject of recent articles is the use of a short vertical noise sensing antenna (long enough to pick up local noise but too short for effective reception of propagated signals), inverting its signal, and combining the result with the regular antenna signal. With proper adjustment, local human-made noise can be cancelled quite effectively, with only slight reductions in received signal strength. The benefit lies in the large improvement in signal-to-noise ratio, the truer mark of effective reception.

Except for very near by sources, such as an arcing pole pig, Man-made noises create the most problems on the lower HF bands.

2. Atmospherics: There are two sources of "atmospheric" noise and energy coupling to antennas:

a. Sparks: Nature also generates wide-band sparks in the form of lightning. There are other atmospheric noise sources, but especially on the lower HF bands, QRN is largely propagated lightning signals. As with all spark energy, the energy decreases as the frequency increases, hence, the quieter high bands. There is little difference in the reception of propagated spark energy between vertical and horizontal energy, since the polarization is lost in the skip refraction. Narrow-banding the pre-receiver reception system can reduce the total energy from such signals that reaches the receiver front end.

b. Charges: The more that air molecules strike each other, the more they lose electrons and become charged. The thinner the atmosphere, as at high altitudes, the longer molecules can stay charged before recombining with lost electrons. It is from phenomena such as these that we get the static charge build-up on antennas. For most home antenna systems, charge build- up was no real problem with tube grids, but a real problem with solid-state front ends. The longer the antenna wire, the windier the location, and the drier the air, the more likely that static charge can build to damaging proportions. At the very least, static charge collection on an antenna is an additional noise source and problem.

For some antennas mounted very high, the energies involved could not be drained effectively before damage occurred to antenna elements. At the extreme, the development of the quad loop was to solve HCJB's end coupling problem with its Yagis: at the high altitude of Quito, Ecuador, the energy coupling was burning the ends off the antenna elements.

Loop antennas have no ends: hence, for a portion of the incoming energy, there is a reduction in the amount of energy coupled to the antenna from wire-end capacitance. Where the high voltage region is distributed across a wire length, whether vertical or horizontal, capacitive coupling is minimized. For this reason, some operators find quads and other loop antennas quiter than Yagis and dipoles.

Regardless of antenna type, static charge is simple to drain away. One technique is to have the antenna at DC ground. Some antenna designs are naturally at DC ground. Loops go from the coax center to coax braid, and if the braid is well grounded, the charge does not build up. Placing an RF choke across the antenna terminals or from the hot terminal to a ground line can continuously drain charge build-up. In some multi-band antenna systems, parallel feed lines can carelessly omit this protection, but a pair of RF chokes, one from each line to ground where the feedline enters the house, can protect equipment. However, remember that the impedance level at that point can be high, requiring a very high value of RF choke to ensure that significant signal energy does not go through the choke.

3. Mixing products: Two signals, neither of which is on the frequency to which we are tuned, can be mixed and produce a third signal (or a bunch of signals) that may fall on a frequency we want to use. The cure for mixing products begins by locating where the mixing occurs. If the mixing occurs in the receiver, then filtration of the unwanted frequency (or frequency range) is the best solution. If the mixing occurs externally to anything one's receiving and antenna system can control, then there is no cure immediately at hand. However, such problems often involve violations of technical standards by one or both of the signal generators involved as the sources of the mix, and patient bureaucratic pressure can sometimes alleviate the problem. If the mixing occurs within one's antenna system, then there is usually something wrong with the system--bad connections, unwanted couplings, less than optimal tuning set-ups: all of these are correctable and should be part of one's routine periodic maintenance on the antenna system.

These are not all the noise sources. Power company equipment problems, such as arcing pole pigs, require a simple procedure: locate the problem transformer, keep on reporting the situation until you get action, and hope there is a ham on the technical staff that handles such complaints. RFI from light dimmers and other home products that use AC waveform chopping to control a voltage level has been noted in many articles and requires that we locate the source and cure it individually. Likewise with noise from computer timing circuits.

Finally, some folks are condemned to live in areas where noise is beyond control and even beyond the ability of the best noise blanker to handle. The solution, short of illegally de-powering these sources, is to save money and move to a quiet location--or to concentrate on portable operation. However, antenna choice, feed system choice, filtration, noise cancelers, and noise blankers can go a long way toward reducing currently unlivable noise to a mere constant irritation.

No. 17 Some Misconceptions About SWR

L. B. Cebik, W4RNL

We have all read dozens of articles about SWR. So we all know that the Voltage Standing Wave Ratio is a complex function of the relationship between the feedpoint impedance of our antenna and the characteristic impedance of our transmission line. When the antenna feedpoint impedance is a pure resistance, the relationship is simple: SWR equals the larger of the two divided by the smaller of the two. If the antenna feedpoint exhibits reactance in addition to resistance, then the SWR is higher by a somewhat more complex calculation.

We also all know that generally, the better the match between the load, the transmission line, and the source (our transmitter outputs), the more power is consumed by the load. Hence, it is generally wise to strive for a well- matched antenna-feedline-transmitter system. So we place an SWR meter in the line in, at, or near the transmitter and monitor the SWR at that point.

Despite all this knowledge, I still encounter some interesting misunderstandings about SWR. Of course, they come from outside the 10-10 ranks, so everyone can claim, "Well, I knew better than that." Even so, it may be useful to review a few of them.

1. "My SWR is low, so my transmitter is safe." In olden days when tube- type rigs had adjustable output circuits, folks worried about burning out tubes and other components "because" of SWR. Actually, the combination of resistance and reactance seen by the transmitter output circuit would sometimes permit only a small RF transferral. However, operators continued to load their finals to full DC plate input power. What is not RF in a final is heat, and that excess conversion of DC power to heat is what destroyed tubes and stuff around the tubes.

Today's transistor rigs have feedback circuits that sample the reverse voltage at the output and automatically reduce drive to the finals in the event of a high SWR. Thus, it is pretty difficult to hurt a rig by connecting it to a high SWR output load. However, SWR is NOT the only thing that can hurt a rig. Overdrive, with or without SSB compression, is a source of major stresses on a rig's circuitry. However, the chief rig killer seems to be voltage surges coming from the antenna, the power line, or the ground. And that is a matter of safety that calls for measures outside the rig--like disconnecting the antenna, power cord, and system ground to totally isolate the rig when not in use.

2. "My antenna system is fine, because the SWR is better today than when I put it up three years ago." The fact of a lower SWR over time is often true. However, the conclusion drawn is false. If the SWR is lower than it used to be, the chief reason is an increase in losses in the system. Losses represent that portion of energy converted to heat along the line and at the antenna terminals, energy that is no longer available as energy to radiate. As systems age, cables become "lossier," terminals become corroded, and a variety of other things contribute to the problem.

Yes, a lowering of SWR can indicate problems, not improvements. It is not impossible, but it is exceedingly rare for an antenna system to change its feedpoint impedance to match the transmission line. It is so rare that the lowering of SWR with time should always be taken as a sign that it is time for antenna system maintenance. Clean, deoxidize, tighten, and seal, as appropriate. If things do not improve, replace the outdoor coax with new stock (but save the old stuff for noncritical uses if it has any life left in it).

3. "My antenna is operating very well because my SWR is a perfect 1:1 match." Unfortunately, my dummy load gives a nearly perfect 1:1 match, and I cannot hear anyone when it is in the line. SWR is one measure of impedance match, but it is not an indicator of the quality of antenna performance as an antenna. Antennas convert radio frequency energy--a form of AC voltage and current--into electro-magnetic radiation (and also the reverse for reception); and they also manage to focus that radiation in various patterns. How well an antenna does this job is only indirectly connected with the impedance match to the transmission line carrying the energy to be converted and directed.

The practical consequences of this fact are pretty basic. First, before committing to an antenna, try to determine what kind of operating you want to do and select an antenna that will enhance that operation--within the limits of what you can handle in terms of finances, maintenance, and home site restrictions. Second, maintain your antenna regularly--even more regularly than most folks change automobile oil. Preventive maintenance will keep your antenna operating to its maximum ability. Third, if you build your own antenna for a long-term installation, use sensible quality materials. Stainless steel hardware is a must. Tubing and wire made for antennas or equally strong and conductive are necessary. Applying No-Ox or similar antioxidation conductive materials at connections of dissimilar metals is always a good idea.

4. "My antenna has a feedpoint impedance of 100 ohms. Surely 50-ohm coax will give me lower losses than the more highly mismatched 450-ohm parallel feedline." This misconceptions stems from the belief that SWR is a direct measure of the ability of an antenna to "absorb" energy and convert it into radiation. SWR is only part of the story.

Every transmission line displays two kinds of losses: first is a basic loss based on two significant factors: the ability of the wires to handle RF currents and the leakage between wires through the insulation. Because any coax we can afford compromises cost vs. effectiveness, all common coaxial cables have a higher basic loss per 100 feet than parallel feedline, whether 300-ohm or 450-ohm. In fact, for the HF bands, most parallel feedline has a minuscule loss compared to coax.

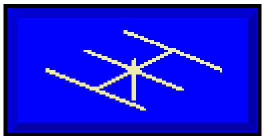
The second loss source is a result of SWR--or rather the mismatch that SWR indicates. Since peak voltages climb, leakage increases. Since peak currents climb, heat conversion losses are higher. In effect, SWR puts a multiplier on the transmission line's basic loss. Since coax begins with significant basic losses, additional losses due to SWR are that much more significant. Parallel transmission lines begin with almost insignificant losses, and the same or higher multipliers usually mean that losses are still insignificant. Under some common conditions, a parallel transmission line with a 10:1 SWR may have lower power losses than a coax cable with a 3:1 SWR. Parallel transmission line is almost always the best bet for multiband wire antennas that require an antenna tuner.

But remember that even at 3:1 SWR on the lower bands, like 80 meters, coax losses will still be too low to worry about. If your 75 meter dipole shows an SWR at the low end of 80 within the limits of your rig's built-in antenna tuner to handle and you would like to work a little CW, go for it.

5. "My meter shows the reflected power to be 25 watts. I'm worried about losing that power at the antenna and what it must be doing to my rig." Most folks who see these kinds of readings have never looked seriously at their forward power under the same conditions. Suppose you set your rig to exactly 100 watts output. Your reflect power reads 25 watts on a decent meter. Your forward power will read at least 125 watts--perhaps a couple of watts more to account for the cable losses just described (and your rig will be putting out about 102 watts). The difference is 100 watts. Where is it--and where did the extra forward power come from?

The reflected power simply returns to the forward direction and adds to the rig's power along the line. No need to worry about the rig, since it is not affected by the reflected power (except as the reverse voltage may activate a power reduction circuit). The antenna is receiving and converting 100 watts of power (less only the very small amount changed to heat due to cable losses). A receiving station cannot tell the difference in signal strength between an exactly matched dipole and one running a 10:1 SWR to a parallel feedline and ATU system. The received signal strengths will be the same, assuming the antennas occupied the same transmitting positions with the same propagation conditions. Both antennas converted just about 100 watts of RF energy into radiation. It may take about a dozen cycles for the high SWR system to build to full power and an equal number to return to zero, but when you have millions of cycles per second to use, those few make no difference to the signal intelligence.

I hope these notes help all those "other" folks approach SWR and antennas a little more intelligently. *WorldRadio*'s Kurt N. Sterba occasionally runs into SWR misconceptions, and I assure you that his treatment is far more entertaining than mine--except to the sources of those misconceptions, who are technical writers who ought to know better. He is a good incentive for writers to keep things right and sensible. The best extended treatment of SWR and for SWR misconceptions is still Walt Maxwell's book, *Reflections*. Unfortunately, it appears to be out of print. You may want to petition ARRL to reprint it. Hopefully your library has a copy. Mine is too dog- eared to be borrowed. Anything right in these notes belongs to Walt. Anything wrong is likely to be noted by Kurt.



No. 18: The Simplest 3-Element Yagi?

L. B. Cebik, W4RNL

In a past episode, I described one of the simplest 2-element Yagis I have encountered. For those who would like a little more gain and a better front-to-back ratio, I want to describe a simple 3-element Yagi. Like the other beam, this one comes from Bill Orr, W6SAI, from his column in *Ham Radio* for May, 1990.

This beam has two essential items for the casual home builder. First, the antenna has a 50-ohm feedpoint impedance with a wide SWR bandwidth. In fact, the SWR stays below 1.4:1 up and beyond 29 MHz when the antenna is modeled for 28.5 MHz. Second, the characteristics (gain, front-to-back ratio) are almost constant for the entire first MHz of 10 meters. The gain ranges from 12.3 to 12.5 dBi, while the front-to-back ratio remains better than 18 dB across the band. Figure 1 is an azimuth plot of the antenna taken every quarter MHz from 28 to 29 MHz at a 35' height. The differences from one line to another are too small to make any difference at all.

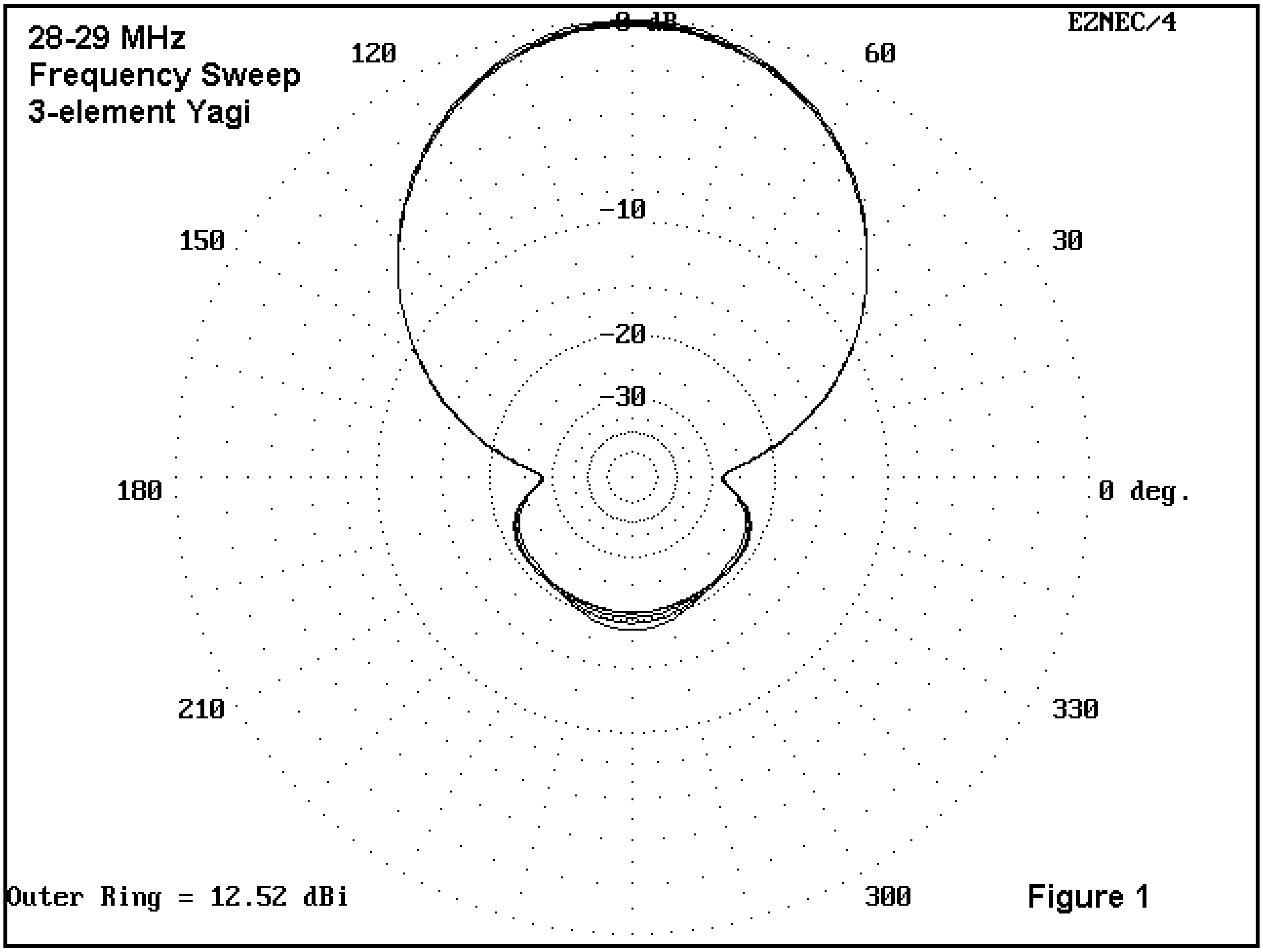


Figure 1

For these benefits, there is a price to pay: lower gain. From a 3-element Yagi on a 12' boom, one can squeeze out another dB of forward gain and improve the front-to-back ratio by a couple more dB. However, these beams have two disadvantages for the home builder. First, they have a narrower bandwidth where these properties show up. Beyond certain frequency limits, the pattern begins to deteriorate. Second, the feedpoint impedance tends to be very much lower--in the 20-25 ohm range. The lower feedpoint impedance requires a matching network. Although adjusting matching networks can become routine, the process can take the pleasure out building one's first beam that works.

Let's go ahead and build one of these wide-band specials. First, we need some dimensions. Figure 2 supplies the data.

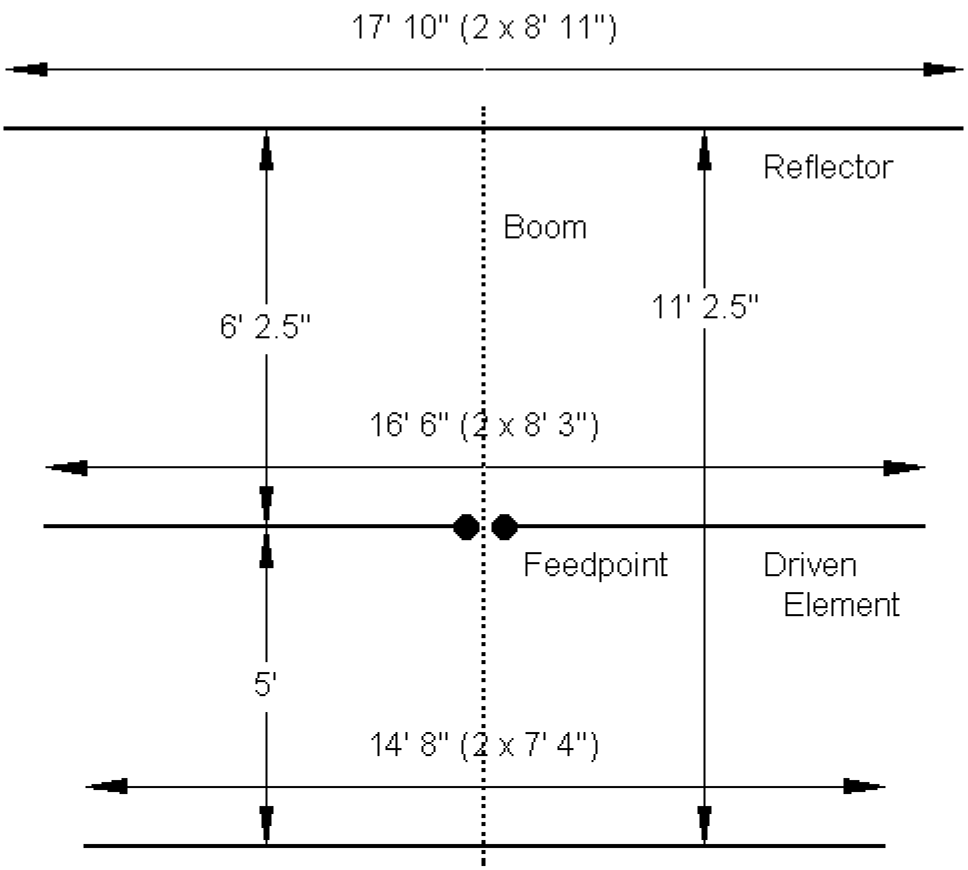


Figure 2 Dimensions of the 3-element wide-band Yagi

For 10-meters and simple installations, hardware store tubing is convenient and accessible. 1" aluminum tubing comes in 8' sections at most hardware depots. You will need 6 pieces, plus a shorter length of 7/8" tubing. You will also need a boom 12' long. One trick I have used is to take two pieces of 6' long 1.5" diameter aluminum tubing and lay them end to end. Now take two lengths of 1 3/8" tubing (or 1.25" if the larger tube is not available). Cut one smaller tube size length in half. Slide 3' of the 6' length of the smaller tubing inside one end of the larger tubing and fasten with stainless steel sheet metal screws. Slide the other piece of large tubing over the exposed 3' of smaller tubing, and fasten. Now slide the 3' lengths of the smaller tubing inside each end of the 12' boom, and fasten (but in such a way as not to interfere with the element mounting to come). We now have a 12' boom adequate for this simple beam.

Now make up 3/8" plywood plates about 6" wide and 3' long. coat them well against the weather. You can taper the pieces outward from the center to save a few ounces of weight. Find stainless steel U-bolts that go around the boom and around the elements. Let the plates go below the boom, and the element go below the plates.

Notice that two of the elements require aluminum pieces that are longer than the twin 8' sections of tubing we bought. Likewise, from the director, we shall cut off short section of tubing. Save them. For the reflector, set the tubes to the required extension. Take a 3' length of the 7/8" diameter tube and slide it inside one of the 1" diameter elements and fasten with sheet metal screws. Now slide either or both pieces of remnant director tubes over the 7/8" tube and position them so that they fit under the inner U-bolts. Again, fasten them to the 7/8" tube with screws. Now slide on the other 8' reflector section and fasten. The short segments of exposed

7/8" tubing will make no significant difference to antenna performance. (If you are a perfectionist, you can purchase one extra section of 1" tubing to make the reflector 1" in diameter for its entire length.)

Since the director only requires trimming to specification and mounting with a pair of U bolts on each side of the plate, the last item of concern is the driven element. Mount the element leaving a 6" space at the center. Slide 18" sections of 7/8" into each 1" tube and bring the ends close together. (The perfectionists can cover the exposed 7/8" tubing with short lengths of 1" tubing for a uniform driven element.) Fasten loosely and begin thinking about a boom-to-mast mounting and a coax connection. A small plate with a coax connector and the shortest possible leads to the antenna elements takes care of the connection. I like to use a 1:1 choke balun of W2DU design (ferrite over a length of coax), and this can be taped to the boom.

Mount the antenna about 10' off the ground pointing straight up. Adjust the driven element for resonance. Now get the beam up about 35' and begin waiting for sunspots.

This beam has only one more element than our 2-element special, but it is twice as large and twice as ungainly with its 12' boom. However, its performance improvement over the 2- element Yagi will show up instantly--or as soon as there are some folks to work. You will notice the effects of the added gain and front-to-back ratio on your local net. The bill will come to about $75 or so, which is not bad, if you have priced commercial beams lately.

There are beams with higher performance figures, but none any simpler to build than this wide-band special.

No. 19: A 3-element 10-Meter Beam on an 8' Boom

L. B. Cebik, W4RNL

As the sunspots return, the search for an inexpensive beam antenna continues. We have looked in past columns at 2-element Yagis and a wide-band 50-Ohm feed 3-element Yagi on a 12' boom. We can shrink the boom length down to 8' if we are willing to accept almost a half dB more gain, a good front-to-back ratio, and a matching network at the feedpoint to transform an impedance of around 25 ohms.

The design is adapted for hardware store aluminum tubing from a design by Brian Beezley (K6STI) in the YA collection that comes with the ARRL Antenna Book. The original design called for smaller tubing that is often hard to find. The revision calls for 7/8" and 3/4" diameter tubing, which may be found at outlets like Lowes or Home Depot.

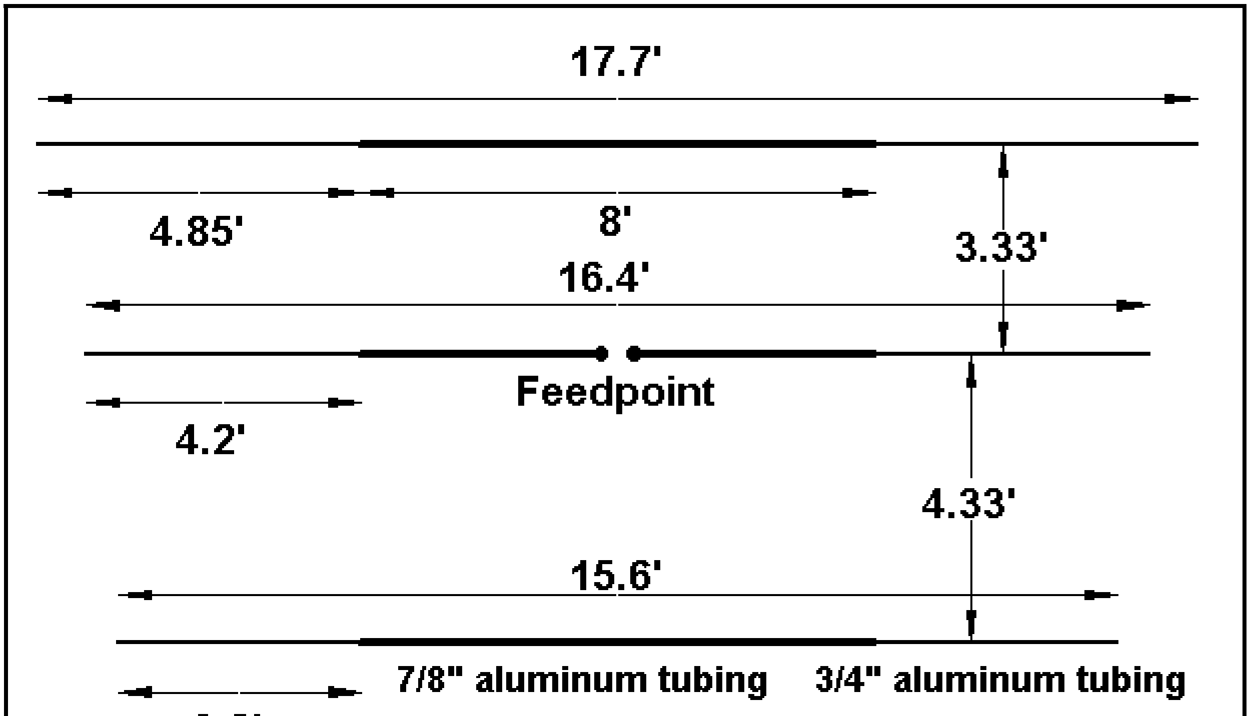


Figure 1. Dimensions of the 3-element Yagi

Figure 1 shows the dimensions of the antenna. The inner 8' of tubing for each element is 7/8" diameter, with the remaining length consisting of 3/4" diameter stock. Three 8' lengths of 7/8" tubing and six 6' lengths of 3/4" tubing are all you need. You can fasten the tubing lengths with sheet metal screws, stainless steel hose clamps (with stainless steel screws), or "pop" rivets. Do not waste weight by using too much overlap in the tubing sections: 2-4" will do nicely. The reflector and the director are continuous elements, but the driven element is split in the middle for the matching system. I use small well- varnished (spar varnish) plywood plates to hold the elements to the boom--you can see the details in almost any of the other Yagi columns.

My favorite 2-element boom--Schedule 40 PVC--gets a bit heavy by the time the boom reaches 8' long. So you might want to use 1.25" or larger diameter aluminum. A light-weight section of TV masting (the kind so light that I would never recommend that it be used as a mast) would also work if you are sure that it will stand the weather and not rust out in the first season.

The key to the antenna is the matching system. My favorite for small antennas is the beta match, but a gamma or Tee match would do as well. The driven element length is set for a beta match, with a resistance of about 25 ohms and a reactance between 20 and 25 ohms. The reactance is the virtual series reactance needed by an L-circuit to transform the 50-Ohm coax cable impedance down to the 25-Ohm resistive antenna impedance.

However, an L-circuit also needs an inductive reactance across the line, as shown in **Figure 2**. The inductive reactance can be a coil, as shown in the lower view. For 28.5 MHz and the 2:1 transformation needed here, the coil needs to be about 0.28 ï¿½H. A coil about 0.5" in diameter and wound with #12 copper house wire will have 6 turns spread over about 3/4" of length with half-inch leads to meet this need.

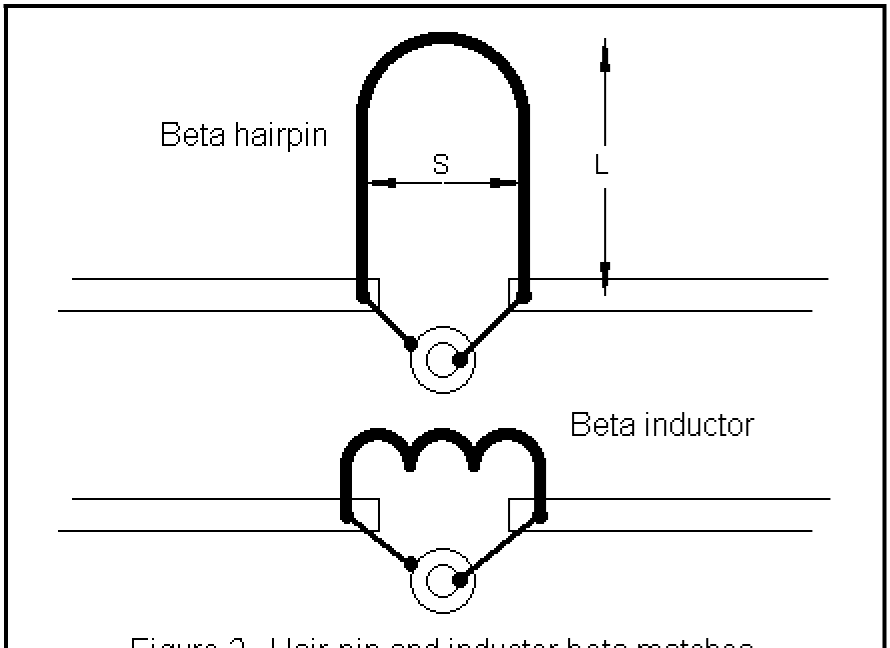
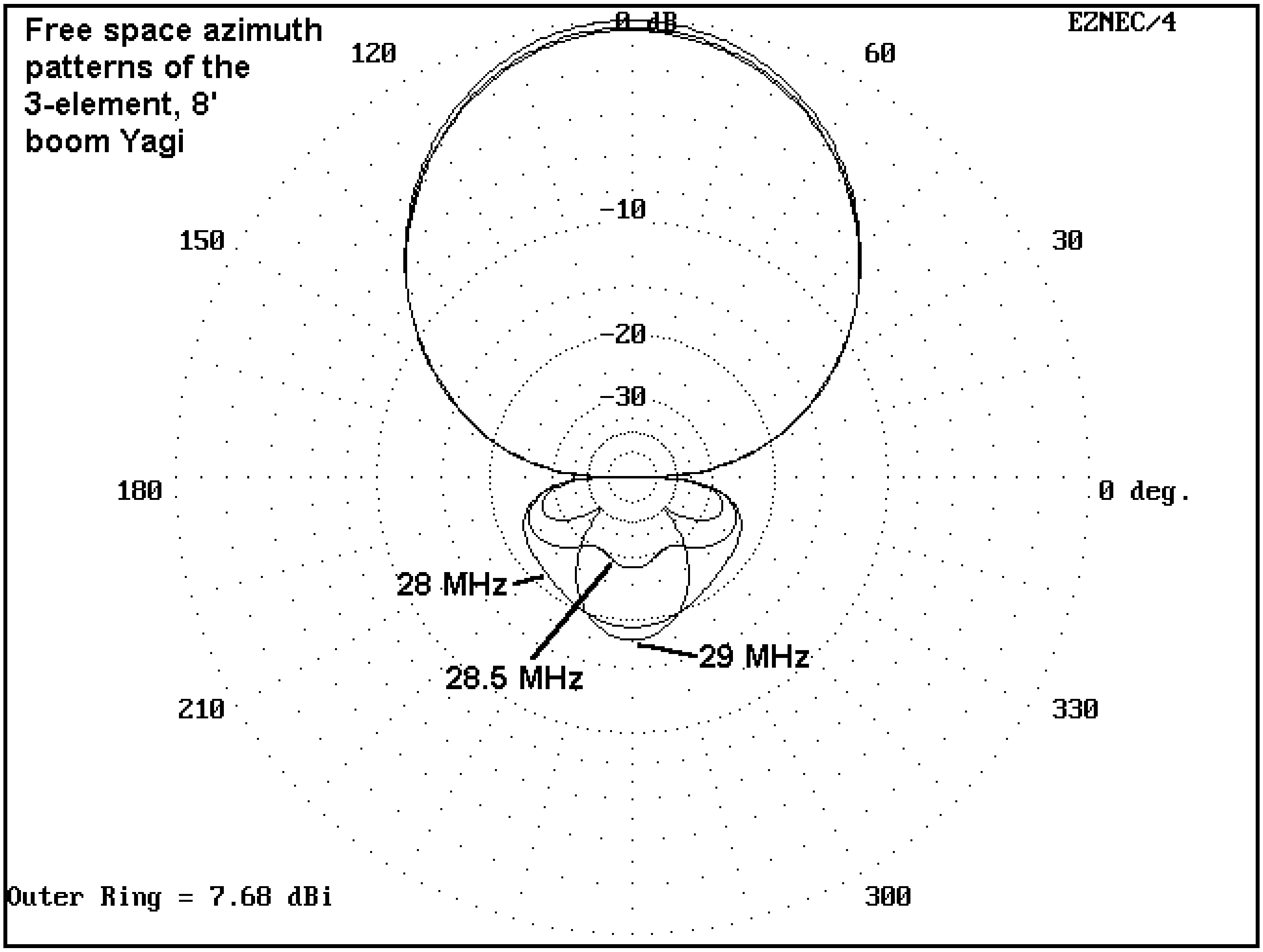


Figure 2. Hair-pin and inductor beta matches

The inductive reactance can also be a shorted transmission line stub or "hairpin." The hairpin can have many dimensions, depending on the wire thickness and the spacing. With a spacing (S) of 2" between wires, a hairpin of 1/8" wire will be about 7.7" long (L), while a similarly spaced hairpin of #12 wire will be about 6.8" long.

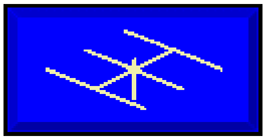
In real life, not everything is exact, and the hairpin or coil may need adjusting to achieve a 1:1 SWR at the target frequency (28.5 MHz in this case). You can adjust the length and/or spacing of the hairpin. Likewise, you can squeeze or spread the coil turns. If neither trick works, adjust the length of the driven element and try again.

How well does the antenna work? Across the first MHz of 10 meters, the gain ranges from about 7.3 dBi to 7.7 dBi (free space gain. In comparative terms, this is about halfway between the gain of the wide-band 50-Ohm beam and a highly optimized 3-element beam with a boom length of about 12' or so. The gain is high enough to compete favorably with most 3-element tri-banders on 10 meters. **Figure 3** shows the pattern at 3 point across the band.



The front-to-back ratio is about 18 dB at the band edges, but for most of the span between it is well over 20 dB, peaking above 27 dB near center band. Not too bad for an 8' boom.

The entire beam will weight between 8 and 10 pounds, including the boom, depending on the materials used. An old TV rotator will turn it, and a guyed push-up mast or roof-top "tower" will put it at a good height. Remember that the fairly high front-to-back ratio is not only a QRM killer, but also a closed back door. In a local net or similar operations, you may also want to have a simple vertical or dipole around to tell when there are signals off the rear waiting for you to turn the beam in their direction.



No. 21: A Simple 2-Element 10-Meter Quad

L. B. Cebik, W4RNL

Quads are popular with many folks, and sometimes for good reasons. So let's see what a dedicated 10-meter 2-element quad might look like after some work in the home shop. We shall use only materials available locally: wire, PVC, and some hardware.

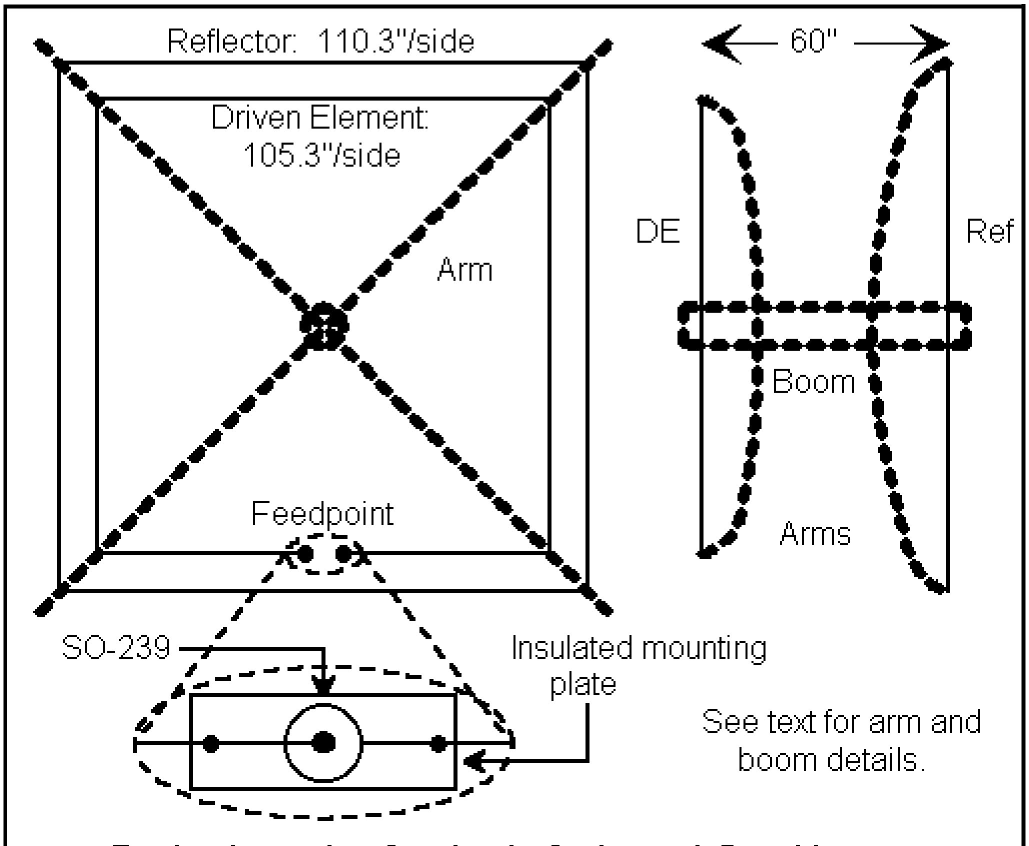
Why a Quad? Quads beams consist of 2 1 wavelength (approximately) loops, ordinarily arranged so that one is the driven element and the other is the reflector. Since the elements are double the size of the half-wavelength elements in a 2- element Yagi, we expect more gain-and we get it. In fact, a 2- element quad has almost as much gain as the 8'-boom Yagi or the wide-band Yagi we discussed in recent columns. However, the 2-element quad does not have as much gain as a fully optimized long-boom 3-element Yagi. Also, the front-to-back ratio of a quad fluctuates around the 20 dB figure, more like a 3-element Yagi than a 2-element Yagi.

Physically, a quad beam--when compared to a Yagi--trades volume for horizontal area. Horizontally, even the 8'-boom Yagi requires a rectangle about 8' long by 16.5' wide. A quad of similar performance has a footprint only 5' long by 9.5' wide, or about 1/3 the area. However, the Yagi is flat, while the quad occupies a 450 cubic foot volume. (That just means that it is as high as it is wide.)

If you decide that you want a quad for most of the HF bands, I recommend that you obtain one of the commercial models. These fairly complex structures are engineered for maximum strength and durability. However, if you need only a 10-meter model (and later want to tuck 6-meter or 2-meter quads within the same framework), then you can build one yourself with simple tools and materials.

The Quad Beam Structure. As shown in **Figure 1**, a good 10- meter quad can be built from two wire loops. If the wire you use is #14 bare copper (stranded or solid), the driven element loop is 105.3" per side or 421.2" overall. The reflector loop is placed 60" behind the driven element and is 110.3" per side or 441.2" overall. If you decrease the wire size of a loop antenna, the total length becomes smaller as well (and not longer, as with a linear wire antenna element). For #18 bare copper wire, the dimensions per side drop to 105" and 110" respectively--not a big drop. but a noticeable one.

These dimensions are for bare wire. Insulated wire has a 2-5% velocity factor, depending on the type and thickness of the insulation. It will require different dimensions that I have not modeled and tested.



Basic elements of a simple 2-element Quad beam.

If we could just starch the wires and toss them in the air, the quad would be a very simple antenna. However, we need a supporting structure, shown by the dotted boom and arms in **Figure 1**. The support structure should be nonconductive, although a metal boom usually does not affect antenna tuning. For 10-meters, the arms can be strong fiberglass, quality bamboo (with lighter wire elements), or thin-wall PVC.

The sketch shows what one might do with an all-PVC structure. The boom can be about 4-5' 1" or 1.25" nominal Schedule 40 PVC. (1" nominal PVC is closer to 1.25" in diameter, while 1.25" nominal PVC is closer to 1.5" in diameter.) The arms can be thinner-wall SDR-135 PVC, 0.5" diameter nominal. Each of the 4 arms per element should be just about 6.5' long, but lets add another half foot to each.

Since PVC comes in standard 10' lengths, we shall need 8 pieces of the half-inch diameter stock, along with 4 end-to-end couplers (plus a 5' piece of fatter Schedule 40 for the boom). You can either drill the ends of the arms for the wires or use half-inch Tee fittings--although the smoother fittings add weight to the assembly.

Assuming a 5' boom, use a 1 1/8" drill-mounted hole cutter to cut two pair of aligned holes in each end of the boom. The outer pair at each end should be about 6-9" in from the end, and the inner set another 1.5" further in. The hole-pairs should be at right angles to each other at each end, and the hole sets at each end should be very closely aligned with each other.

Now we can make the wire supports. First, place an end-to-end coupler in each hole and run a stainless steel nut and bolt through the boom and coupler to fasten the assembly. Using PVC cement, add 7' lengths of the half-inch thin-wall PVC to each coupler end. Add Tees to the ends, or drill out and deburr generous holes for the wire about 1/2" in from each arm end.

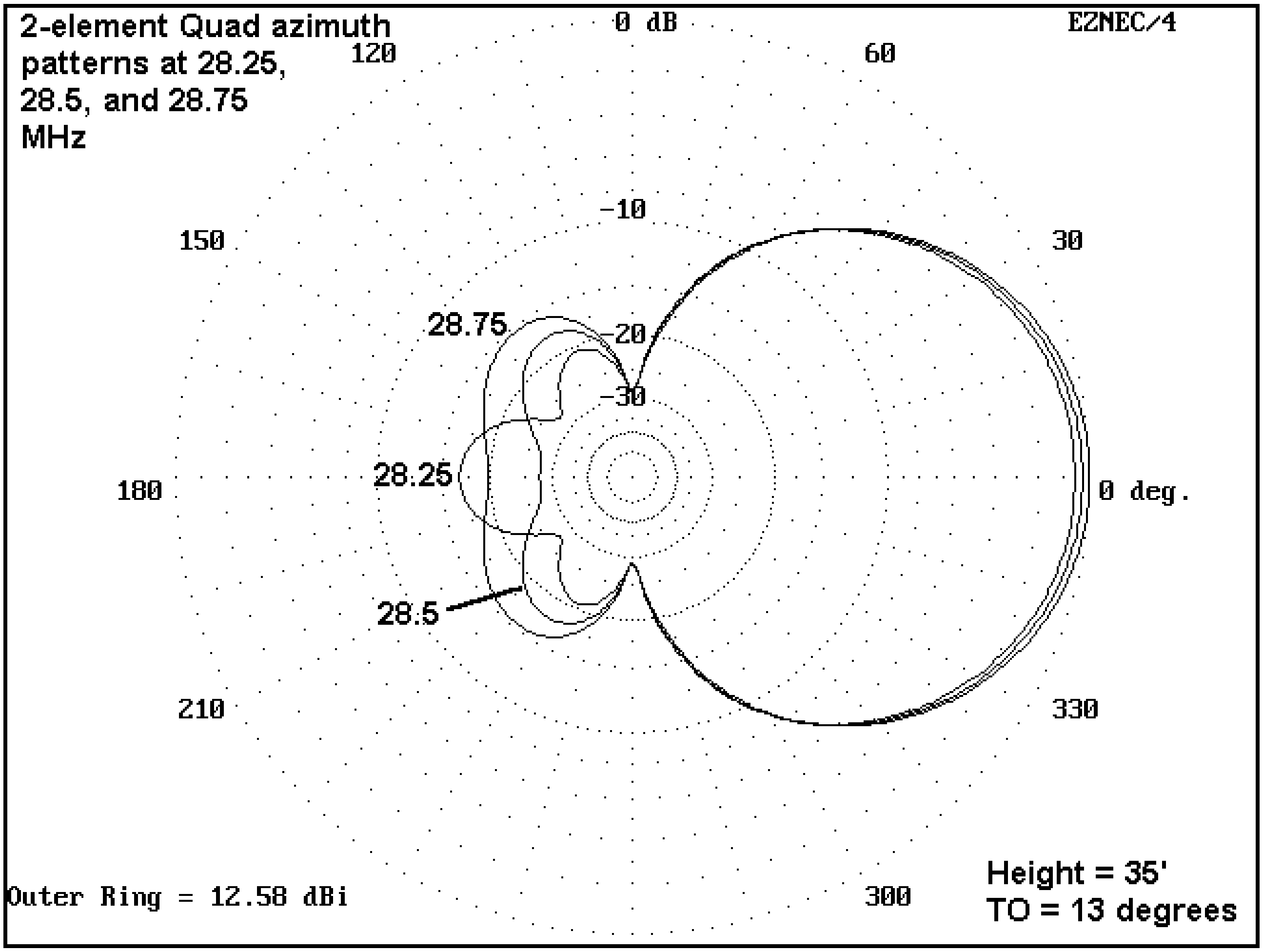
Use a length of cord marked the same length as the wire that will replace it--with some excess. Run the cord through the holes and stress the arms outward toward the boom end until the cord matches the element size. Tie it off. If you use fresh nylon cord, you can leave it in place even after you add the wire--it will not hurt anything. Since cord stretches, you may experience some flex reversals, but after a few of these, you will learn how to keep the arms flexed in the correct direction.

Now add the wires. Make the reflector loop solid by twisting the ends of the wire together and soldering. The driven element requires a small insulated plate and a coax connector.

Assuming you have or can build a boom-to-mast mounting plate and have the U-bolts to mount the structure, you are almost ready to go. But let's not hurry.

Performance. The 2-element quad we have just built was designed for best front-to-back ratio from about 28.25 through 28.75 MHz. Below 28.25 MHz, the front-to-back ratio decreases rapidly to a little over 10 dB. Above the target frequency range, the front-to-back ratio decreases more slowly so that the 10 dB figure is not reached until about 29.4 MHz.

Forward gain of this antenna is maximum at the low end of the band and decreases about 0.1 dB per 100 kHz. Gain is best in the first half MHz of 10 meters, rivaling the gain of the 8'-boom Yagi. It remains as good as any 2-element Yagi all the way to the top end of 10 meters.



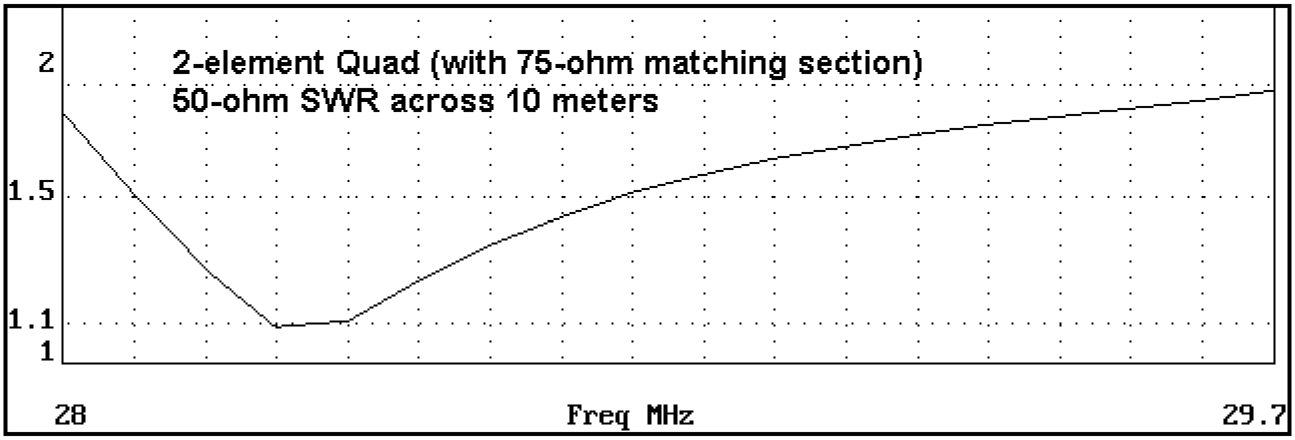
Since I am not trying to sell you anything, notice that I have told a story about what happens to the gain and front-to-back ratio rather than citing peak figures for each. **Figure 2** shows the azimuth pattern at the elevation angle of maximum radiation when the antenna is modeled at 1 wavelength up (about 35' high).

Figure 2 shows not only the variation in front-to-back ratio and the rear pattern, but also the gradual reduction in gain with increasing frequency.

Feeding the antenna. The feedpoint impedance of the antenna alone varies from about 70 to 150 ohms across 10 meters. since we anticipate feeding the antenna with standard 50-ohm coaxial cable, we need to add one more component: a matching system.

The simplest and most effective matching system for this antenna is a 1/4-wavelength section of 75-ohm coaxial cable, such as RG-11 (for higher power) or RG-59 (for lower power levels). Both cables have a velocity factor of 0.66, which means that a full wavelength of cable is 0.66 of the wavelength in free space. Let's use 28.5 MHz as our design frequency. A wavelength at this frequency is just about 34.5' long. A quarter wavelength is a little over 8.6' or 103.5" long. The quarter-wave matching section is 0.66 of this or 68.3" long.

A perfect quarter wavelength will transform an impedance higher than 75 ohms to a lower impedance, which is just what we need. In fact, when fed with a 50-ohm cable to the shack, the quarter-wave section shows under 2:1 SWR all across the 10- meter band. **Figure 3** shows anticipated SWR curve.



Do not operate this antenna without the quarter-wave 75-ohm matching section or an equivalent matching circuit.

If a 2-element quad meets your space and operating needs, this one will do the job about as well as it can be done. Feel free to alter the support structure using materials with which you are comfortable in your shop. (For me, PVC is tinker toys for adults.) A TV rotator will easily turn this light antenna. For best results, be sure the bottom wire is at least 20' up, and a tower or mast height of 35' is a good minimum target height for excellent DXing.

No. 22: The Handy Quarter-Wave Matching Section

L. B. Cebik, W4RNL

In the quad project we looked at last time, we specified the use of a 1/4 wavelength matching section of 70- to 75-ohm coax between the antenna feedpoint and the 50-ohm coax run to the shack. Let's find out why we needed it and how the matching section does its work. These types of matching sections are handy and easy to make, so you may find them useful in future antenna projects.

The Raw vs. the Matched Antenna: Let's start by comparing the feedpoint impedance of our quad both with and without the matching section. The figures are based on a quad beam that is self-resonant just below 28.25 MHz. The 1/4 wavelength section of 75-ohm, 0.66 velocity factor coax was cut for 28.5 MHz and turned out to be 68.3" long. All SWR figures are relative to 50 ohms.

Frequency in MHz	Without matching section Feed Z (R+/-jX Ohms)	SWR	With matching section Feed Z (R+/-jX Ohms)	SWR
28.00	70.6 - j29.2	1.81	66.9 + j27.1	1.73
28.25	96.8 + j 3.4	1.94	58.1 - j 2.7	1.17
28.50	125.1 + j25.9	2.63	43.1 - j 9.1	1.28
28.75	150.1 + j39.4	3.23	34.9 - j 8.5	1.51
29.00	168.6 + j47.7	3.67	30.7 - j 7.1	1.68
29.25	180.8 + j54.8	3.97	28.2 - j 6.0	1.81
29.50	188.2 + j63.1	4.22	26.6 - j 5.4	1.91
29.75	192.6 + j73.6	4.45	25.1 - j 5.2	2.02

Without the matching section, the SWR figures for the quad are high enough that the automatic shut down feature of most current solid state rigs would reduce rig output to almost nothing. With the matching section, the SWR figures within 10 meters permit normal operation.

As the unmatched impedances go up, the matched impedances go down. This gives us a clue to how the matching section operates. Every length of coax of any characteristic impedance (Zo) is an impedance transformer. For odd lengths, the transformation is complex. However, when a length of coax is exactly 1/4 wavelength long at a given frequency, the transformation is simple, especially if the impedance to be transformed is wholly resistive. We can use a calculator to handle this equation:

$$\mathbf{Zmatched = Zo2 / Zantenna}$$

This little formula is only approximate in the real world. for example, with the quad, there is a reactive part of the antenna feedpoint impedance in every line of the table. Moreover, the matching section is only an exact 1/4 wavelength at 28.5 MHz and nowhere else. However, if the reactances are not too high and the frequency span is not to great, the simple equation makes a good approximation. As we look at the table, for a single ham band and for reactance values less than half the resistive values, the simple equation works well enough for antenna building.

Remember that for purely resistive impedances, a 2:1 50-ohm SWR accommodates an impedance range of 25 to 100 ohms. This resistive range shrinks when we combine reactances with resistance. However, note the 4:1 range of impedance that these SWR limits can handle. (Also remember that the 2:1 ratio is somewhat arbitrary as a set of limits. It's chief effect is noted by automated power reduction circuits in transceivers. Apart from this, there would be little difference in radiated power between, say, SWRs of 1.8 and 2.5.)

With a 1/4 wavelength 75-ohm matching section, again in purely resistive terms, we can take antenna feedpoint impedances between just above 56 ohms up to 225 ohms and transform them to values that fit the 50-ohm 2:1 SWR limits--again, a 4:1 range. Notice that our quad does not reach 225 ohms when the matched SWR exceeds 2:1, but notice also that there is considerable reactance that accompanies the resistive value at 29.75 MHz.

Likewise, at 28 MHz, we would expect the antenna impedance of 70.6 ohms to yield about an 80-ohm figure instead of the 66.9-ohm figure that actually emerges. However, not only do we have reactance at the antenna feedpoint, but as well the matching section is shorter than 1/4 wavelength at this frequency. Hence, the impedance does not undergo a full quarter wavelength transformation. (Likewise, above 28.5 MHz, the impedance undergoes more than a 1/4 wavelength transformation.)

These are the finer points of using a 1/4 wavelength matching section that affect the matching range by just a little bit and throw the actual impedances somewhat off the calculated results from the simple formula. But the simple formula works well enough for most ham antennas. To be on the safe side, if you have a range of antenna feedpoint impedances from about 80 to 200 ohms, then a 1/4 wavelength section of 75-ohm coax will transform them to values appropriate to a 50-ohm feedline and transceiver system.

Other Applications: 50-ohm and 75-ohm coax cables are the ones most easily obtained by hams, even though other values are available from manufacturers. However, this fact does not limit us to matching only values above 50-ohms to our 50-ohm system. If you cut 2 lengths of 75-ohm cable to 1/4 wavelength and connect them in parallel (center conductor to center conductor and braid to braid at both ends), you have a 37.5- ohm cable. If we plug this value into the simple equation, we find that we can match impedances values below 50-ohms up to values within the 2:1 50-ohm SWR limits. This is useful for Yagis and other antennas that often have feedpoint impedances in the 20-35 ohm range. The double line can be a bit bulky, but that is about its only significant disadvantage over other matching methods.

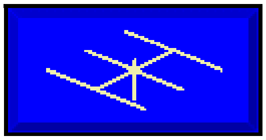
Consider another situation: At certain wire antenna heights below 1/2 wavelength, the feedpoint impedance of a dipole is not 70 ohms, but more like 80-95 ohms. The 75-ohm matching section would transform these values to a 70-60 ohm range. However, we can broaden the range over which these values apply by first running a section of 50-ohm cable that is 1/2 wavelength long or a multiple of 1/2 wavelength (allowing, of course, for the cables velocity factor). Cut the 50-ohm cable for a frequency at the band center, such as 7.15 MHz for a 40-meter dipole. Since the cable is short at the low end of the band, the impedance will be higher than at the antenna at the same frequency. Equally, since the cable is long at the high end of the band, the impedance will also be higher than at the antenna terminals. The result will be band edge values closer to 100-120 ohms.

Now, if we plug in our 1/4 wavelength 75-ohm matching section, we have lower SWR values across the band than we would have by placing the 75-ohm matching section at the antenna terminals. In fact, such a system can, with some dipole heights on 80 meters, cover more than 4/5 of the band with under 2:1 SWR.

75-ohm quarter wavelength matching sections (and derivatives) make up a quite flexible array of methods for adapting 50-ohm transmission line to antennas that do not present 50-ohms at their feedpoint terminals. However, they do have some major limitations. Because a length of coax is 1/4 wavelength long at only one frequency, this technique is for monoband antennas only. If you have a multiband antenna, you will have to use some other method of matching your 50-ohm coax/transceiver system to the antenna.

Likewise, the transformations become far more complex the higher the reactance at the antenna feedpoint. Hence, the quarter wavelength matching system is also only for low- reactance matching situations, such as the one shown in the table for the quad. If you have higher reactances, you may need a different matching system.

But where the 1/4 wavelength matching section is suited to the task, it is simple, inexpensive, low-loss, and effective. Those are pretty good credentials.



No. 23: Some Notes on Antenna Safety

L. B. Cebik, W4RNL

What would you like to protect from harm? Yourself? Your family? Your home? Your station? Your neighbors and their property? I guess that is enough to start a column on safety. Obviously, we can never finish it, but perhaps a few ideas might help you fill some gaps in the safety net around all you wish to protect and preserve.

Static Build-Up: As the wind and weather pass over the antenna elements, a charge builds up. On long wire antennas, it can generate enough of a charge to draw a visible spark across a gap to ground. On smaller antennas it can create unnecessary static. The best way to avoid problems here is to be sure that the antenna is at DC ground. Some antennas are designed with a DC ground; others are not. For low impedance antennas (less than 150 Ohms feedpoint impedance) fed with coax, the simplest way to insure a DC ground is to place an RF choke across the antenna terminals. This gives you a DC ground path but leaves the antenna RF-hot. At 10-meters, a 100 micro-H RF choke provides about 1800 ohms of reactive isolation, but a low resistance to charge build-up. Just be sure your coax braid is grounded somewhere along the line so that the charge has somewhere to go other than to your equipment.

Parallel feedline systems, such as all-band doublets require a different treatment, since the impedances they may see can range up to 5000 ohms and more. Here we can use high value resistors where the feedline enters the house. Run a 1 Mohm resistor from each line to a ground rod where the line meets the shack. It is also useful to add a knife switch or other disconnector (with the alternate contacts directly grounded) to remove the connection to the equipment when the antenna is not in use.

Station Grounding: Everyone is familiar with the need for a common ground bus for all station equipment with as short a lead as possible to a ground rod outdoors. If you have a tower, it should also be ground rodded. All ground rods (including the house ground at the electrical service entry) should be connected together by the largest copper wire you can obtain. Some folks use copper flashing cut into long strips. These days, braid is not recommended because its very large surface area open to weather deteriorates it quickly. Use solid mechanical connections, not solder (which melts in the presence of lightning like a teenager in the presence of a rock star: instantly).

If ground rods are widely separated, add ground rods in a row from end to end, spaced about the length of each ground rod apart. This is not over-kill--just the opposite. It is over-safe by holding the resistance between everything in your house and shack at the absolute minimum. Even a slight resistance may give a lightning surge an alternative path to ground through your "stuff."

Towers and Coax: Some studies have shown that the bulk of lightning current travels in the shield of the coax. A considerable voltage difference can exist between a tower leg and the coax braid if the first connection between the two is at the bottom of the tower. You may want to consider breaking your coax near the top of the tower, having one section to the antenna with the flex loop to accommodate rotation and another section down the leg of the tower. Securely fasten a plat to a tower leg and use a double female connector with chassis nuts (often called a bulkhead connector) to join the two coax lengths. This gives you a connection between the coax braid and the tower leg. This is not the only ground you should use, but an extra one.

Total Disconnection: During violent electrical storms, surges can enter the station equipment from several sources: the antenna lines, the AC power lines, and ground. When dealing with surges, do not think in terms of complete electrical paths. A surge can charge components, cases, and chassis, and create high voltages across components that are designed for low voltages. Hence, during violent storms, do a complete disconnect.

Outdoors, disconnect all antenna feed lines and reconnect them to a ground rod in the station ground system. Indoors, disconnect antenna feedlines from the station equipment. Unplug all equipment--or that power strip you use as a master switch. Most power switches are single pole, so one must unplug in order to break the neutral and ground line paths along which surges can travel. Also disconnect the station equipment from the master ground lead to the outdoor ground rod system. If you do some careful planning, you can make all these moves in under a minute. Just be sure that all connections are accessible and require no tools to connection and disconnection.

While it may be true that a direct strike is rare, most damage occurs from nearby strikes that place heavy voltage surges on power lines, antennas, and the ground. You can do a lot to keep them outdoors, where they belong.

Towers: Towers, whether free standing or on the roof top, require some special thought. Too few hams actually study tower installation before putting up the first one. Here are some things to think about:

1. What are the requirements for the tower base, including the concrete, rebar, excavation, etc.? Never under-support a tower at its base.

2. What, if any, are the guying requirements? If a tower is a guyed model, install the guying system to at least the manufacturer's standards. Be certain that guys are correctly and adequately anchored--and that they do not present a hazard to those who use your yard. If the tower can use a building support, be sure the building is up to the job. Most roof-line facia boards on a house are not.

3. Where does the tower go? Place it where it cannot hurt neighboring property (or people) if the tower and antenna fall under the worst conditions imaginable. Also try to place it where it will not hurt your own home and family if it falls.

4. Where do the feedlines go? Be sure that feedlines do not create either an electrical or a physical hazard for family members or visitors.

5. What are the codes? The more urban your setting, the more you may be subject to codes and ordinances that require permits, special requirements (for example, conduit for control voltages over a certain value), inspections, and, in some cases, licensed installers. Do not under any conditions bypass these requirements. Investigate in advance to know what you have to do and what it will add to the cost of the installation.

6. What about intruders? Towers are in some places classified as attractive dangers, which is what they might be to a neighborhood child with an urge to climb. Hollering is a deterrent, but not protection. Consider fencing in or cladding the lower tower sections so that the tower cannot be climbed.

7. Are any of the tower conveniences dangerous? Crank-up and tilt-over towers are convenient, but usually rely on cables, pulleys, and gearing to go up, come down, and stay in position. Analyze the stresses on these auxiliary parts to ensure that they can safely handle the loads. Develop a maintenance schedule for inspecting and for replacing cables before their lifetime is ended. If they die on the job, disaster often results.

RF Safety: RF hazards come in two varieties. One is radiation. Current FCC regulations provide standards for safe amounts. Use the worksheets and analyze your station, even if you think you may be exempt by virtue of power levels and spacings. Be sure.

A second hazard comes from direct contact with antenna elements carrying RF currents. Ground mounted verticals and inverted Vee ends provide the greatest hazards, since both children and adults can come into contact with them--either directly or with some implement having a long metal handle.

Isolate ground-mounted verticals with fencing or other barriers which are effective especially in preventing children from touching a potentially active antenna. A vertical in or adjacent to a children's play area may mean station silence during periods when children are present: if contact is not a danger, radiation may be.

Elevate and insulate horizontal antenna ends above the level where anyone can touch them with a metal rod. Never underestimate the ingenuity of a child with a small mean streak or a large curiosity.

Insurance: Carry all you can afford that may be relevant to hazards that antennas may present. However, never let the existence of insurance be a substitute for the best possible practice in the installation and maintenance of antennas and their supports. The lives you preserve may include your own and those of your loved ones.

This is not a complete look at all the facets of antenna safety. We have not even reminded you to keep your antennas and supports well away from power lines. But perhaps we have said enough to prompt you to do a periodic inspection of your own safety measures--and perhaps some reading into the handbooks and other literature. The three key words are these: protect, divert, and prevent. They are three ways of saying that you care enough to do the very best.

No. 24: Three Ways to Skin a Quad Loop

L. B. Cebik, W4RNL

A single quad loop makes a compact and effective bi-directional array for 10 meters. It has somewhat more gain than a dipole, and most users note that it is quiet, that is, not as susceptible to local noise as an open-ended dipole. With some sort of supporting system, the loop is a good choice for many ham back yards.

A quad loop does its work with the antenna in the vertical plane, like a giant fly swatter. Maximum radiation is off the two broad surfaces and is minimum off the edges.

Now comes the hard part: deciding what kind of loop to use. There are at least three versions, each with advantages and disadvantages. Let's look at them in order of complexity.

The Standard Square Loop

The first sketch (**Fig. 1**) shows a standard quad loop made from #12 AWG copper wire. (If you use a different size wire, you may have to change the dimensions just a bit for resonance.) This antenna is a proven performer, with about 3.3 dBi free space gain, which translates into about 8.3 dBi gain at 1 wavelength above ground for the bottom wire (about 35'). The elevation angle of maximum radiation is about 19 degrees, which provides access to low-angle incoming DX signals.

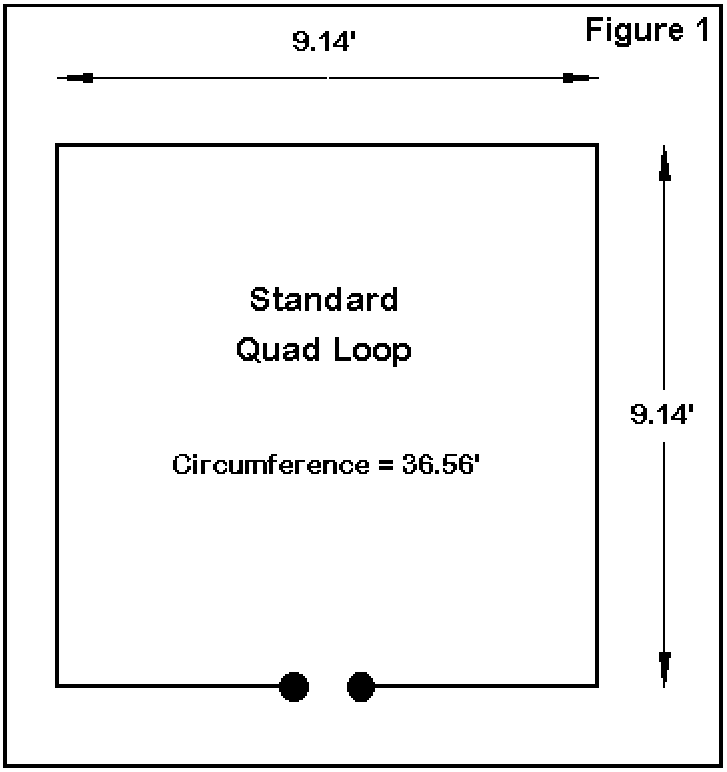


Figure 1

The feedpoint impedance is about 125 Ohms at the 28.5 MHz design resonance frequency. A quarter wavelength section of 75-Ohm coax (about 5.7' of standard RG-59 with a velocity factor of 0.66) will provide a very low-loss match for the 50-Ohm coax to the shack and provide less than 2:1 SWR over all of the first MHz of 10 meters, plus a little. With this set-up, the antenna has the broadest operating bandwidth of all of the loops we shall examine.

The old standard way of making a quad loop is to use criss- cross spreaders of bamboo, fiberglass, or--more recently--PVC. However, there are no rules that forbid you from stretching the quad loop from its corners to trees or other vertical supports. You can also use tubular horizontal members and wires vertical sides, although you may have to adjust the dimensions--most likely to enlarge them a bit.

The Elongated Loop

In July, 1996, K6STI wrote in QST of an old idea: by elongating the quad loop we can achieve a little more gain and, at the same time, bring the feedpoint impedance close to 50 Ohms for a convenient match with our standard 50-Ohm coaxial cables.

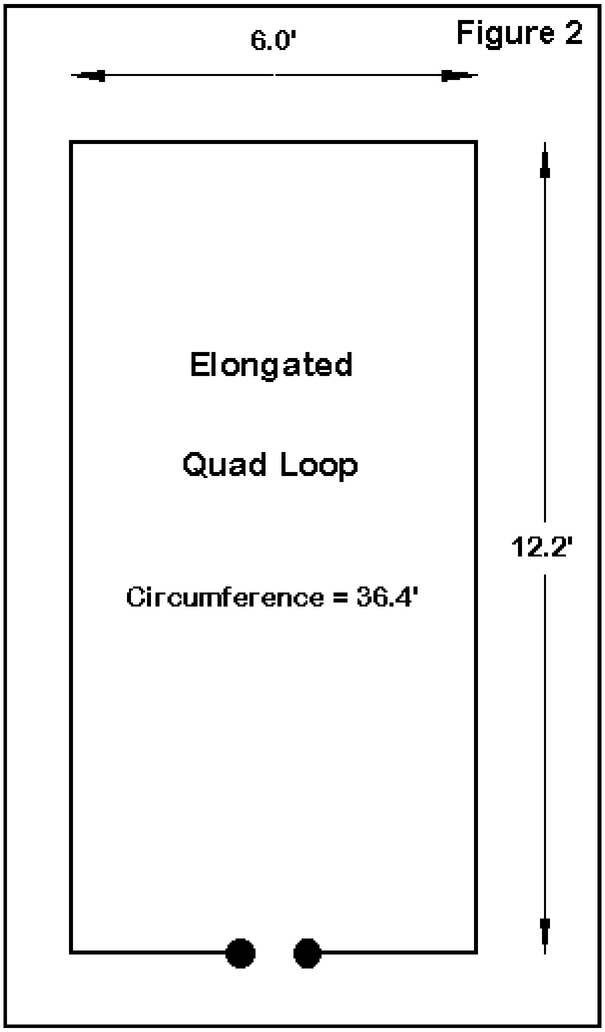


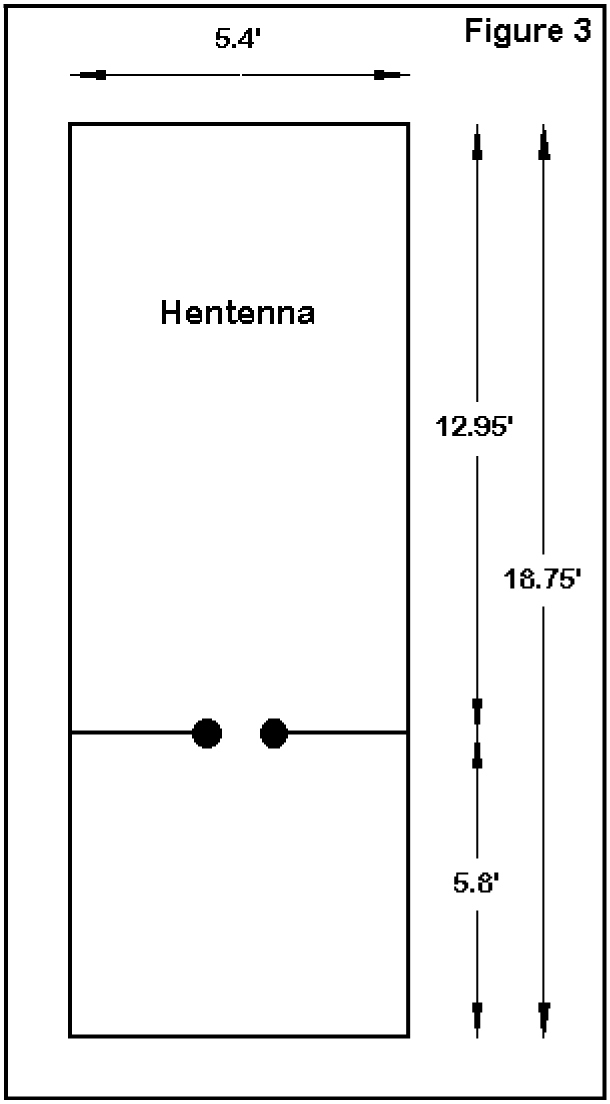
Fig. 2 shows the dimensions of a #12 AWG copper wire loop meeting these goals. The feedpoint impedance is almost exactly 50 Ohms at 28.5 MHz. However, the 2:1 SWR operating bandwidth is only about 800 kHz, somewhat narrower than the standard loop with a matching section attached.

The gain of the loop with the bottom wire at about 35' is 8.9 dBi (4.2 dBi in free space), and the taller assembly lowers the take- off angle to 17 degrees. Both the gain and the lower angle of maximum radiation contribute a little extra to our DXing efforts.

Most likely, you would want to build a fixed version of this kind of loop by supporting the wire from its corners by ropes running to adjacent supports. As an alternative, you can build a rotatable version by using tubular horizontals and wire vertical sides (again, with dimensional adjustments that owe to the fat horizontal elements) attached to (but insulated from) a center mast. With a height about 3' taller than the normal quad loop, support requires a bit more work than the standard loop. Yet, if the top of this loop and the top of the standard loop are level with each other, this elongated loop loses some of its advantages in gain and lowered take-off angle.

The Hentenna

The Hentenna is an invention of Japanese hams (and "hen" means "what is it?"--or so I am told). It consists of the full wavelength upper loop with a secondary lower loop that allows a close match to 50-Ohm coaxial cable. See **Fig. 3**.



The gain of this antenna, if the bottom wire is at the same level as the other two loops (1 wavelength or 35'), is about 9.8 dB (5.0 dBi in free space), with a take-off angle of 15 degrees, making it a good DX antenna among loops. However, its performance depends very much on the added height of the upper wire, which is nearly 19' from the bottom. The antenna is 60% as wide but more than twice as tall as the standard square loop. If we lower the top wire to parallel it with the top wires of the other two loop designs, the hentenna turns out to be only a little better than they are.

The operating 2:1 SWR bandwidth is the narrowest of the three loops, about 600 kHz or a little over half of the first MHz on 10 meters with the design frequency of 28.5 MHz used here. Like the other loops, construction can be all wire, with the corners attached by thin (UV-resistant) rope to supports. Or, you can once more use larger diameter upper and lower horizontal members with wires sides and a wire feedpoint element for a rotatable antenna.

Pattern Comparison

To give you a better idea of what to expect from each antenna, here are two elevation patterns, each of which contains patterns for all three loops.

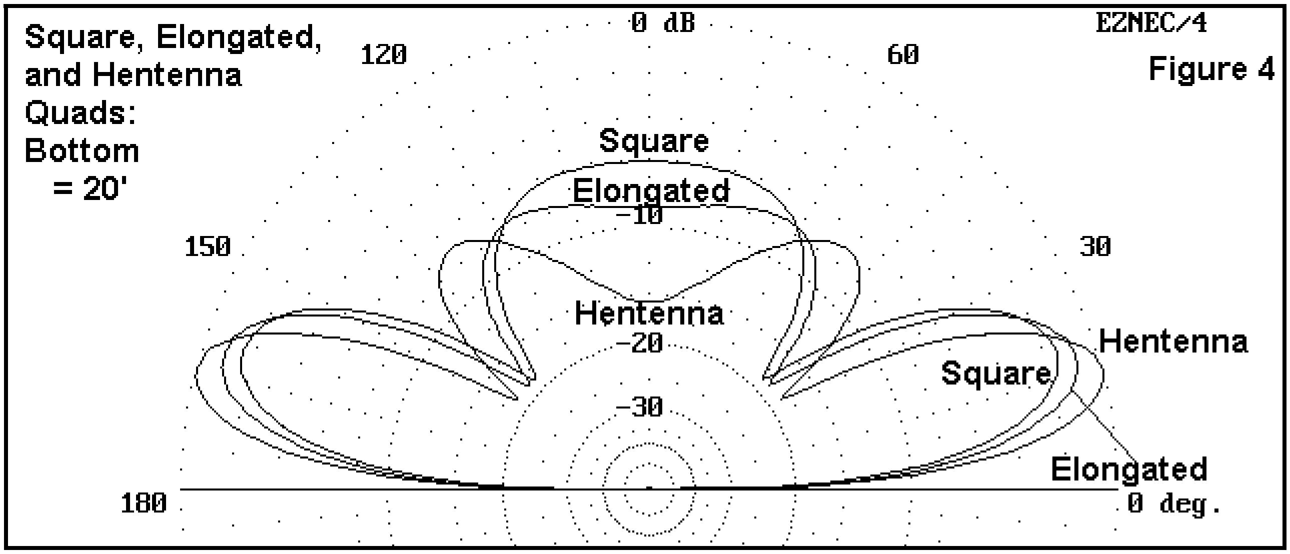
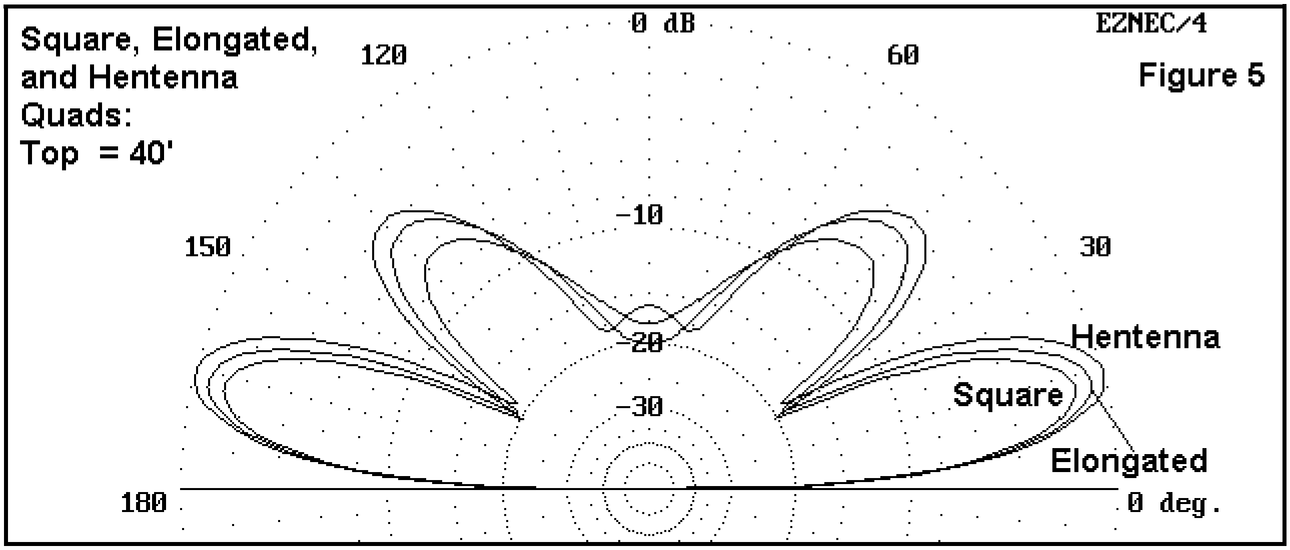


Fig. 4 compares the antennas using a common bottom horizontal wire height of 20'. This arrangement places the elongated loop top wire above that of the square loop, and the hentenna top wire above both the others. The advantage in gain and lowered angle of radiation for the larger kloops is clear.

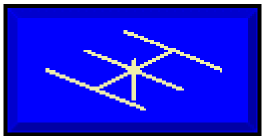
Fig. 5 reverses the procedure and places the top wires of all 3 antennas at 40' up. For many installations, top height is more absolute than bottom height. In this configuration, all three antennas have comparable TO angles, with only small gain advantages as the loops grow larger.



Whichever loop you choose, assuming that a loop fits your operating needs, give your best ingenuity to construction. If at all possible, figure out how to make the antenna free standing so that you can rotate it by hand (if not by a TV rotator). You will need to turn at most less than a half turn, since the antenna is bidirectional. All of the loops have very deep side nulls on a plane with the wires, and just these nulls alone can get rid of more than half the QRM that might get in the way of your QSOs.

Loops are also handy in contests, where you really do want to hear what is happening in most directions. You never know in advance from where your next contact will come. If you build the loop to be collapsible, you can set it up for Field Day and other hilltopping exercises.

The basic quad loop is a versatile antenna that lends itself to many construction techniques. If you want a little more performance than a dipole can give and you think it is fun to have a fly swatter waving in the breeze above your QTH, then one of these three designs may be the next antenna to build.



No. 25: The 10-Meter L-Antenna

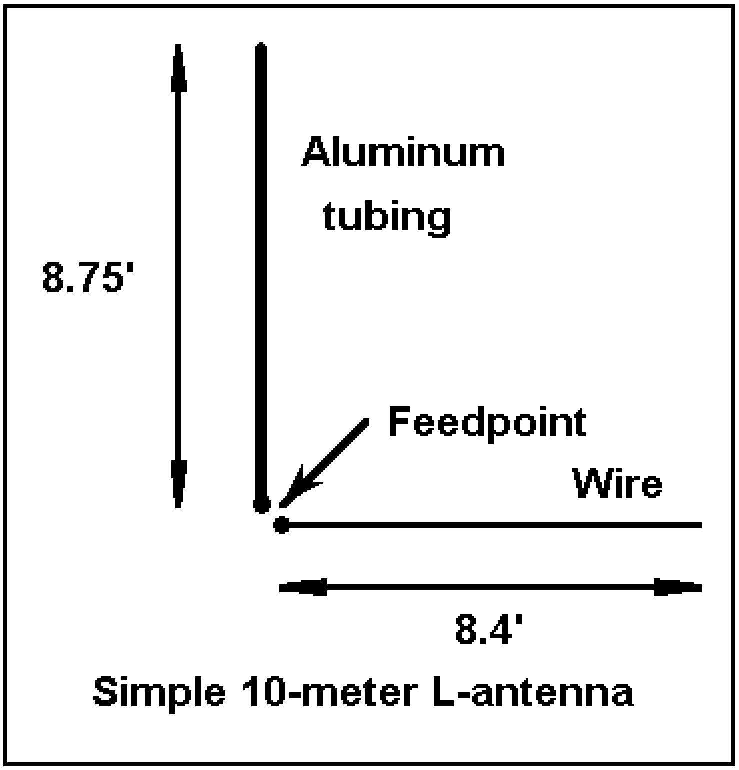
L. B. Cebik, W4RNL

A large number of 10-10ers are just getting started. They are unsure of whether to go with a vertically polarized antenna or a horizontally polarized antenna. They have heard that cross polarization reduces signal strength by some amount from 3 dB on upward. They do not yet know what the prevalent polarization is in the local area. They do not want to put a lot of money into their first antenna, but they would like to enjoy 10 meters for both skip and local contacts. They may also have some severe space restrictions. What's a person to do?

There is a simple and cheap solution. But first, a little background. For skip paths, polarization makes no difference almost all of the time. The ionosphere skews polarization. Highly elevated beams have an advantage, but simple antennas perform well on 10 meters, whether vertical or horizontal.

Polarization makes the greatest difference with local area contacts, where line of sight is the general rule. Some of the gang run verticals, some horizontals. How to get started before one discovers which types of operating are the most fun is the tough question.

Why not make a simple L antenna out of hardware store supplies. Suppose you have a typical rooftop abut 25' up, and a chimney or similar solid mounting point. Less than 10' of aluminum tubing and less than 10' of copper or aluminum wire, along with some mounting hardware to keep the parts solidly mounted but insulated, will produce a nice compromise antenna.

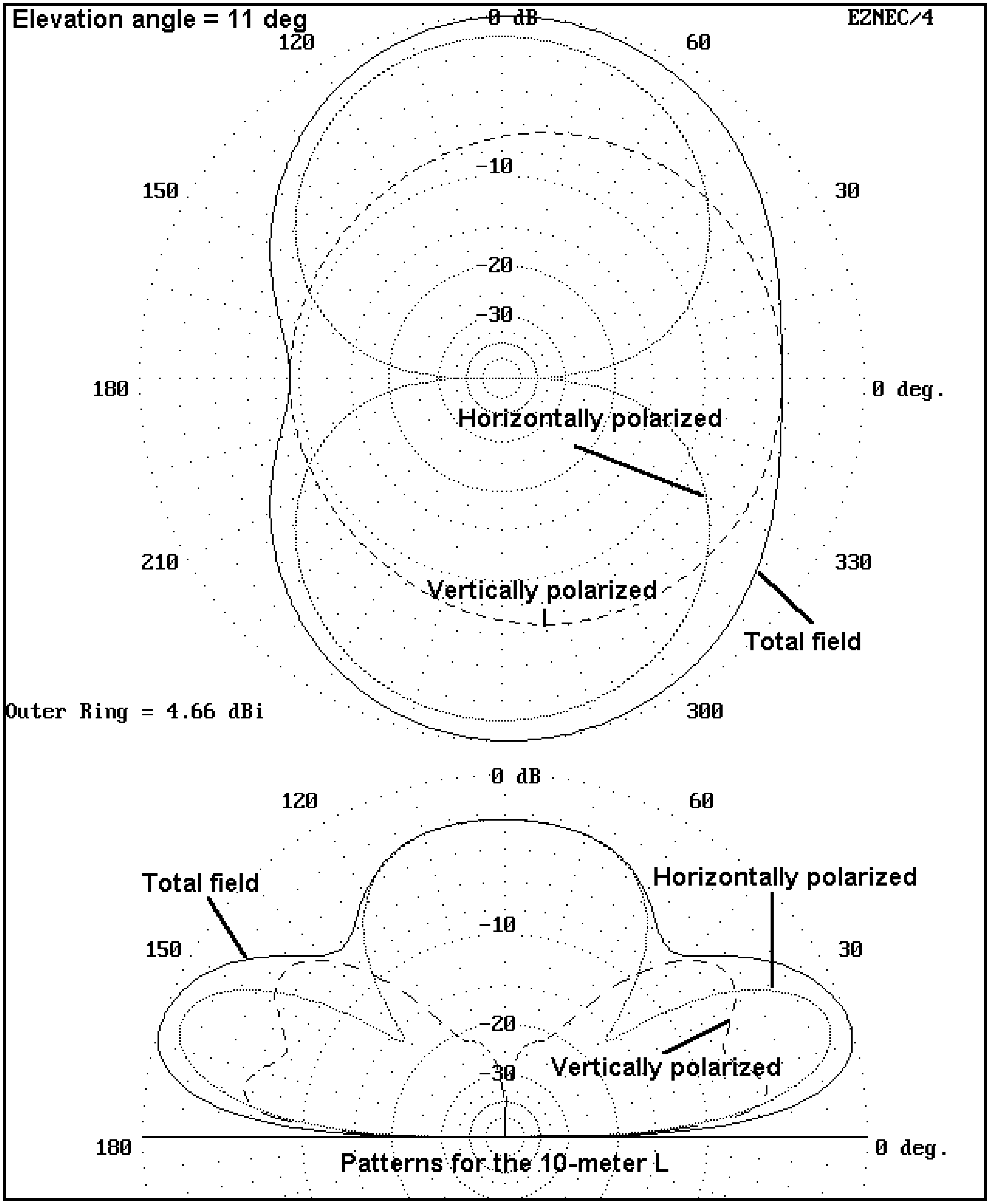


Simple 10-meter L-antenna

The vertical section consists of 2 pieces of tubing in the 3/4" diameter neighborhood. The tubing is self-supporting once you fix the base area solidly. The horizontal portion is wire, perhaps running along the roof ridge, elevated at least a few inches and more if you can manage it. Dimensions are not too critical. You can adjust the wire horizontal part by pruning the far end. And you can adjust the vertical part by sliding one section of tubing inside the other before clamping.

Adjusting the antenna for minimum SWR will do just fine. The modeled feedpoint impedance is about 40-45 ohms, so it makes a good match for RG-58, RG-8, RG-8X, or RG-213 coax. I highly recommend a choke balun, such as the W2DU ferrite- over-coax designs, at the feedpoint to minimize RF on the outer braid of the feedline.

What do you get for your $15 investment? A pretty good local antenna with both vertical and horizontal polarization. The patterns above assume the antenna is mounted atop the typical 25'-high rooftop crest. As the patterns show, the vertical part produces a vertically polarized signal (and receives the same) that is almost as strong (or sensitive) as a pure vertical. The horizontal wire produces a horizontally polarized signal (and receives the same) about half as good as a full size dipole. The result is a low-angle total pattern shaped like a kidney bean that will handle signals, whatever their polarization.



Patterns for the 10-meter L

By using light tubing for the horizontal piece, with perhaps a collapsible AM radio whip as the end section, you can make up a dandy portable or hill-topper antenna. A few nesting sections of PVC along with antenna pieces that also nest when not in use will make an antenna that takes almost no room in the car trunk. 5-10 minutes work, and you are on the air from your local scenic mountain or picnic area.

To get a better idea of the antenna's operation, think of it as an inverted Vee that has been rotated until one leg points straight up and the other is parallel to the ground. Unlike the Vee, this antenna is a good candidate for a rooftop or an attic.

In fact, if you must have an attic antenna, there is nothing wrong with using a Vee, either right-side-up or inverted, for getting a little polarization diversity to catch all the locals. Use 45-degree angles to maximize both types of polarization in the best compromise. If the L will not fit your attic vertically, then perhaps a Vee will fit the space.

For outdoor use, the L is likely a better mechanical choice, since you need only one solid mount and a secondary mount to keep the horizontal wire horizontal. The antenna has a minimal profile, and you can even put a PVC tube over the vertical tubing and fly a flag from it.

As with all elevated metal structures, be sure you have fat wire to a ground rod to bleed off charges built up by the weather. A 100 mH RF choke across the feedpoint terminals would not hurt either. Always build antennas with safety in mind.

So, if you are undecided about vertical vs. horizontal polarization, if you do not want to put a lot of money into an antenna while finding out which you prefer, or if you just need a good, cheap local antenna for 10 (that will also do quite well with skip), then the L may be right for you. When you finally invest in your long term antenna, you may want to keep the L in place as a back-up or for emergencies.

No. 26: When Should I Use a Vertical on 10?

L. B. Cebik, W4RNL

Most of the antenna we have discussed in this column have been horizontally polarized. There are some good reasons for this fact. First, 10-meter horizontal antennas are fairly compact, with a half wavelength being about 16-17' long. Second, the shortness of a wavelength on 10 meters (35') generally simplifies the process of supporting a horizontal 10-meter antenna at a good height (at least 1/2 wavelength, with over 1 wavelength preferred for best performance). Third, even 3-element 10-meter Yagis are fairly light-weight, for easy support, even in field or hilltop operations.

Nevertheless, there are some good reasons for using a vertically polarized antenna on 10. Although the gain of such antennas may not usually compete with a well-installed horizontal antenna of the same size, this factor is rarely a problem when the band is open. So let's look at the question of when to use a vertical.

1. **Mobile in Motion**: The standard these days for mobile-in-motion operation is the short, center-loaded, magnetic mount vertical set on the car roof. Although the least efficient of almost any antenna used on 10, these antennas acquit themselves well. Full size 1/4 wavelength whips have gone out of vogue, especially with the increased use of plastics in autos. When auto bodies themselves become universally plastic or fiberglass, we may have to rethink the center-loaded mag-mount vertical for mobile operation.

2. **Lunch-Time Operation**: With small rigs, short antennas, and an open band around noon, 10-meter lunchers are more numerous than we imagine. Since the lunch hour (or half-hour) is all too brief, operators want a system that wastes no time in set-up and take-down. The vertical--again, usually a mag-mount antenna in the parking lot--fills the bill.

3. **Local Convention**: In some towns and cities, most of the locals may use vertical antennas. Sometimes, this represents a lot of mobile work; sometimes it represents former citizen's band operators who have joined the amateur ranks and cut down their old antennas to resonate on the higher frequencies. Since local work is mostly point-to-point, as in VHF operation, cross- polarized antennas result in major losses in signal strength. So if the local group is mostly vertical, then it will pay you to have a vertical at home (as well as on the car) to join the fun full strength.

Since the path through the ionosphere generally skews signal polarization, distant stations will not suffer from being cross polarized relative to your antenna.

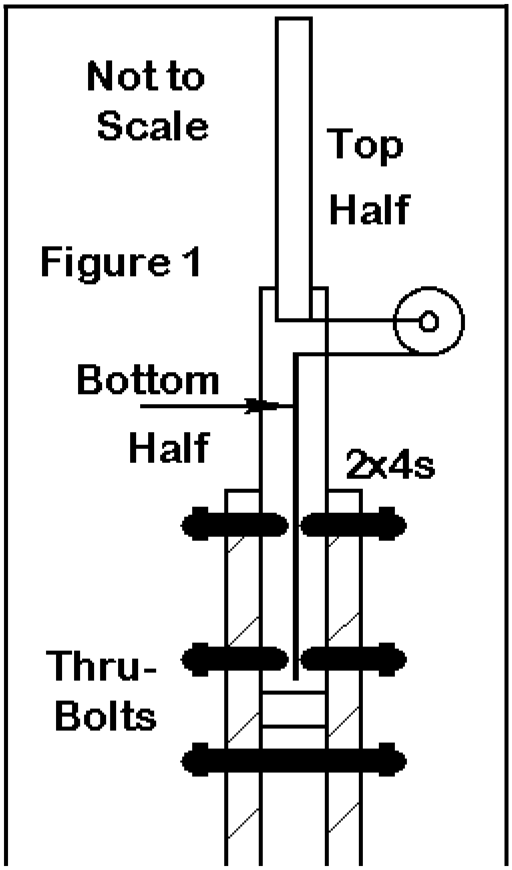
4. **Lack of Space**: Many hams live in homes without large yard. So space for antennas must compete for space with play equipment, patio furniture, and flower gardens. A vertical may be the only antenna type the home owner can erect.

The question here is not whether to use a vertical, but what kind of vertical to use. There are a number of multi-band verticals now on the market that will open many of the ham bands. They come in two major types.

If the roof top is the mounting area of choice, then one of the 1/4 wavelength trap verticals may be best. The heaviest part of the antenna is mounted near the roof top or chimney mounting system for maximum support. The necessary radials, installed according to the antenna makers instructions, can run along the roof top. If the antenna is at the end of the house, radials in the open direction can be run to trees or fence post, well out of reach of children or adults.

Where space is too restricted for an elevated radial system, one of the half-wavelength verticals may be more fitting. Some demand an elevated mounting point and may rest well on top of a fence post, short flag pole, or even a mast attached to a deck post. Other models call for ground mounting and can be placed in the most clear usable place in the yard with buried coax.

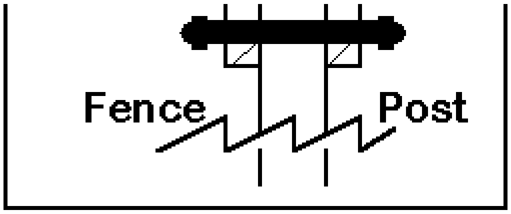
In all such installations, safety to children, family members, visitors, and neighbors is a top requirement. These antennas are rarely large enough to cause damage to neighboring property if they fall. Of course, they should be well clear of any utility lines crossing the yard. Finally, they should be isolated so that no one can get an RF burn by touching the antenna while in use. For some models, we achieve this last safety measure by elevating the antenna above reach, even by fence-climbers. Ground-mounted models require some extra thought. Setting up a flower bed and small fence around the antenna can keep most folks away. Sheathing the lower portion of the antenna in large-diameter black plastic down-spout drainage pipe for about 8' up is quite effective in preventing children from touching the antenna and has been found not to adversely affect performance. The protective sheathe can be attractively painted (with non-metallic paint) to call attention away from the antenna. Whatever the safety measures we take, we should also insure that they meet FCC requirements regarding RF exposure to other people.



Even hams with room for a host of horizontally polarized antennas may wish to consider installing one of these multiband verticals. They make good (even if not great) low-band antennas, provide back-up service in case the main beams collapse in high winds or ice, and allow the operator to match the polarization of locals using mobile whips or other vertical antennas. so even if you can afford the highest, the biggest, and the best, one of these simpler antennas makes good sense as part of the antenna farm.

5. **Home Brewers**: Some of us like to build antennas. Some of us have to build antennas to save the cost of commercial versions. Whatever the reason, a vertical dipole for mounting at least 20 to 25 feet up at the center on a non-conducting mast is a good starter project. I suggest a vertical dipole, since it saves a lot of grief over where to run the radials for a quarter- wavelength ground-plane model. The vertical dipole also takes less space than a horizontal dipole and requires no turning for maximum signal.

You can construct a vertical dipole from hardware store materials: aluminum rod or tubing (a little over 8'), PVC, and wood are the main ingredients. **Figure 1** shows in bare outline a vertical dipole I once used to capture Worked All Continents in about an hour at the



height of a long-ago sunspot cycle. The 4x4 fencepost was the main support, with underground bracing from bagged concrete. The side rail 10' 2x4s supported a good quality 2x4 mast, with the 4" side running between the rails. Two long galvanized bolts braced the mast. Removing the lower bolt permitted tilt-over operation.

The antenna itself began with an 8' length of aluminum tubing for the top extension. The lower part of the antenna consisted of insulated #12 house wire, purposely cut long. I tuned the antenna to frequency by trimming the lower wire for minimum SWR. Many local hams seemed initially horrified by the idea of a dipole made from unequal diameter elements and trimming only one end. They thought that terrible things would happen to performance, since the antenna was obviously as unbalanced as its builder.

Actually, virtually nothing happens except for a bit of building and adjusting convenience. Half-wavelength antennas lose nothing in performance by being fed slightly (or even radically) off-center. The feedpoint impedance does not begin to change noticeably until the feedpoint is well off center. The only precaution was for safety: the dipole end is a high-voltage point on the antenna, so it had to be inaccessible to human touch when in operation.

There you have it: some good reasons for using vertical antennas on 10 meters, whether they are commercial multi-band antennas or home brew specials. There are other reasons of a specialized nature that we could add. For example, if you live by the seaside, expect an exceptional increase in performance over the same antenna placed on a rocky hillside in the Smoky Mountains. Verticals have proven to be more than good enough in some island contesting locations. Some operators even prefer the wider beamwidth of a vertically oriented Yagi to one that is horizontal. Whatever the reasons, vertical have and will always have an important place in 10-meter operation, even if we never mention FM and repeaters at all (which I just did).

No. 27: A Compact Aluminum Moxon Rectangle

L. B. Cebik, W4RNL

I often receive inquiries from folks who cannot quite support the width of a 10-meter Yagi (either 2 or 3 elements) because obstructions give them less than the 16.5' needed. Is there an antenna with decent performance that will fit in a space about 12-13' wide? If it can be home built to save money and require no fancy tuning or matching system, so much the better.

In fact, there is an antenna that fits this category almost perfectly. Imagine an antenna with the gain of a 2-element Yagi (6 dBi), the front-to-back ratio of a 3-element Yagi (>20 dB from 28.3 to 28.5 MHz), and an SWR of below 2:1 from one end of 10 to the other. In fact, imagine that the antenna has better than 15 dB front-to-back ratio all the way down to 28 MHz and still has about 12 dB front-to-back ratio at 29.7 MHz. (All figures are free space modeling estimates.) Imagine also that the antenna can be directly connected to 50-ohm coax with no matching system whatsoever (even though I always recommend a 1:1 choke balun). Imagine also that you can make it yourself from hardware store materials, that it will weigh about 10-15 pounds including the boom, and that you can make it in your garage with no special tools. Imagine also that when it is done, you will still have change from a $50 bill.

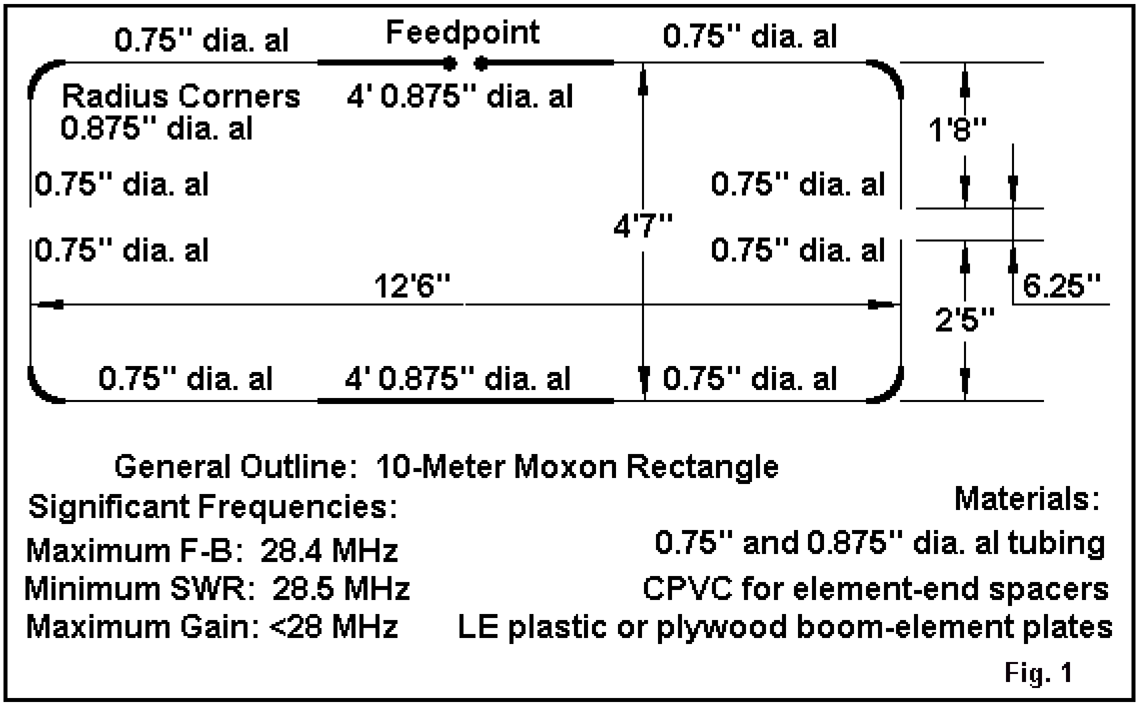


Fig. 1

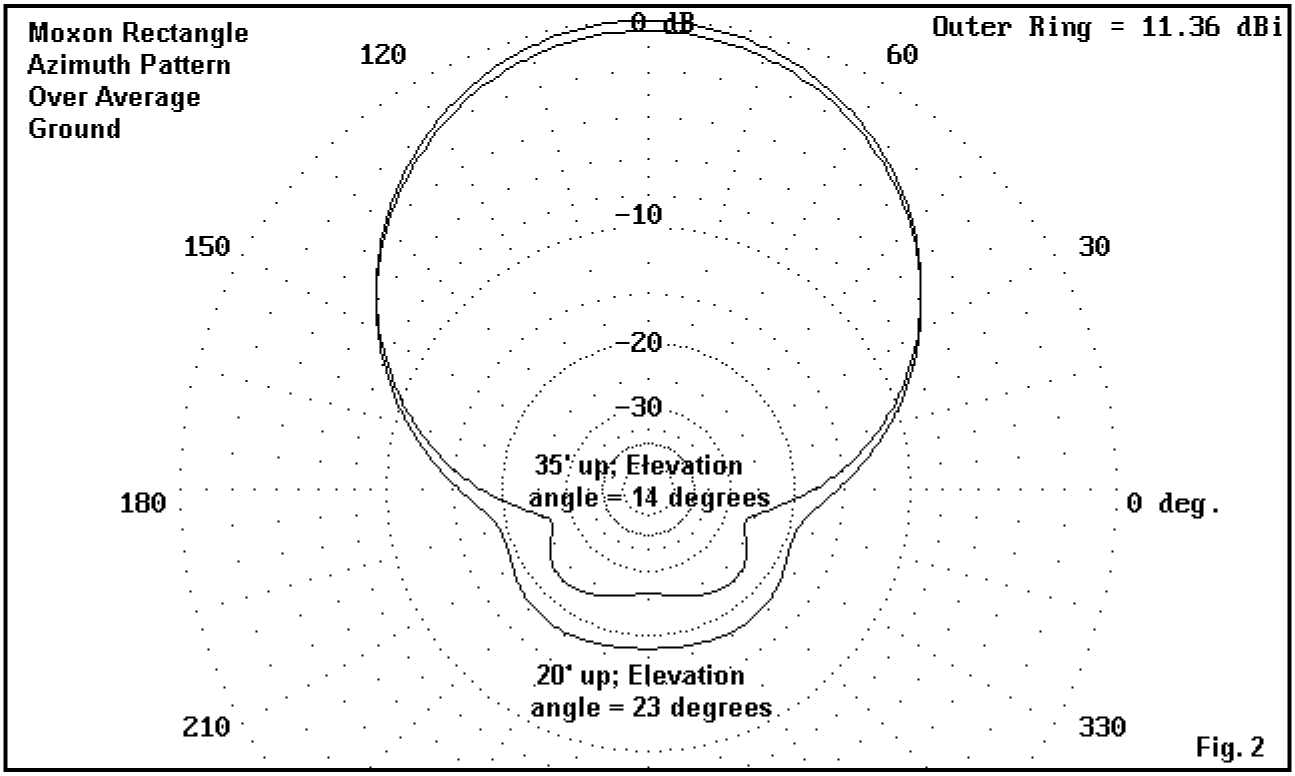
The antenna is the Moxon rectangle. Past versions that I built using wire elements required lots of PVC to support them. However, if we translate the antenna into hardware store aluminum tubing, we can build a 1-boom version. Now peak at the sketch of the pieces in **Fig. 1**. Some 7/8" and 3/4" diameter aluminum tubing form the main elements, with 3/4" tubing for the side elements. The corners can use radius-bent tubing or be squared by making some corner supports from L-stock. The combination of 7/8" and 3/4" aluminum tubing lets you telescope the ends into the center for a precise fit or a center frequency adjustment.

Since the end spacing and alignment is critical to make the antenna give its full performance, you can slide a piece of CPVC or similar lightweight, durable tubing either inside the ends or over the ends and lock them in place with sheet metal screws. The rigid spacer is also a good idea to limit the twisting force placed on the curved or right-angle corners. Sheet metal screws also connect the 3/4" and 7/8" tubing together. Be sure that all hardware screws are stainless steel.

For element-to-boom plates, you can use any durable material. Spar varnished 3/8" plywood or 1/4" LE plastic make good plates. About 3" by 9" (or longer) plates give ample room to U-bolt the elements to the plate and have room for U-bolts that go over the mast. As with all good antenna structure, let the elements hang under the boom. What boom? Well, almost anything, from 1-1/4" nominal diameter PVC to a good grade of aluminum tubing (thicker-wall than the usual 0.55" hardware store variety) to a 5' length of spar varnished 1.25" diameter closet rod. Make up a boom-to-mast plate similar to the boom-to-element plates, only a bit more square, and you are in business.

The dimensions of the antenna in the drawing are too fussy, being direct translations of the computer model used to generate the antenna. Just try to keep the dimensions within about 1/4" of the drawing, and no one will be able to tell any difference in performance. Squaring the corners or missing the dimensions by a half inch will shift the performance centers by about 100 kHz at most. In most cases, you will not be aware of any difference at all.

Note that the antenna is just about 12.5' wide and under 5' front-to-back, for a turning radius of about 6'8" or so. Strapped up on the side of the house, the antenna is unlikely to overhang the neighbor's yard line. The antenna is light enough for hand rotating, but an old TV rotator might come in handy. Because of the antenna's characteristics, you may not need to rotate it much.



The pattern figure shows the optimal front-to-back ratio in azimuth patterns 20' and 35' antenna heights. Note the very broad forward lobe that is almost a cardioid, giving reception and transmission as wide as your peripheral vision. Behind you is silence--or at least a large dose of silencing. Les Moxon, G6XN, uses a wire version of the antenna with both elements remotely tuned: that way he works the world just by electrically reversing front and rear elements with a fixed mounting. If you want to learn more about the Moxon rectangle, find the Spring, 1995, issue of *Communications Quarterly*, and look at pages 55-70.

It is unlikely that anyone will ever produce this beam commercially, since it is a monobander without the super gain that avid DXers and contesters crave. You can only get that kind of performance from many Yagi elements. However, you can build your own compact antenna with a pretty good chance of success on the first try. It will beat a fixed wire dipole or a vertical hands down. So if you need a compact 10-meter beam for your compact home site, then you might roll your own version of the aluminum Moxon rectangle.

For further details on the construction of this antenna, see *The ARRL Antenna Compendium*, Vol. 6, pp. 10-13.

No. 28: Beta Coils and Hairpins

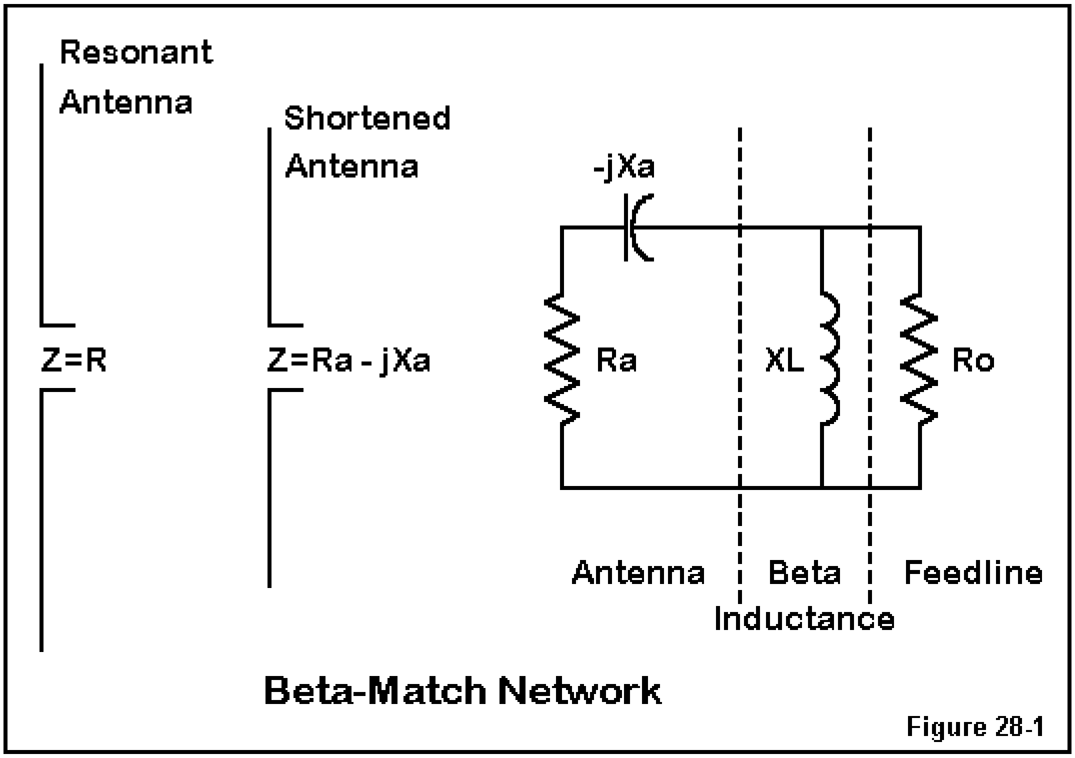
L. B. Cebik, W4RNL

In a number of columns, I have mentioned the beta match. Let's take a brief look at what it is and what it does.

The beta match appears to be simply a small coil or hairpin placed across the terminals of an antenna, most often a Yagi. Some folks mistake the coil for an RF choke, while others mistake the hairpin for a short circuit.

Actually, the beta coil or hairpin is one part of an impedance matching circuit, where the remaining elements are invisible, if you do not know what to look for. Many Yagi antennas have feedpoint impedances in the 20 to 35 Ohm range, somewhat low for feeding directly with coaxial cable. We need to raise the impedance to 50 Ohms--and that is what the beta match system does.

The coil is not the only element in the circuit. There is also a capacitor--or, more correctly, some capacitive reactance. We get that part of the circuit from the antenna element itself.



Beta-Match Network

Figure 28-1

Fig. 28-1 shows how we move from a resonant driven element to a beta match. Let the resonant antenna impedance be low, say about 25 Ohms. If we shorten the element, the resistance does not change significantly, but the antenna becomes capacitively reactive, as the middle part of the figure shows.

If we shorten the element by the right amount, we get the right capacitive reactance in series with the antenna resistance to go together with an inductance across the coil to make an L-circuit. An L-circuit is one of the fundamental impedance transformation circuits, and in this case, -Xa and XL together change the 25- Ohm antenna resistance to 50 Ohms.

We can calculate the needed values if we know the antenna feedpoint resistance (Ra). (We know the coax has a characteristic impedance (Ro) of 50 Ohms.) First we calculate a value called "delta" by some and "working Q" by others. Delta = the square root of [(Ro/Ra)-1]. Now we can easily calculate the necessary values of capacitive reactance in the antenna (- Xa) and of inductive reactance to place across the terminals (XL). Xa = Delta times Ra. XL = Ro / Delta.

Since these values are given as reactances, you need to convert the inductive reactance into a component value. The capacitive reactance will be developed by simply shortening the antenna element until the beta match gives us 50 Ohms.

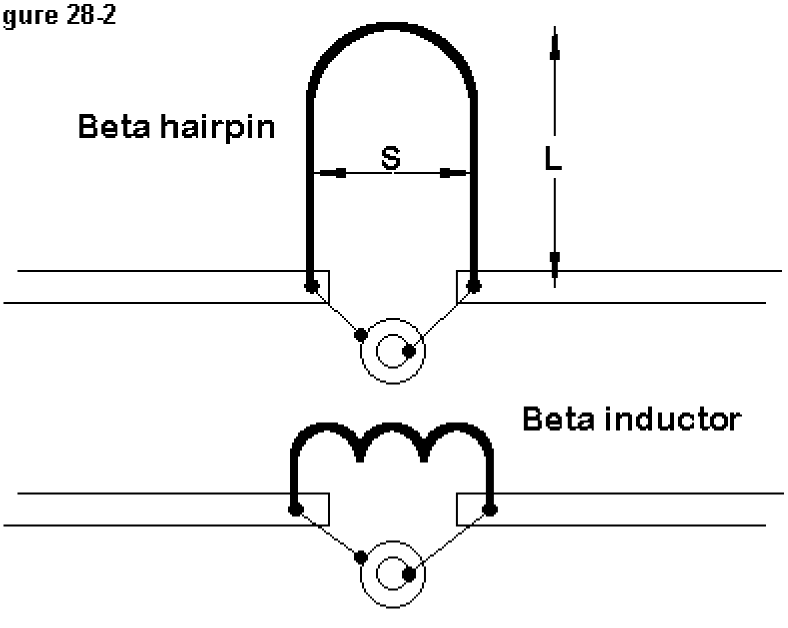
For reference, here is a small table of values we commonly encounter with beta matches with 50-Ohm coax for various values of antenna feedpoint resistance (Ra):

Ra	**33**	**25**	**17**
Delta	**0.7**	**1.0**	**1.4**
Xa	**23.6**	**25.0**	**23.6**
XL	**70.7**	**50**	**35.4**

Notice that the capacitive reactance reaches a peak when delta = 1, while the inductive reactance gets smaller as the feedpoint resistance gets smaller.

We have not yet converted these inductive reactances (XL) into a component value, because there are two distinct ways to achieve the required reactance across the coil. **Fig. 28-2** below shows them both:

Figure 28-2



Hairpin and Inductor Beta Matches

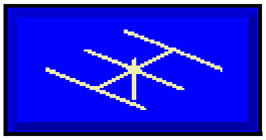
The beta inductor is simply a coil with the value of inductance that provides the inductive reactance at the operating frequency. If you divide the required inductive reactance by the product of the operating frequency (in Hz) and twice pi, you get the right inductance.

The hair pin version of the beta inductor is actually a small shorted stub of parallel transmission line. Rather than go through the calculation procedure, I shall simply once more recommend that you obtain a recent copy of HAMCALC, a suite of handy ham calculation programs in GW Basic. You can get a copy for $5 to cover disk and mailing costs from George Murphy, VE3ERP, 77 McKenzie Street, Orillia, ON L3V 6A6, Canada. Among the selections on the disk is an excellent program that will calculate the dimensions of a hairpin for the match. It was written by Thomas Cefalo, Jr., WA1SPI. The program will also tell you the equivalent inductance in case you want to wind a coil. Other programs in HAMCALC will help you wind an accurate coil.

Many antenna builders use the experimental technique of adjusting the driven element for a beta match. After calculating the beta coil or hair pin, they install it and then adjust the element length for a low SWR. Antenna modelers tend to determine the required element length in advance from their software and save some time fumbling for the right element length.

Either way, the beta match results in a very low loss match. For inductor Qs over 100 (easy to obtain, but some maintenance is required to maintain the Q), losses will be well under 1%--and even less for the hairpin.

If you like to build antennas, you should become familiar with the beta match. Some folks actually avoid the beta match because it is "too simple to really work." However, it does work, and very well indeed for antennas with moderately low feedpoint impedances. Since there are easy-to-use utility programs for calculating everything you need, there is no need to avoid either the beta match or antennas that require one.



No. 29: Some Larger 10-Meter Yagi Designs

L. B. Cebik, W4RNL

Occasionally, I am asked to recommend some larger Yagi designs that one might build for 10 meters. I can do little better than recommend the designs by Dean Straw, N6BV, that appear in the K6STI, Brian Beezley, program, YA, which has been distributed with The ARRL Antenna Book. In past columns, we have noted other designs originating from YA/YO. We have also featured various 2-element and 3-element Yagis of interest.

The present designs use 4, 5, and 6 elements. Each has been optimized for stable gain, front-to-back ratio, and impedance across the first MHz of the band. I have cross-checked each of them on other antenna modeling programs to confirm the numbers, and all appear to be very promising designs for the home builder.

The gain of a Yagi depends more on the boom length than on the raw number of elements. Therefore, each design will use a longer boom in conjunction with the increasing number of elements to achieve its objectives. Merely adding more elements within the same existing boom length will rarely produce any significant additional gain.

The element listings use a combination of 5/8" (0.625") and 1/2" (0.5") diameter tubing. Only one side of the antenna, relative to the boom, is listed, with the other side being a mirror image. Both the outer segment length and the total half-element length is listed for convenience. The smaller diameter element sections should be at least 3" longer than the lengths listed for insertion into the larger diameter element sections. All dimensions will be in inches. The decimals in the tables correspond the 1/8" increments of length.

The element assemblies are considered medium duty for maximum winds just over 90 miles per hour. For structural details of large Yagi construction, consult one or more of the many handbooks on antenna building. These beams are not casual projects, since they represent a considerable outlay for materials and result in large structures. Their weight may require a larger rotator and other improvements to your tower. Even the smallest of them should not be mounted on something so light as a telescoping mast.

4-Element, 14' Boom Yagi

Distance from Reflector	**Length of 0.625"**	**Length of 0.500"**	**Total (1/2) Element Length**
0.000	**36.000**	**70.000**	**106.000**
36.000	**36.000**	**63.875**	**99.875**
72.000	**36.000**	**62.250**	**98.250**

162.000	36.000	53.125	89.125

The mid-band free-space gain of this antenna is about 8.4 dBi, with an excellent (greater than 20 dB) front-to-back ratio.

5-Element, 20' Boom Yagi

Distance from Reflector	Length of 0.625"	Length of 0.500"	Total (1/2) Element Length
0.000	36.000	71.375	107.375
36.000	36.000	63.375	99.375
72.000	36.000	62.750	98.750
140.000	36.000	61.500	97.500
234.000	36.000	56.375	92.375

The mid-band free-space gain of this antenna is about 9.7 dBi, with an excellent (greater than 20 dB) front-to-back ratio.

6-Element, 36' Boom Yagi

Distance from Reflector	Length of 0.625"	Length of 0.500"	Total (1/2) Element Length
0.000	36.000	70.875	106.875
37.000	36.000	62.875	98.875
80.000	36.000	62.375	98.375
178.000	36.000	60.125	96.125
305.000	36.000	59.250	95.250
426.000	36.000	55.250	91.250

The mid-band free-space gain of this antenna is about 11.6 dBi, with an excellent (greater than 20 dB) front-to-back ratio.

All of these antennas have feedpoint impedances that are designed for a beta or similar matching system. The resistive part of the impedance is in the low-20s, with a comparable amount of capacitive reactance. You may lengthen the driven elements to resonance without adversely affecting antenna performance. A resonant driven element of about 25 Ohms can be matched to a 50-Ohm coaxial cable with a quarter wavelength section of 35-Ohm coaxial cable. Such cable can be purchased for about $3.00 per foot. You may also fabricate a satisfactory line using parallel lengths of 75-Ohm cable with the braids and the center conductors each soldered together at each end.

The smallest of these monoband 10-meter beams will generally outperform the 10-meter section of all but the very largest tri- banders. The longest of the beams is a serious DX-hunting machine. To obtain the maximum performance from any of these beams, place them at least 1 wavelength above ground and preferably closer to 2 wavelengths.

Installing large beams at considerable heights above ground is not a casual process. First, there may be zoning and other legal restrictions or permissions to consider. Second, proper tower installation may cost many times more than the materials in the beam. Safety for yourself, your family, your property, and your neighbor's property are of paramount importance. So too is durability of the performance of the whole system, including the tower, coax, rotator, guys, grounding system, and the antenna.

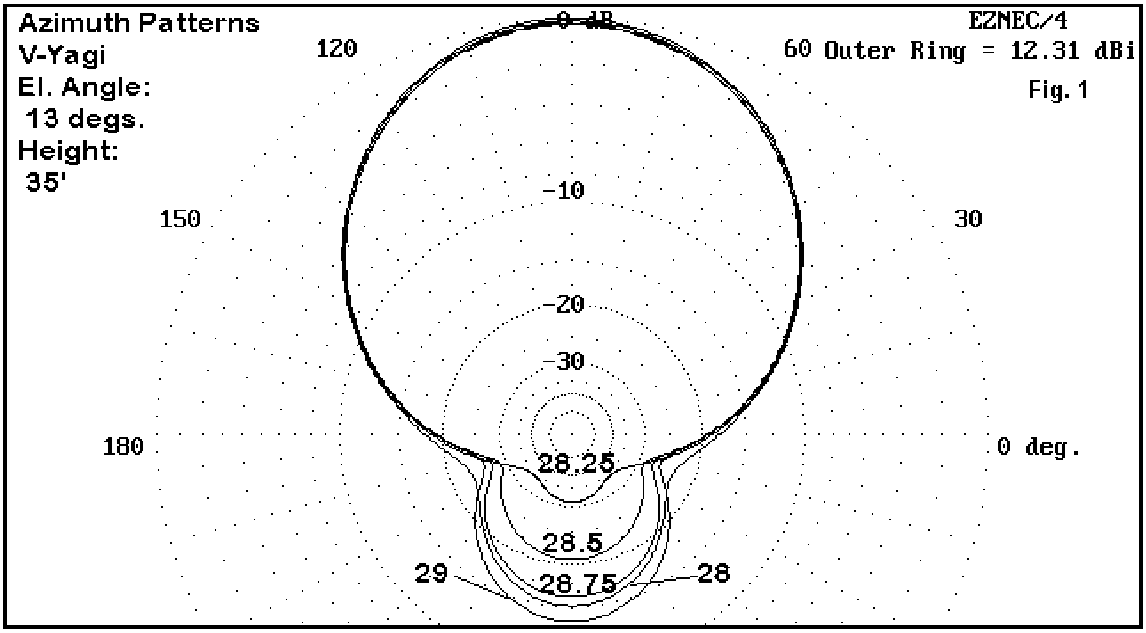
Before moving to large beams and complex tower installations, learn all that you can about every aspect of the task. If you have any doubts, consult professional tower installers for answers and for help. Do not violate or ignore applicable laws and ordinances. Do not settle for any installation that does not measure up to good engineering standards. And, for heaven's sake, do not rely on luck to keep your antenna in the air and lightning in someone else's yard.

As you can see, a big antenna--even for 10 meters--is only the beginning and not the end of a much larger enterprise. If you have all the other pieces in place, then one of the N6BV designs may be the answer to the antenna part of the puzzle. Other designs, some with feedpoint impedances in the 35 to 50 Ohm range are also available from various ham magazines. Collect lots of designs and ideas before you start cutting aluminum. The more design articles you read, the more you will learn about the art of building big beams.

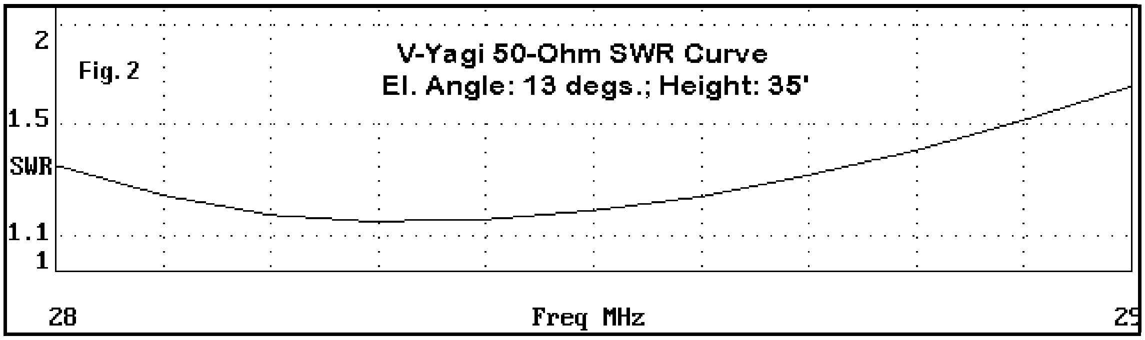
No. 30: The V-Yagi

L. B. Cebik, W4RNL

In May, 1998, QST, NW3Z and WA3FET published an interesting 3-element beam for 40 meters, using one tubular element and two wire elements. The result was a light weight (for that band) beam with excellent SWR and F-B characteristics. It superficially resembled an old design by Dick bird, G4ZU, but had been optimized for performance resembling that of a Moxon rectangle: great F-B ratio, wide pattern forward, and direct coax feed. However, with an extra element, it had more gain. Why not adapt the design to 10 meter?

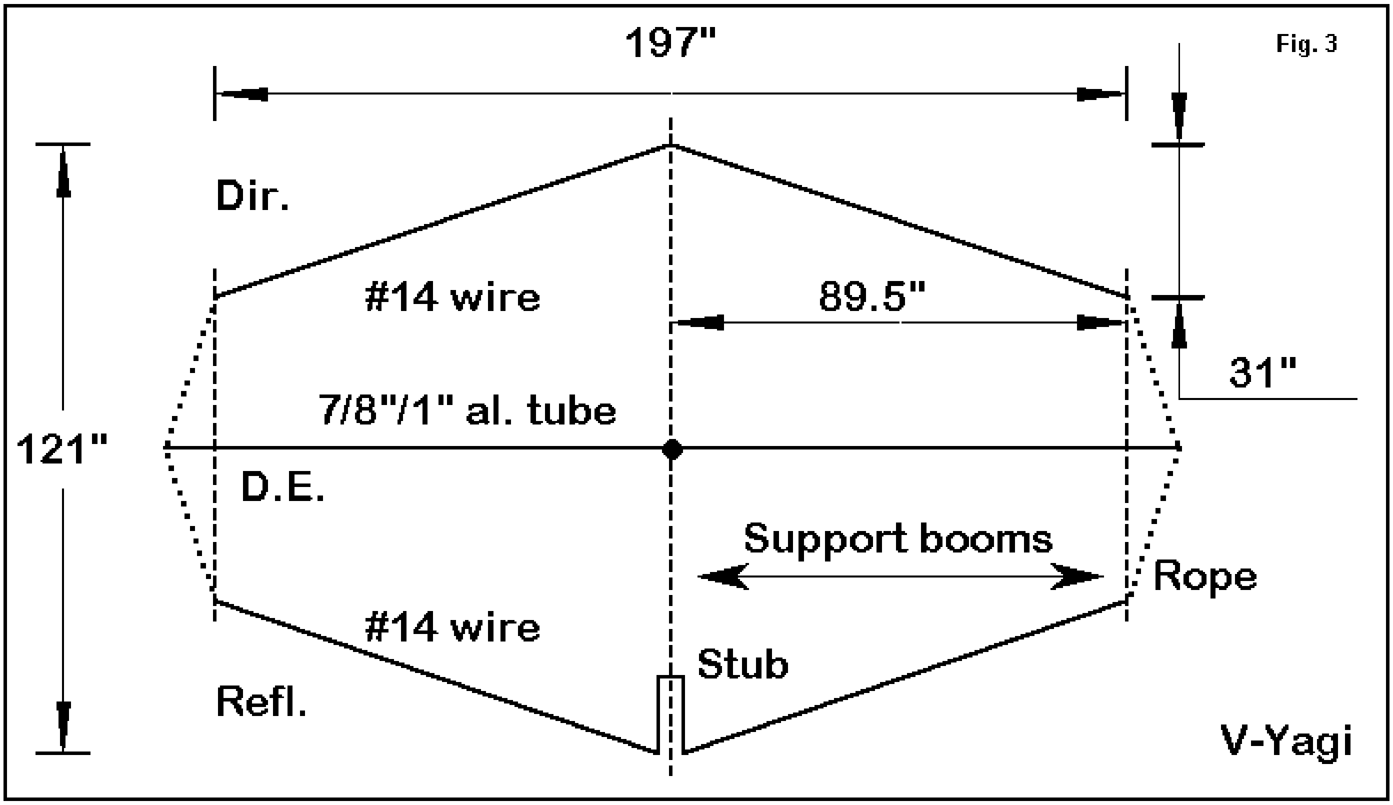


As Fig. 1 shows, the adapted antenna for 10 meters has decent gain and good front-to-back ratio across the first MHz of the band. The patterns are taken with the antenna modeled at 35' (1wl) up.



The SWR curve strongly suggests that direct coax feed is certainly in order. As always, I recommend a choke balun at the feedpoint.

Now that we have seen what the antenna can do, all we need to know is what the antenna looks like and how hard it might be to build. Like all Yagis, it will have significant side-to-side and front-to-back dimension. However, unlike the usual Yagis, only one of the elements will be made from aluminum tubing, while the other two will made from #14 AWG copper wire.



As the sketch shows, the driven element is the longest part of the antenna. Overall, it is 197" long, with a insulated mounting plate to permit direct connection of the feedline to the element. The inner parts of the element are 48" lengths of 1" diameter hardware store aluminum, while the outer ends are made from 7/8" diameter tubing from the same source.

The dashed lines crossing the driven element are booms to support the wire elements. They can be made from fiberglass or aluminum, with the center boom stronger, since it is about 12' long. The end support booms can be lighter, but need to support the wire ends. If the end booms are made from aluminum, they should be insulated from the driven element and set farther outward, so that the wire elements can terminate at an insulator. Simple UV resistant rope (3/16" diameter) connects the wire and end-support boom to the driven element ends, which helps prevent the wires from loading the end supports too much.

The wires are each 94.4" long from the center boom to the end (at an insulator or at the support boom). At the ends, they should be between 30 and 31 inches from the driver. Since both wires are the same length, we need to load one of then to electrically lengthen it to become a reflector. A shorted transmission line stub about 65.55ï¿½ long will do the job, although you may want to adjust the exact length when tuning up the antenna. The length in degrees translates into 50.125" of RG- 58/RG-8 (velocity factor 0.66) line. You can use standard stub equations to calculate the length of 300-Ohm or 450-Ohm line as a substitute.

The V-Yagi will not give all of the gain that a 12' boom is capable of giving if the elements were linear and fatter. In fact, this antenna is about 1 dB shy of maximum gain for the boom length. On the plus side of the ledger, the antenna is quite light, study, and has a smaller turn radius, since the corners are shortened by the slope of the director and reflector wires. A TV rotator should turn the beam with ease. However, you may not have to turn this beam as often as you might have to turn a standard Yagi, since the beam width is quite a bit wider.

The V-wire for 10 meters is not for everyone, not even for every addict of home brew antennas. However, I have learned over the years that different folks have different needs, different skills, and access to different materials. So I never try to prejudge what mechanical designs are acceptable and which are not. That would limit folks to only my own level of construction ability. Instead, I pass along ideas for designs, and let those who can make good use of them have at it. Others can pass up this design, hoping for a more suitable one in the next column.

Over the past 7 years or so, we have looked at a lot of antenna idea. And yet, we have only scratched the surface.

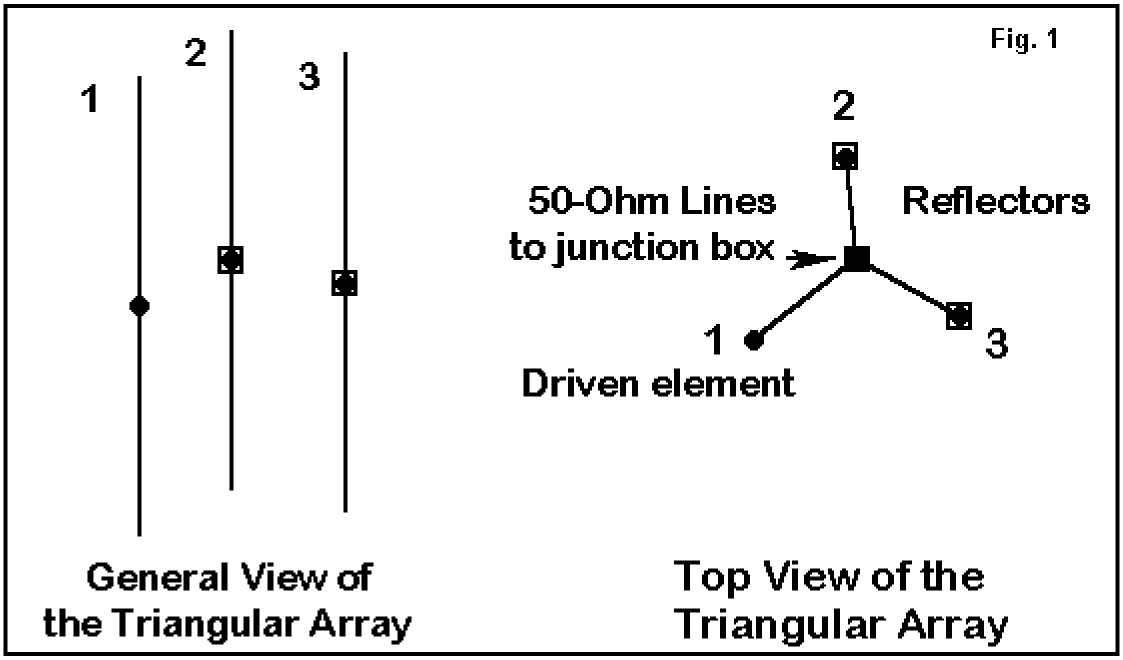
No. 31: A Triangular Vertical Array

L. B. Cebik, W4RNL

Most beams we have discussed have been horizontal. I have not wanted to neglect fans of vertical antennas, but good designs that are not just horizontal antennas flipped 90 degrees are not easy to find.

In some areas, the local gang use vertical whips and mobile antennas. Skip contacts do not care what polarization your antenna uses, since the ionosphere skews the polarization of the original signal. So the question is whether we can find a decent vertical antenna that will serve both local and distant needs.

Well. . .how about a set of 3 vertical dipoles that require no rotator and only a simple weather sealed box with some relays inside. With a flip of a switch, you can cover the entire horizon in three broad lobes with little if any gap in coverage. The gain will not rival a long-boom Yagi, but the antenna array will give some gain and very decent a front-to-back ratio, with a direct coax feedline connection.



Let's start with three vertical dipoles, each 15.6' long made of 3/4" hardware store aluminum tubing. See **Fig. 1**. We shall set these up in an equilateral triangle 8.6' on a side (1/4 wavelength). If we run a mast up the middle of the array, we can use PVC or other means of supporting the vertical at just about their center points, leaving the feedpoint separation free for connections. The arms for such a system would have to be just about 5' long from the center mast.

Next, we shall cut 4.97' (yes, 5.0' is OK) lengths of RG-8 foam or RG-58 foam coax. We must use the foam type to get the right velocity factor (0.78) so that the lengths are electrically correct. Each line goes from one feedpoint to a central waterproof junction box. The coax from the shack and a 12-volt DC line also enter the junction box.

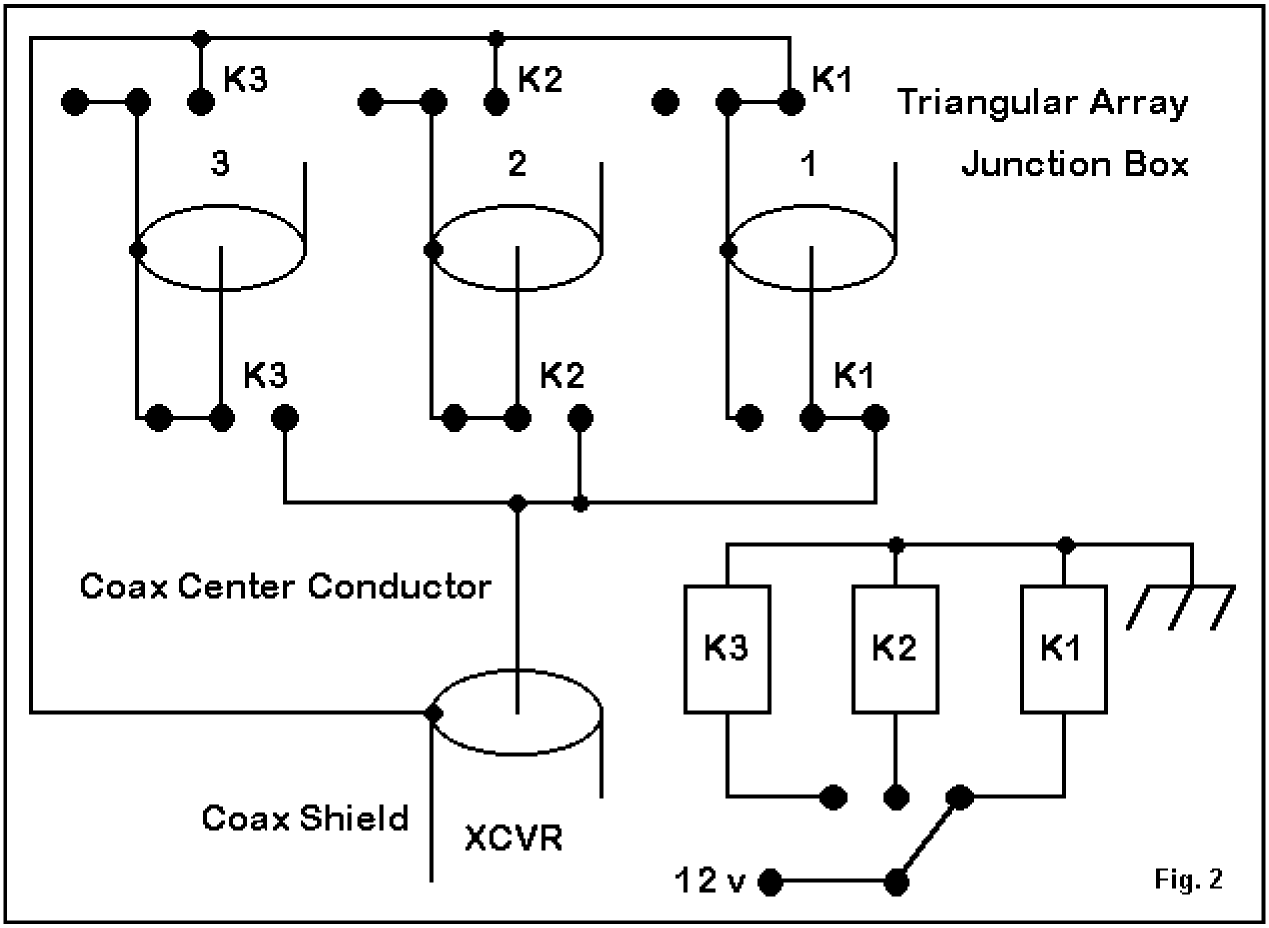
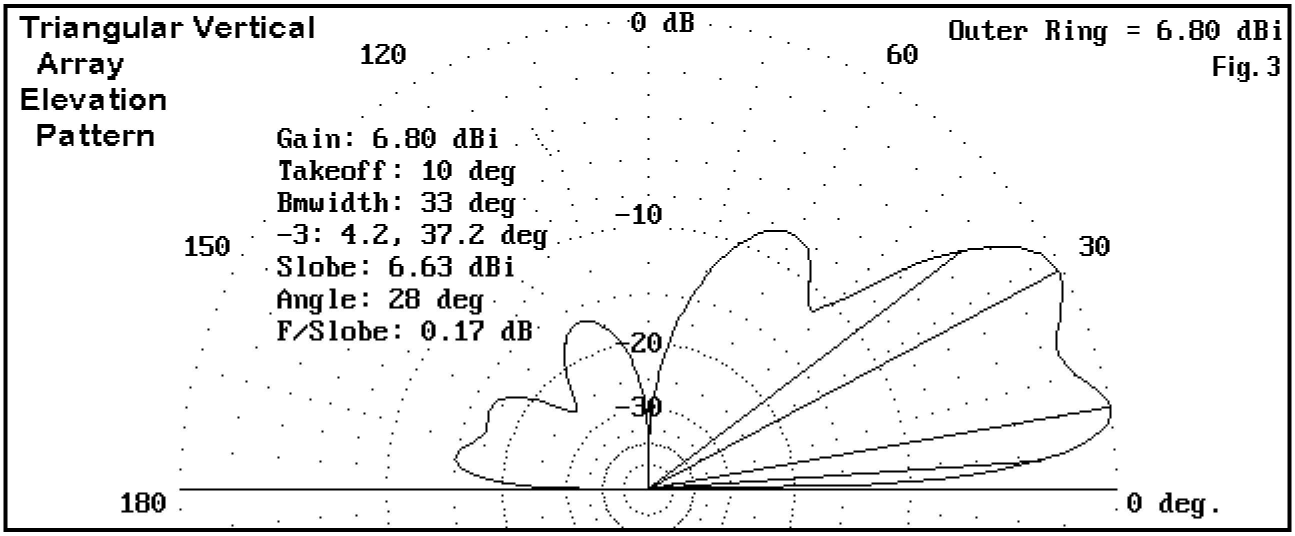


Fig. 2

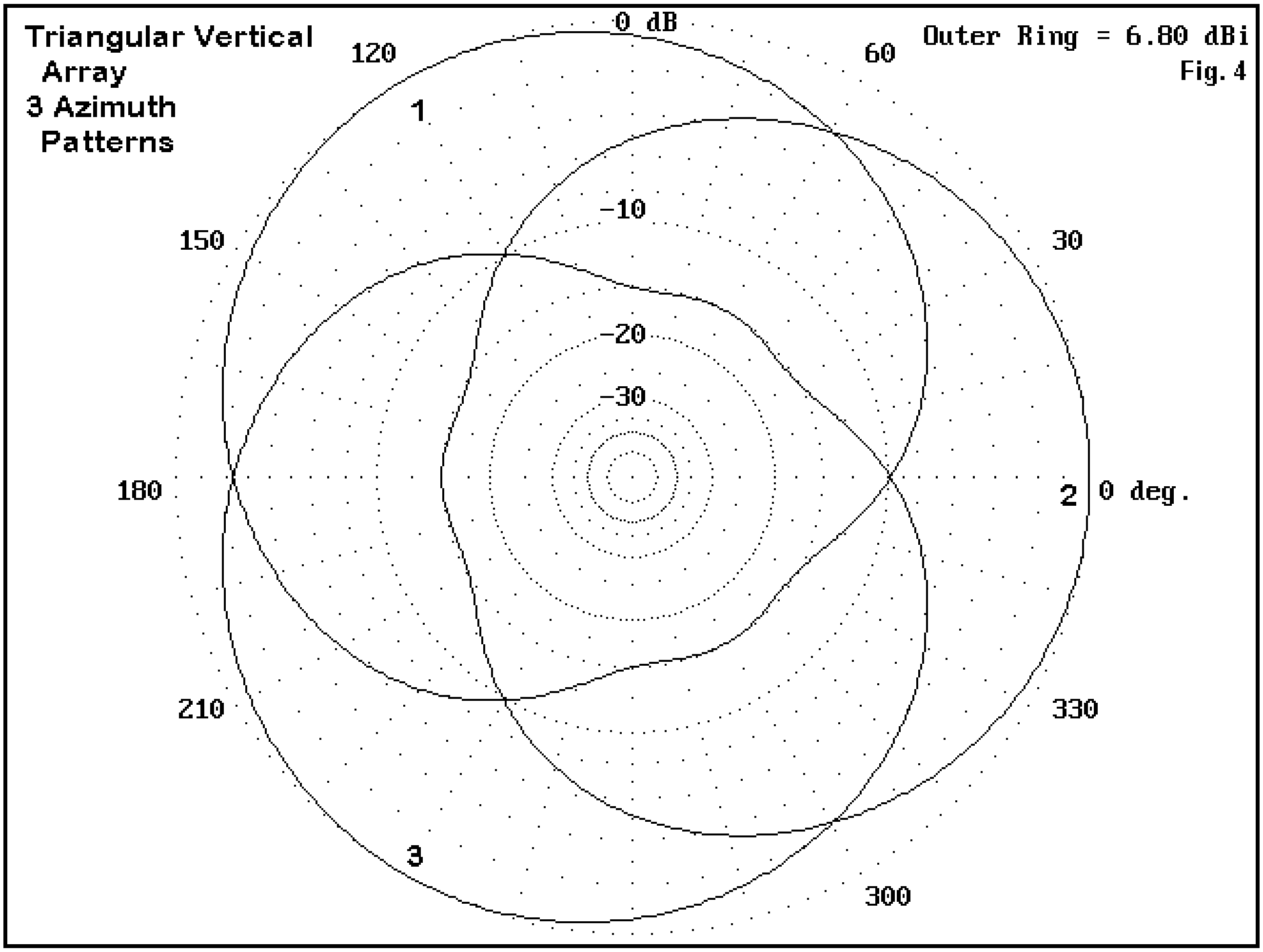
The schematic diagram in **Fig. 2** shows the hook-up for 3 DPDT 12-volt relays in the box. (The switch is shown in the box, but it will be in the shack.) As we change positions on the switch, we activate one relay, moving the connectors so that the center of the coax from one antenna goes to the RF cable and the shield goes to the shack coax shield. The inactive relays let the coax from the other two antennas simply be shorted out.

The shorted lengths of coax are stubs that electrically lengthen the other two antenna elements so that they work better as reflectors. Now we have 2 reflectors and one driven element in a vertical array.



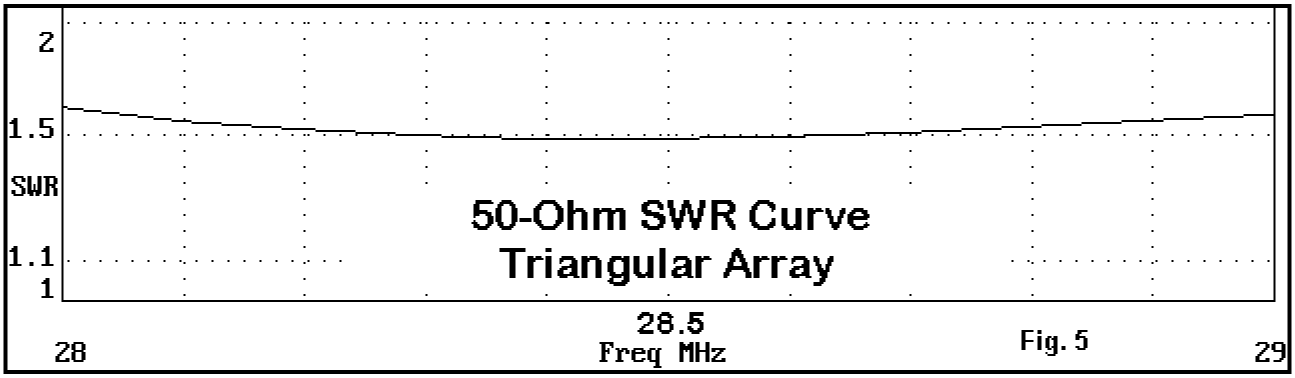
The elevation pattern created by this system and shown in **Fig. 3** gives us a low angle pattern, good for both local and dx contacts. The front-to-back ratio varies between 12.5 and 15 dB across the first MHz of 10 meters. The gain is very usable, but not world beating. However, remember that we saved the cost of a rotator with this array, and we can work the vertical locals with ease.

In addition to all having gain and appreciable front-to- back ratio, we can cover the entire horizon just be changing the switch position. The switch simply converts one element from a reflector into a driven element, changing the overall heading of the array. The beamwidth of a vertical antenna is very large--well over 120 degrees between -3 dB points. Hence, three headings are enough to cover the world.



The composite azimuth patterns in **Fig. 4** give you a good idea of how large the beam width is and how good the overall coverage is. If you construct the basic support system well enough, you will have an antenna with no moving parts other than the relays in the box. Servicing a relay at the top of the tower is easier than servicing a rotator.

The array can be fed directly with coaxial cable, as the SWR curve in **Fig. 5** shows.



All of the figures shown are modeled with the antenna at 35' at its center. The higher, the better, but the antenna will still work quite well with its lowest point at least 20' off the ground.

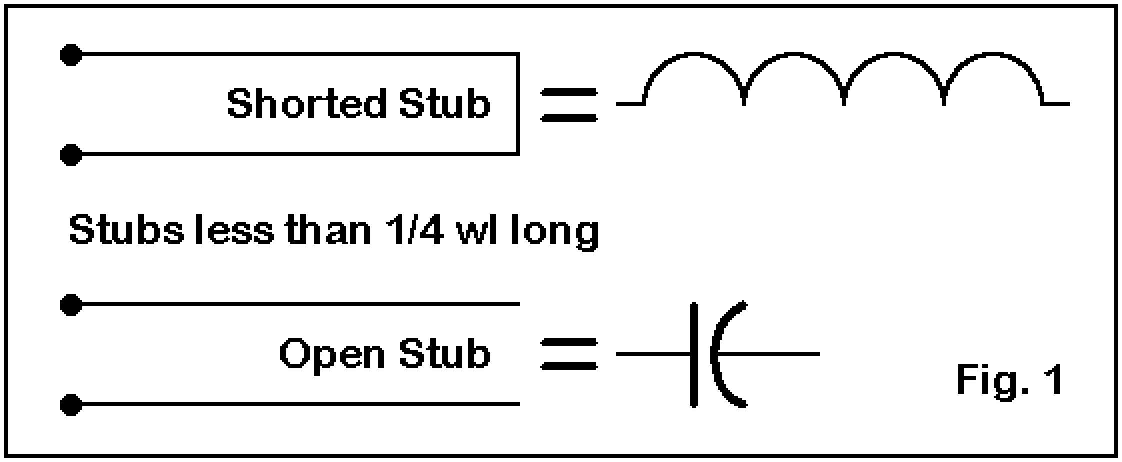
Verticals acquit themselves very well on 10 meters, and this vertical array will add some directional gain and some QRM nulling. Relative to a beam, the cost will be low, and the maintenance should be easy. Possibly, it is time to think vertical.

No. 32: What the Heck is a Stub?

L. B. Cebik, W4RNL

Some of the antennas we have looked at in these columns have used transmission line stubs. I often receive this question: "Just what is a stub and what does it do?" So let's look at stubs. To keep things simple at the beginning, we shall confine ourselves to stubs shorter than a quarter wavelength.

The Basic Principle



A shown in **Figure 1**, a stub is a length of transmission line. When the line is shorted at the far end, it acts as an inductive reactance and can actually replace a coil. When the far end is open, the stub acts as a capacitive reactance and can replace a capacitor. Stubs would be too large to use in HF circuits, but they are convenient in antenna applications, where space is usually no problem. They can handle high voltages and currents, often with greater ease and cost-effectiveness than lumped components.

The amount of inductive or capacitive reactance is proportional to the length of the stub. However, the relationship is not linear. Let's look at how we calculate the reactance of a shorted stub to see why.

$$X_L = Z_O * \tan L_d \qquad (1)$$

where X_L is the inductive reactance in Ohms, Z_O is the characteristic impedance of the transmission line used for the stub, and L_d is the length of the line in electrical degrees. since we are using lines shorter than 1/4 wavelength, L_d will be between 0 and 90 degrees.

For the same value of reactance, the higher the Z_O of the transmission line, the shorter the line length. Hence, parallel transmission line is often used for inductive stubs to save space. Since the tangent of angles above 45ï¿½ grows larger very fast, we usually restrict ourselves to modest value of inductive reactance so that we can prune the line length precisely without overshooting the mark.

Shorted stubs for inductive reactance are more common than open stubs for capacitive reactance. The reason is easy to see from the formula.

$$X_C = \frac{Z_O}{\tan L_d} \tag{2}$$

where X_C is the capacitive reactance in Ohms and the other terms have the same meaning as in the earlier equation. Smaller values of capacitive reactance (the most common need) require longer transmission line stubs. While some applications call for open stubs, shorted stubs for inductive reactance are far more common.

Application #1

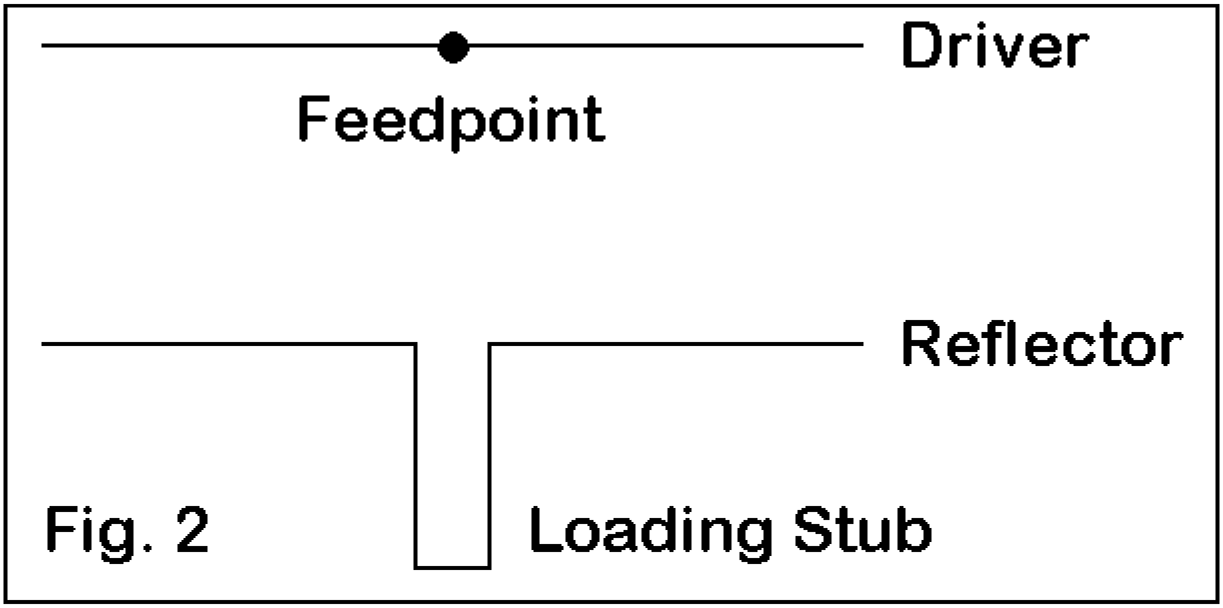


Fig. 2

Figure 2 shows one common use of shorted (inductively reactive) stubs: to load an antenna element to make it electrically longer than its physical length. We know that a Yagi reflector is longer than the driven element, but in the figure, they are the same physical length. The load value of X_L is 85 Ohms to make the reflector work like an element somewhat longer than the physical length would permit. Now we can place a coil in the load position. At 28.5 MHz, a coil of 0.47 microH would do the job, but its resistive losses might be of concern. Short stub losses are nearly negligible, so let's use a stub instead.

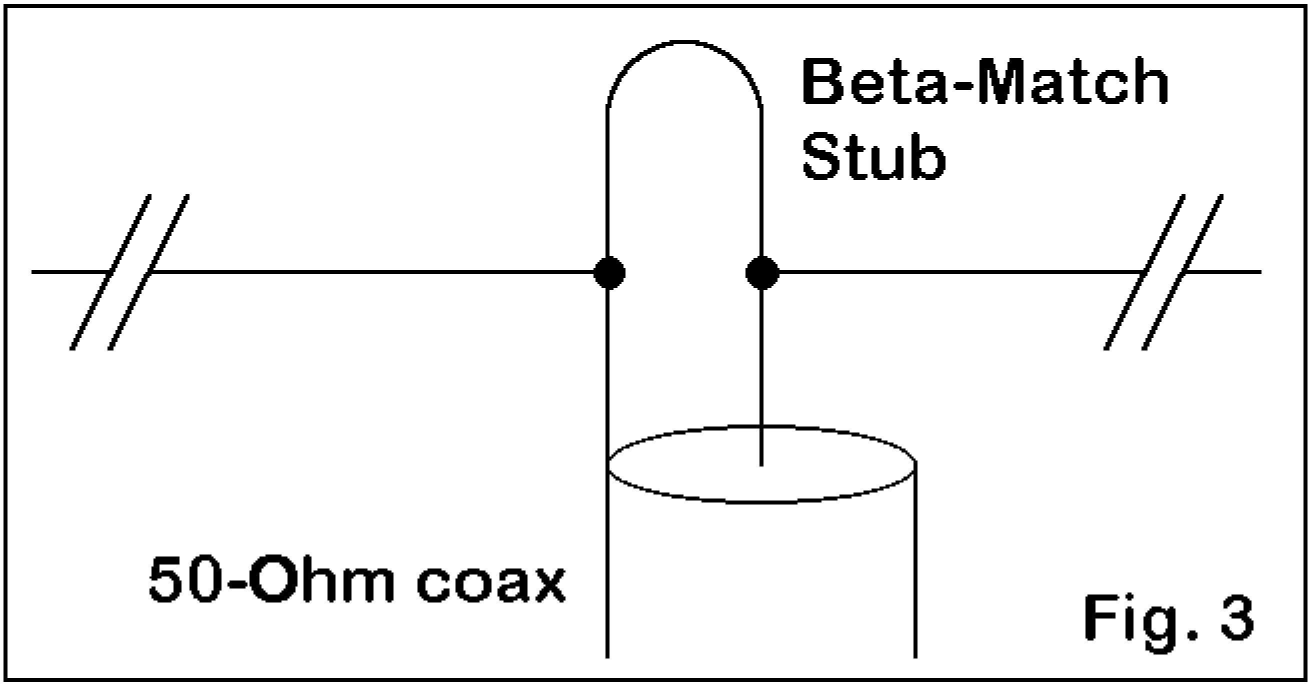
At the given frequency of 28.5 MHz, a shorted stub might be made from either RG-58 (50 Ohms, 0.66 VF coaxial cable) or parallel transmission line (for example, 450-Ohms, VF 0.95). The first step is to take the ratio of X_L and Z_O. For 50-Ohm cable, this is 1.7, and for 450-Ohm line, it is 0.19.

The second step is to figure the length in degrees. The "arctan" (backing out the degrees when you know the tangent of an angle) of 1.7 is 59.5ï¿½, while the arctan for the 450-Ohm line is 10.7ï¿½.

Now let's figure the real line lengths needed. First, we know that a wavelength at 28.5 MHz is abut 34.5' long for a full 360ï¿½. 59.5ï¿½ means a 5.71' length. 10.7ï¿½ is 1.025' long at the same frequency.

However, remember that the actual transmission lines had VF (velocity factor) values. The coax value means that its length needs to be 0.66 times the calculated amount, or 3.77' (45.22"). The parallel line had a VF of 0.95 and thus needs to be about 0.97' (11.7") long. Personally, I would use, if possible, the 450-Ohm line, since it is shorter, lighter, and easier to handle. But that is not the right decision for every situation.

Application #2



Some antennas use a beta match system, which requires an inductive reactance across the antenna terminals so that an antenna with a low impedance can match a 50-Ohm coax system, as sketched in **Figure 3**. Although coils are quite effective, most commercial beta matches use a "hairpin." The hairpin is nothing more than a U-shaped piece of wire, which is itself nothing more than a shorted parallel transmission line.

Using standard equations for L-networks we can calculate the inductive reactance we need to place across the coil. If the antenna has an impedance of 25 Ohms, then the required reactance is 50 Ohms. We can make a hairpin from our 450-Ohm transmission line, using the same procedure. 50/450 = 0.11. The arctan of this number is 6.34ï¿½. This number of electrical degrees amounts to 0.61' (7.29") at 28.5 MHz. If the VF is 0.95, then the final length is 0.58' (6.93").

For both applications, we would start with lines a little long and prune them to exact length. We can do this by having an adjustable set of contacts at the terminals or we can trim the shorted end and resolder the shorting bar.

The math in this exercise is mostly to acquaint you with the general properties of stubs--which call for shorter lengths and which call for longer. Those inclined to do so can calculate a bunch of 10-meter stubs to see what the lengths look like for various values of X_L and X_C and different types of transmission line. Then when you encounter stubs in articles, presence and general dimensions will be familiar to you.

The antenna array we discussed in the last column used stubs in the reflectors. I'll bet the next column also has a stub.

No. 33: The Cheapest 2-Element Beam?

L. B. Cebik, W4RNL

"Can I build a small directional antenna for less than $20?" That was the challenge presented to me. The answer is yes. However, remember that this is a project designed for the dollar sign, so the gain and directivity will be modest. Here is what we need:

- 32' #14 copper wire (Radio Shack and elsewhere)
- 15' 2x2 (good quality)
- 7' 1x2 or similar size Schedule 40 PVC
- 1' 450-Ohm parallel feedline
- SO-239 coax connector
- Boom-to-mast bracket/hardware

The antenna is a 2-element wire parasitic beam with the ends tapered back toward each other. The elements are the same physical length, but the reflector is stub loaded to increase its electrical length. (See the last column for information on stubs.) Gain is about half an S-unit over a dipole, and the front-to-back ratio is about 2 S-unit. Feed is a direct coax match, and coverage is about 900 kHz of 10 meters.

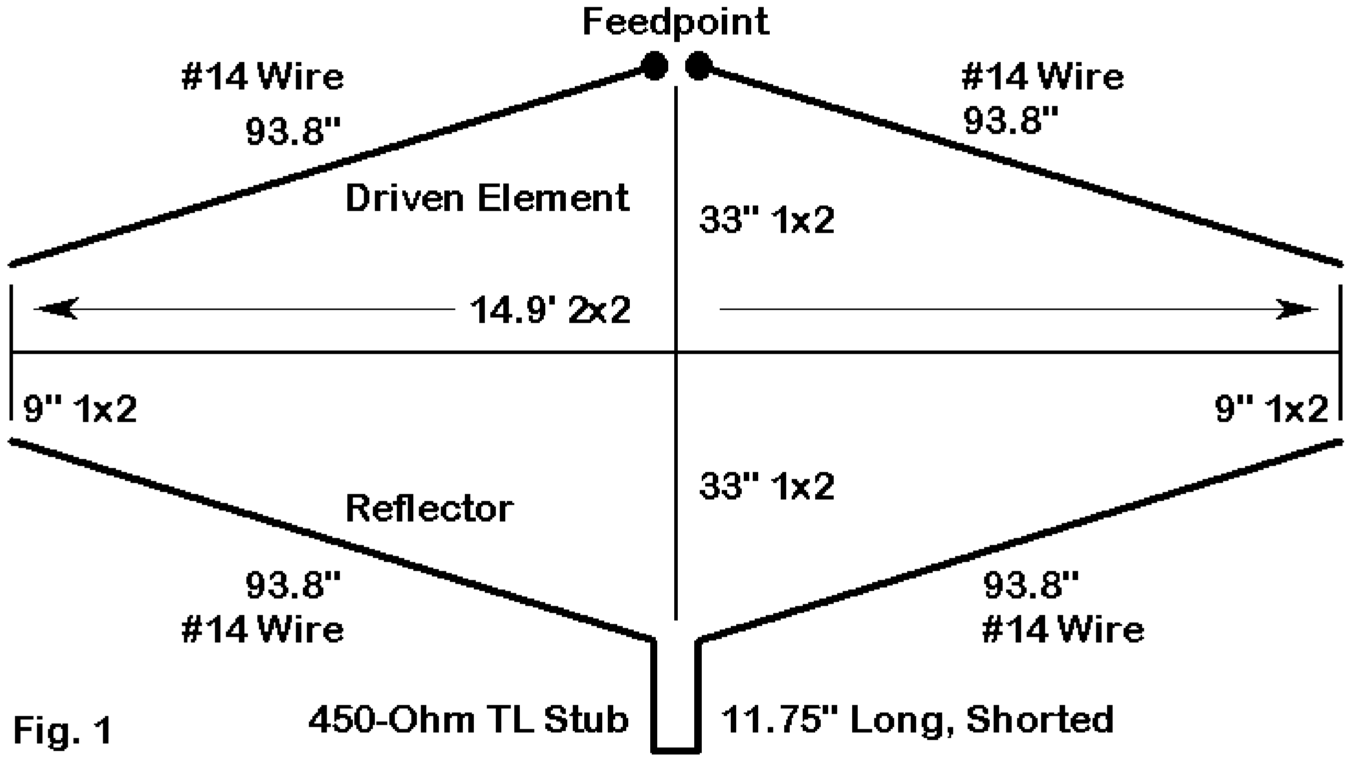


Fig. 1

Figure 1 shows both the wire and support frame dimensions. The 2x2 determines the side-to-side dimensions, while the cross piece determines the maximum front-to-back dimension. The end cross pieces keep the wire ends 9" apart.

Use a good marine (spar) varnish (or modern poly equivalent) on all wood. Expect to re-varnish the wood annually. Be sure the 2x2 does not sag a lot. The cross pieces can be PVC or 1x2. If wood, give it the same spar varnish treatment.

Details of coax connector mounting, wire termination, and mast support are subject to many variations, so I shall bypass them here. Check with any handbook for many different ways to achieve the same goals. Likewise, mast details are omitted here.

The figure shows the stub dangling, but you can tape it to the center cross piece. Not shown is the 1:1 choke balun at the antenna feedpoint that I use on all antennas to reduce RF on the outside of the coax to the shack.

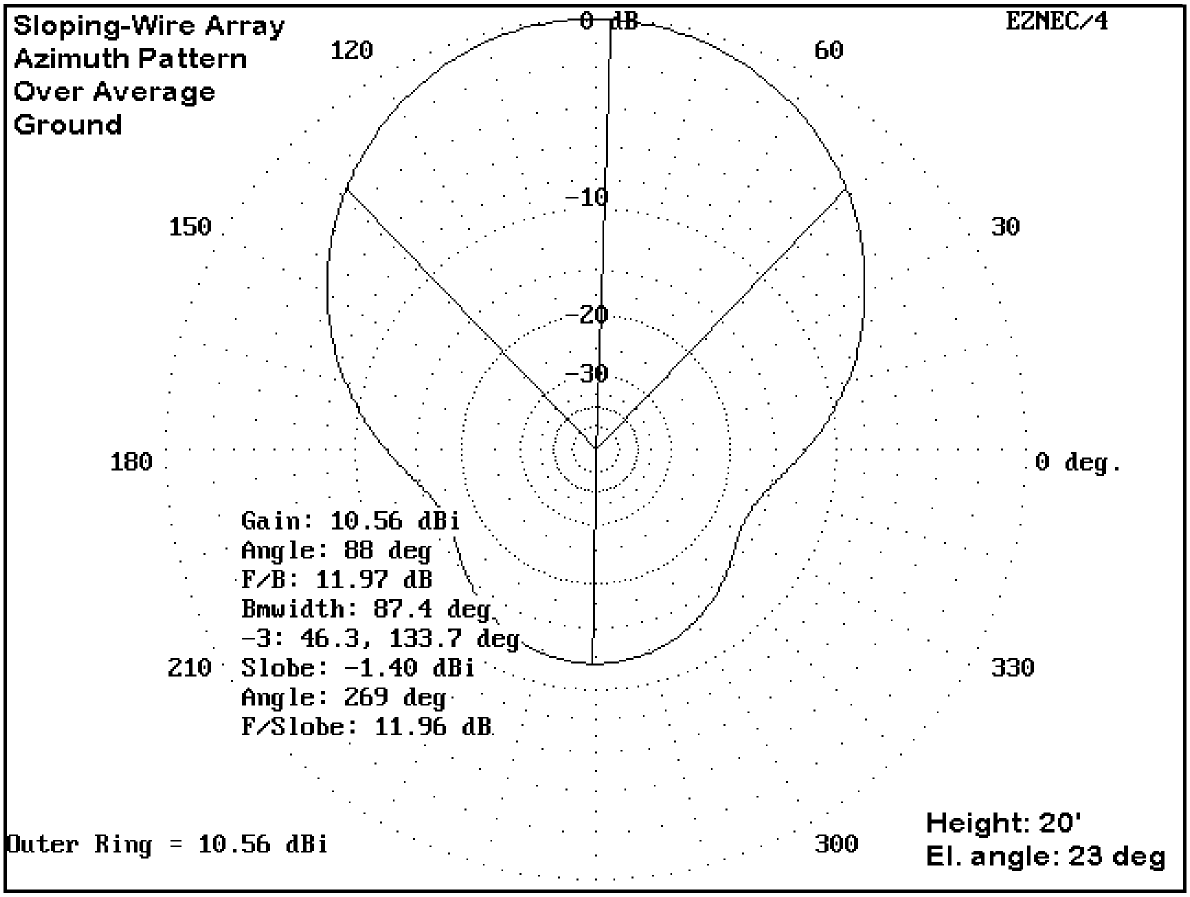


Figure 2 shows the azimuth pattern with the antenna at 20' over average ground. 20' is the height of two sections of TV masting, which makes an adequate support system for hand rotating the beam. Whatever system you use to elevate the antenna (which I shall assume is as inexpensive as the antenna itself), be certain that the mast is well guyed or bracketed for safety.

The antenna pattern is not a paragon of gain or rear nulling, but it does have some nice features. The forward beamwidth is wide enough so that a single twist of the mast will cover all of Europe or all of the VK-ZL area--or from each of these places, a single setting will cover all of the USA and Canada. The rear has only one lobe, so that there are no antenna positions susceptible to QRM from some quartering rear direction.

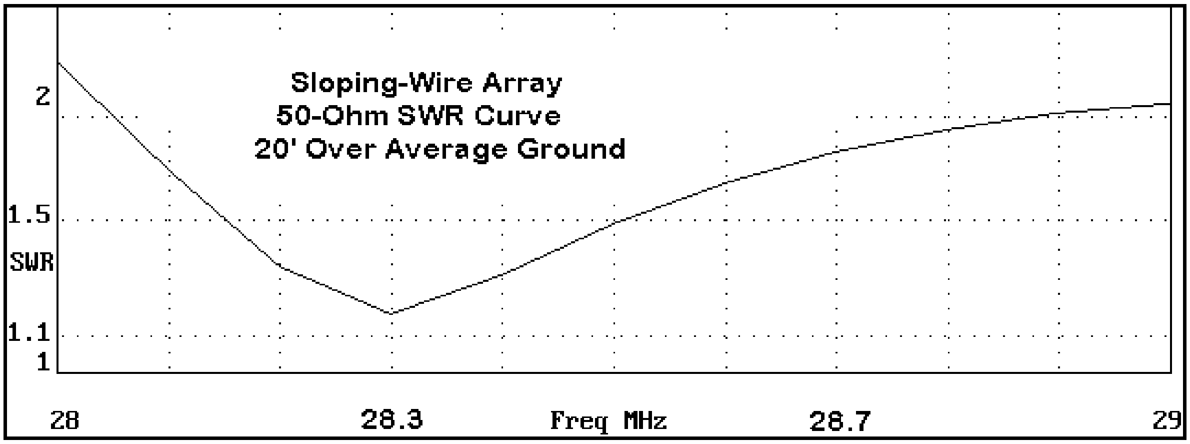


Figure 3 is the modeled SWR plot across the first MHz of 10 meters. The antenna was designed for 28.35 MHz to provide a low SWR for the most popular segment (28.3 to 28.5 MHz). You can shift the SWR curve downward by increasing the length of both wires equally about 2" or so--or shorten them by the same amount to move a bit up the band. However, keep the wire end separation at the prescribed 9" with the end cross pieces.

The antenna is related to the standard Yagi, although the elements are not exactly parallel. The element end coupling also relates the design to the Moxon rectangle, but the sloping wires prevent us from achieving the high front-to-back ratio of that design while still having any forward gain worth using.

So while the performance is modest, the price is attractive. The sdloping wire array is a fun antenna to play with, since the cost is so low. However, the most important aspect of the design is that in an emergency--perhaps after some natural disaster has knocked down all of the regular antennas--this design can be fabricated from scraps from the rubble. You can make the electrical elements from house wiring that is no longer functional and lash together a frame with bailing wire.

If you have no inclination to play with the design at this time, you may wish to file this column away in your notebook labeled "In the event of emergency or disaster. . .."

No. 34: The Turnstile Antenna on 10

L. B. Cebik, W4RNL

Net control stations often ask for an omni-directional horizontally polarized antenna. One of the simplest antennas to meet this need is the turnstile. The basic outline appears in **Fig. 1**.

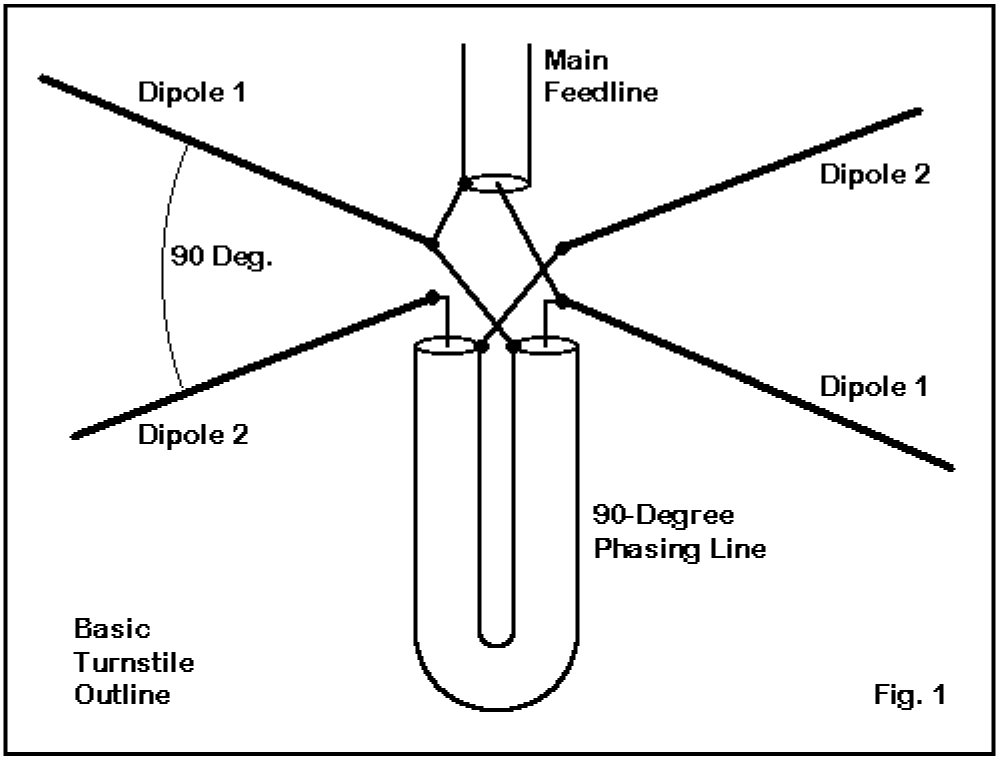


Fig. 1

Essentially, the turnstile consists of two dipoles at 90 degree angles to each other. One dipole is connected to the main feedline, in this case a 50-Ohm line (since the two dipoles together will give a 36-Ohm feedpoint impedance). Between the feedpoint of Dipole 1 and Dipole 2, we run a 90-degree or 1/4 wavelength section of 72-Ohm coax to effect the required phase shift between the two dipoles. It is this phase shift that gives the turnstile its nearly omni-directional pattern.

For 1/2" to 5/8" tubing--or a combination of the two--the dipoles can each be 16.5' long--8' 3" on each side of center. This size will make them resonant at about 28.5 MHz. The dipoles must not touch each other. You can accomplish this by mounting them on opposite sides of a square plywood board or by keeping the feedpoint separations large enough so that nothing touches.

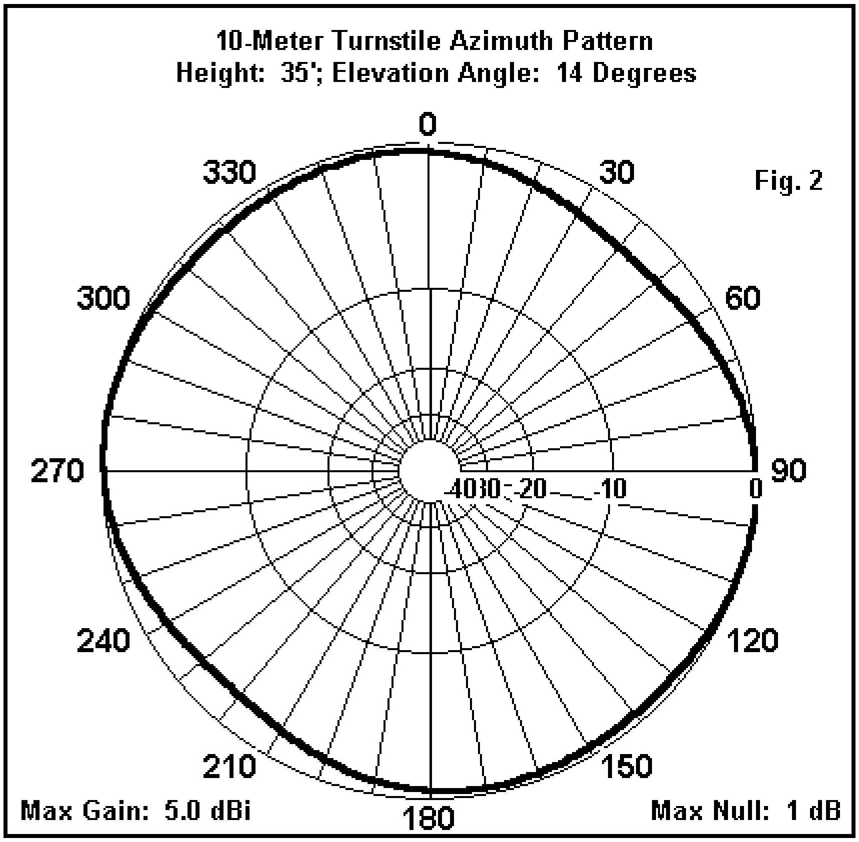
Connect the main feedline across one dipole. Then connect the phasing line from the feedline connection points to the other dipole connection points. If you use a balun, connect it only to the main feedline. Let the phasing line droop. You can tape it together for control. But it is best to keep it spaced from any metal antenna mast you use to support the antenna.

The phasing line length will depend on the velocity factor of the line you use. 72-Ohm coax comes with either solid or foam insulation. The solid insulation usually gives the line a 0.66 velocity factor, while foam lines have a velocity factor of about 0.78.

Use the velocity factor as a multiplier on the basic 1/4 wavelength to determine the physical length of the line. 1/4 wavelength is about 8.63' at 28.5 MHz. A 0.66 VF line will be about 5.69' long, while a 0.78 VF line will be about 6.73' long. As with any antenna, be sure to weatherproof all connections to prevent rain from entering the coax line.

Since the turnstile impedance is about 36 Ohms, a 50-Ohm feedline will show an SWR of between 1.3:1 and 1.4:1. Do not try to tune the antenna for a 1:1 SWR, since that will require shortening the elements below individual dipole resonance. The resultant pattern will no longer be omni-directional. On the other hand, once you have built the antenna close to the dimensions suggested here for both the elements and the phase line, it will be very broad-banded, covering all of 10-meters.

What kind of performance can we expect from a turnstile. **Fig. 2** gives us an answer.



The pattern is a blunted circle with only a 1 dB decrease from maximum gain along two of the flattened edges. This is as close to a perfect circle as you will come with a horizontally polarized antenna of this efficiency. The maximum gain is about 5 dBi when the antenna is 1 wavelength (about 35') above ground. At this height, the antenna has 2 elevation lobes, one at 14 degrees for long hauls and the other at 48 degrees for short skip and e-layer reflections. The local point-to-point abilities of this antenna are quite good.

As always with horizontal antennas, the higher, the better--up to about 1.75 wavelengths or so--especially for local contacts. The turnstile gain is lower than the maximum gain of a dipole along, but remember that a single dipole has only two main lobes working at one time. The turnstile has 4 overlapping lobes. Since the power for any operation is constant, it must distribute itself over more territory--and hence will not be quite as strong as when we can limit its coverage to two lobes. (The uni- directional beam gets its gain from concentrating almost all of the power in one lobe.)

The turnstile can be a useful antenna for net control stations. It may also be useful for folks who want a dipole, but do not wish to turn it with every new incoming signal. You can orient the antenna along any axis, so you have some options in fitting it into the space you have.

However, the turnstile has limitations. For its area, gain is not high. In the same footprint, you can create a small 3-element beam with much higher gain and directivity. Also beware of the temptation of folding the ends around to reduce the space required by the crossed dipoles. The omni-directional pattern will become a bi-directional, weak set of dipole lobes. Finally, the turnstile is a monoband antenna, due to the requirement for the 90-degree phasing line. If you want a turnstile for another band, you will have to design the entire antenna--both dipoles and the phasing line--for the new design frequency.

So the turnstile is a special-purpose antenna. If it has the pattern you need, use it. If you need a different pattern, then try one of the other antennas in this series.

No. 35: A 10-Meter, 6-Element OWA Yagi

L. B. Cebik, W4RNL

There is a very interesting 20-meter Yagi design called the Optimized Wideband Antenna, or OWA. Although only one of several designs within this genre, developed by Nathan Miller, NW3Z and Jim Breakall, WA3FET, the 20-meter version is one of the most adaptable. It employs 6-elements in the space that many other designs use 5. **Fig. 1** shows the general proportions of the antenna.

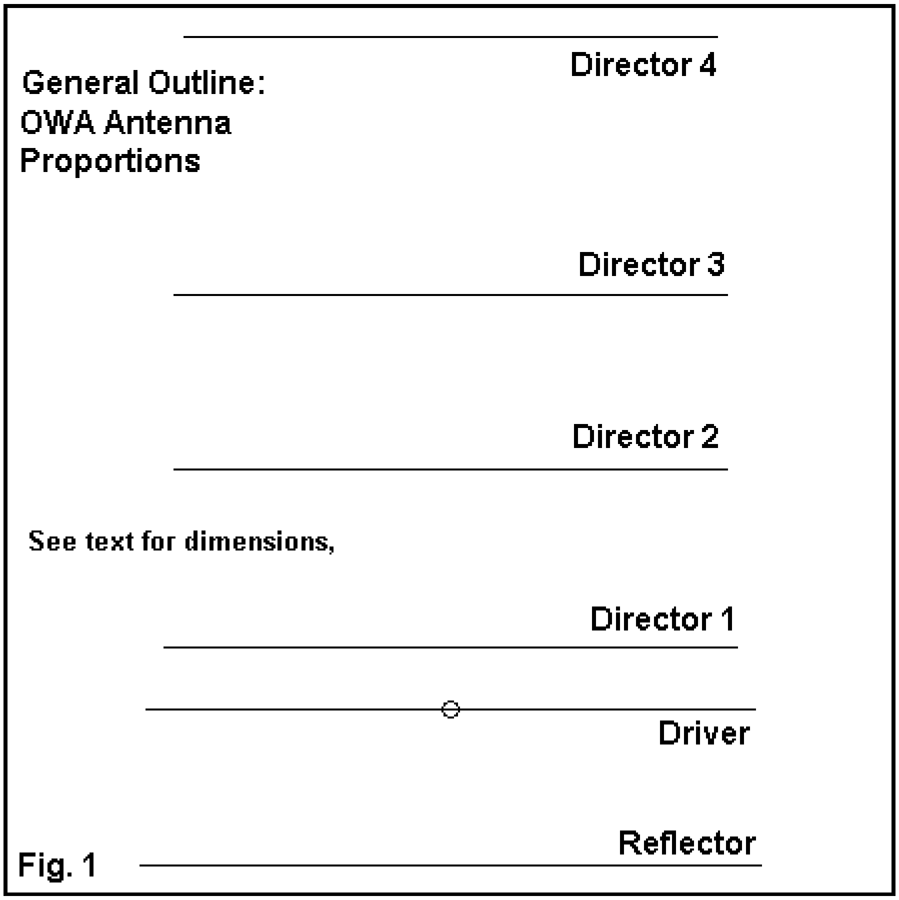


Fig. 1

The 20-meter antenna has several features that deserve special note. Director 1 is perhaps the most significant, since it represents the added element to previously standard 5-element designs. By the use of this parasitic element, the driver can be more closely spaced to the reflector and still show a feedpoint impedance very close to 50 Ohms resistive. Moreover, the antenna shows wideband VSWR characteristics, with values less than a 1.3:1 from 14.0 through 14.35 MHz.

Not only is the feedpoint impedance quite stable, so too are the other main operating characteristics, including both gain and the front-to-back ratio. The antenna shows better than 10 dBi forward gain in free space models across the entire 20 meter band, with more than a 20 dB front-to-back ratio across the same span. Many 5-element designs show much larger variations in all three of the main Yagi parameters: gain, front-to-back ratio, and feedpoint impedance.

The remaining elements of the OWA are also interesting. Directors 2 and 3 are either the same length or the forward director is slightly longer than the rearward member of the pair. Director 4 and the reflector are available for making small changes in the upper and lower frequency limits of the design to spread the operating characteristics across the desired bandwidth. The 20-meter band is about 2.5% of its center frequency. The OWA is capable if significantly greater operating bandwidths with little loss in any of its main characteristics.

The reason for making extensive note of the OWA design is that it scales quite easily (but not without some readjustment) to create very usable Yagis for 10 meters. Although only a few hams have the wherewithal to construct a 48' boom Yagi for 20 meters, 24'-boom Yagis for 10 are more common--and more manageable. The resultant beam shows a free space gain above 10 dBi across the band, a front-to-back ratio always in excess of 20 dB, and very low 50-Ohm SWR values for direct coax feed systems.

Scaling the initial OWA to 10 meters involved converting the 20-meter design into its equivalent uniform diameter element equivalent, scaling this antenna, and then creating a set of tapered diameter elements suitable for 10 meters, adjusting their lengths to be equivalent to the substitute model. The table lists the overall element length, the spacing from the reflector, and the exposed tubing lengths of each size tubing used on one side of the element. (Be sure to double the length of the largest size tubing and to have extra inches on the remaining sections for the tubes to nest.) All dimensions are in inches.

Element	**Overall Length**	**Spacing from Refl.**	**0.5" Inner**	**0.375" Middle**	**0.25" Outer**
Reflector	**216.8**	**------**	**35.75**	**35.75**	**36.9**
Driver	**209.2**	**44.68**	**35.75**	**35.75**	**33.1**
Dir 1	**199.36**	**69.26**	**35.75**	**35.75**	**28.18**
Dir 2	**193.23**	**132.40**	**35.75**	**35.75**	**25.12**
Dir 3	**193.24**	**192.83**	**35.75**	**35.75**	**25.12**
Dir 4	**186.05**	**282.96**	**35.75**	**35.75**	**21.53**

The antenna was scaled and reset to cover the span from 28 to 29 MHz. Some adjustment of the reflector and 4th director was required to achieve the added bandwidth. The first MHz of 10 meters represent a 3.5% operating bandwidth, about 40% greater than demanded of the 20-meter antenna. The following table shows representative modeled figures for 5 points across the band. All figures are based on free space models using NEC-4.1 with Leeson corrections invoked for greatest accuracy.

Parameter	**28.0**	**28.25**	**28.5**	**28.75**	**29.0**
Gain dBi	**10.00**	**10.10**	**10.19**	**10.26**	**10.27**
F-B dB	**20.29**	**26.57**	**30.22**	**24.47**	**21.34**
Feed Z:					
R	**38.4**	**41.9**	**44.4**	**44.6**	**36.5**
jX	**+5.0**	**-1.1**	**+1.3**	**+0.5**	**-2.6**
50-Ohm SWR	**1.33**	**1.20**	**1.13**	**1.12**	**1.38**

The greater bandwidth demanded of the 10-meter design shows most clearly in the rise in SWR and decrease in feedpoint impedance at the low and high ends of the bandpass. Nonetheless, the design meets all of the objectives. The gain changes only by about a quarter dB across the band. With further tweaking, the feedpoint impedance might be brought upward toward 50 Ohms a bit, but the reactance figures are extremely low for an antenna covering a full MHz of 10 meters. All of this suggests that the OWA design concept is capable of significant expansion beyond its original implementation.

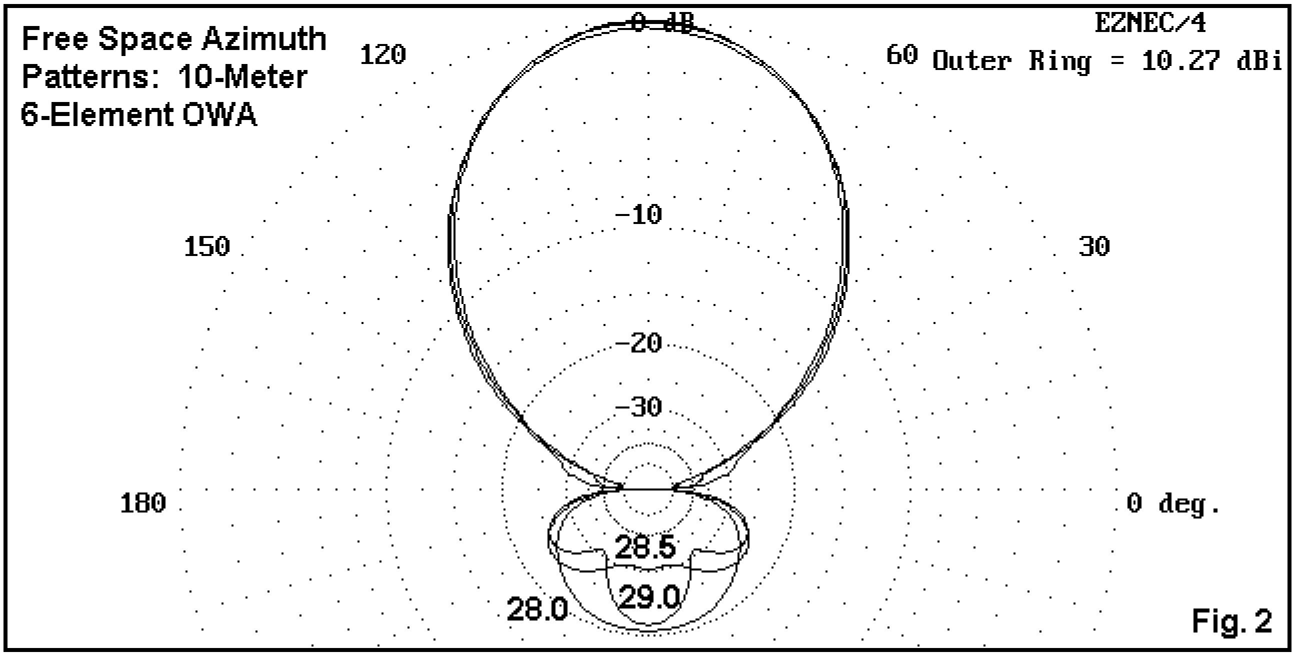


Fig. 2

The antenna pattern itself is a model of good behavior, with no undesirable side or rear lobes. Note in **Fig. 2** the change in the shape of the rearward lobe across the band, which is a normal progression for well-behaved antennas of this type.

Just for the drama, **Fig. 3** shows the 50-Ohm SWR sweep, taken at 0.1 MHz intervals across the band. There are no impedance spikes anywhere in the bandpass of the antenna.

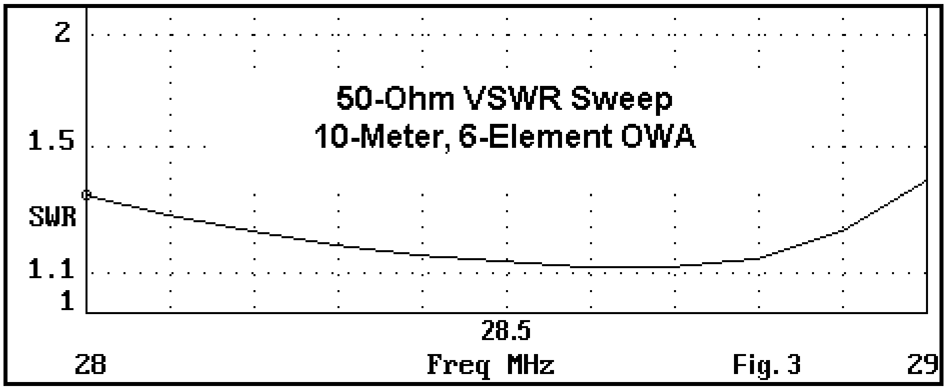


Fig. 3

As a high-performance 10-meter antenna covering all of the first MHz of the band, the 24' 6-element OWA is a worthy monoband competitor with other designs for the band.

For those who prefer somewhat beefier construction, here are the dimensions of the NW3Z model on a 24' boom using 0.75" diameter inner tubing, 0.625" diameter middle tubing, and 0.5" diameter tip sections. Note that the element lengths and spacing are slightly different than the slim-element version above. When adapting Yagi designs, do not simply take the dimensions you find in an article and use whatever materials you have. Differences in element diameter and where the steps in the diameter occur will make a difference in the required element lengths and spacings. A hasty near-copy may not perform to full specifications.

Element	**Overall Length**	**Spacing from Refl.**	**0.75" Inner**	**0.625" Middle**	**0.50" Outer**
Reflector	**215.04**	**------**	**24.00**	**18.00**	**65.52**
Driver	**207.18**	**43.86**	**24.00**	**18.00**	**61.59**
Dir 1	**195.80**	**69.18**	**24.00**	**18.00**	**55.90**
Dir 2	**191.76**	**131.30**	**24.00**	**18.00**	**53.88**
Dir 3	**192.34**	**192.70**	**24.00**	**18.00**	**54.17**
Dir 4	**183.14**	**282.00**	**24.00**	**18.00**	**49.57**

All credit for the OWA design belongs to its originators. Further details can be found at the following website: http://www.contesting.com/nw3z/. This exercise has only shown that one of the implementations of the basic design can be advantageously adapted to other bands. None of the models presses any limit of the NEC and, therefore, they are quite reliable, both as analyses of the antennas and as guides to construction. Of course, using still another element diameter taper schedule than the ones shown will require resetting the element lengths to accommodate the materials used.

In addition to being rather good Yagis of their size, the OWA designs may also serve as a standard against which to measure other designs that present themselves. Even if you never build one of these designs, the data provided here may be useful for comparative purposes.

No. 36: 4- and 5-Element OWA Yagis

L. B. Cebik, W4RNL

The OWA (Optimized Wide-band Antenna) design for Yagis means different things to different designers. For some, it means simply a low SWR across a passband (like 28-29 MHz), regardless of the impedance. To others, it means a low 50-Ohm SWR across the passband. Since many 10-meter users are more comfortable with a direct coax feed (with a choke balun for protection from common-mode currents down the line), let's take the latter approach.

Last time, we looked at a 6-element 24' OWA using fairly thin elements. This time, let's look at some shorter designs using elements with larger diameters. In fact, in this episode and the next, we shall look at a total of 4 OWA design ranging from 13' to 36' long, all with the same element structure.

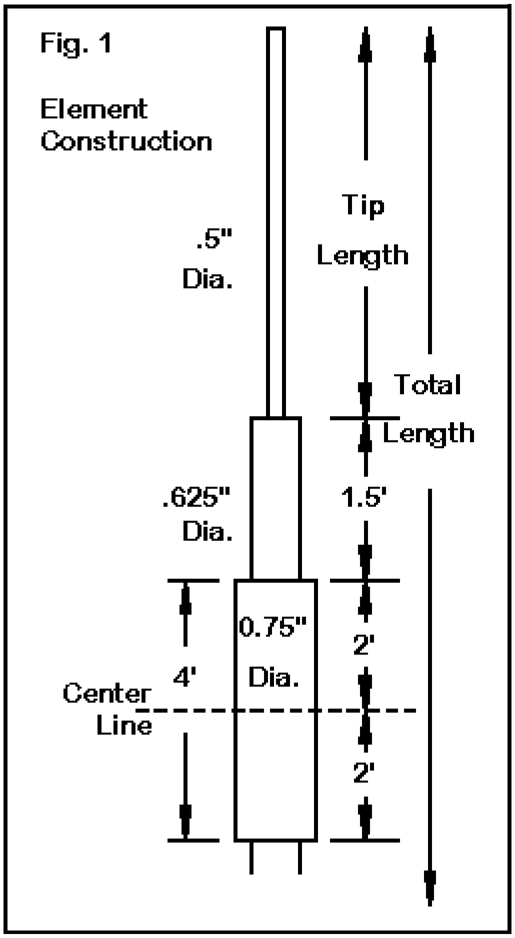


Fig. 1

Element Construction

Fig. 1 shows the element structure that all of the beam designs will use. The 4' center section is 3/5" tubing, with a short 1.5' (plus 3" for overlap) section of 5/8" tubing following. The "tips" are 1/2" tubing. All this can be obtained from sources that advertise in QST or CQ. In the element length tables, be sure to add 3" to the 1/2" tubing for overlap.

For higher wind loads, you can let the 5/8" tubing go all the way through the 3/4" element. For lesser winds, the 3" overlap will do well.

Of course, the driven element must be open at the center for the feedline connection. You can use a fiberglass tube or rod across the gap to keep the element aligned and to strengthen it.

A 4-Element OWA

OWA design requires one additional element to achieve the 50-Ohm feedpoint impedance compared to beams with feedpoint impedances in the 25-Ohm range. Shorter OWAs must also be a bit longer than their 3-element low-Z counterparts for the same performance. While a 3-element Yagi with about 8 dBi free space gain needs a 12' boom, our OWA will need a 13.5' boom.

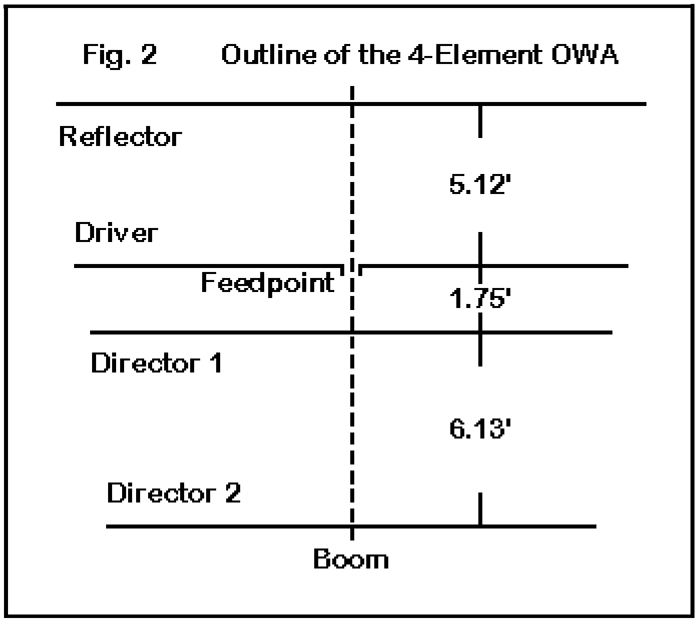


Fig. 2 Outline of the 4-Element OWA

Fig. 2 provides the outline of the 4-element version, with the spacing between elements shown. The following table lists the element spacing from the reflector, the tip length, and the total element length from tip-to-tip for reference, all in feet.

Element	**Space from Reflector**	**Tip Length Length**	**Total Length**
Reflector	**0**	**5.34'**	**17.68'**
Driver	**5.12'**	**5.10'**	**17.20'**
Director 1	**6.87'**	**4.57'**	**16.14'**
Director 2	**13.00'**	**4.10'**	**15.20'**

The elements are designed to be insulated from the boom. If you change materials or element structures, an entire redesign will be needed. Do not be casual in your construction of Yagi designs you find in handbooks. They simply will not perform up to the original design if you alter the element diameters or the tapering schedule.

The 4-element OWA provides an average gain of over 8 dBi (free-space). The front-to-back ratio is above 20 dB across the 28-29 MHz span. The 50-Ohm SWR is exceptionally low. Hence, the beam is a fit candidate for reproduction in the home workshop.

A 5-Element OWA

If we add about 6' to the boom and one more element (respacing all of the others), we can add about 1 dB to the overall gain of the OWA Yagi. A 19' boom will hold the elements, which use the same construction as the 4-element version.

Fig. 3 Outline of the 5-Element OWA

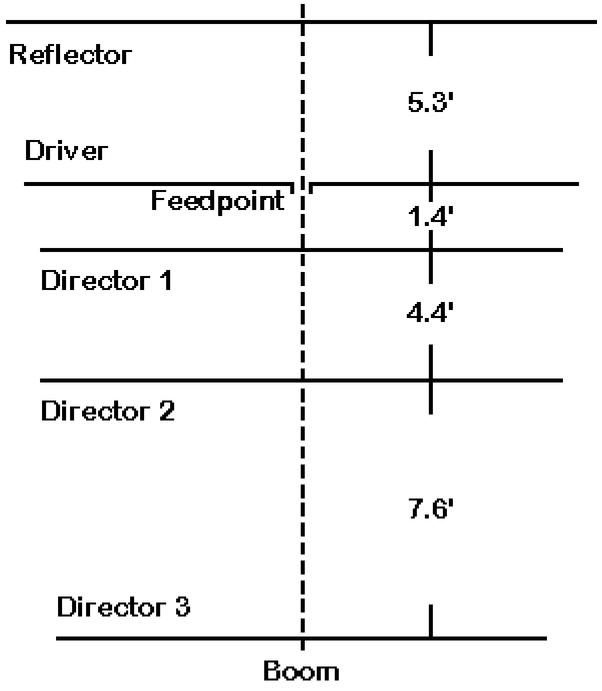


Fig. 3 gives us the outline of the 5-element OWA, as well as the inter-element spacing. The following table provides the structural details.

Element	**Space from**	**Tip Length**	**Total**
	Reflector	**Length**	**Length**
Reflector	**0**	**5.52'**	**18.04'**
Driver	**5.30'**	**5.16'**	**17.32'**
Director 1	**6.70'**	**4.70'**	**16.40'**
Director 2	**11.10'**	**4.65'**	**15.30'**
Director 3	**18.70'**	**4.13'**	**15.26'**

For the extra element and boom length, we get a gain that ranges from 9.1 to 9.4 dBi (free space) across the 28-29 MHz span. The front-to-back ratio is close to or above 20 dB over that same frequency range. The SWR is quite smooth across this range.

Once more, the design is for elements insulated from the boom. There are many systems for mounting elements to the boom. I tend to prefer 6" by 12" plates of polycarbonate (a generic name for the material sold as Lexan), which has good sun (UV) resistance, good RF properties, and is very strong. 1/4" thick material works well at 10 meters. It is much more durable and maintenance-free than plywood (which needs periodic varnishing) or more common acrylics (which become brittle after a season or two in the weather). I also use stainless steel hardware throughout, including U-bolts with saddles for the elements and the boom. Other systems also work well, but this one satisfies my experimental needs, meaning that antennas are always being reconstructed into new configurations.

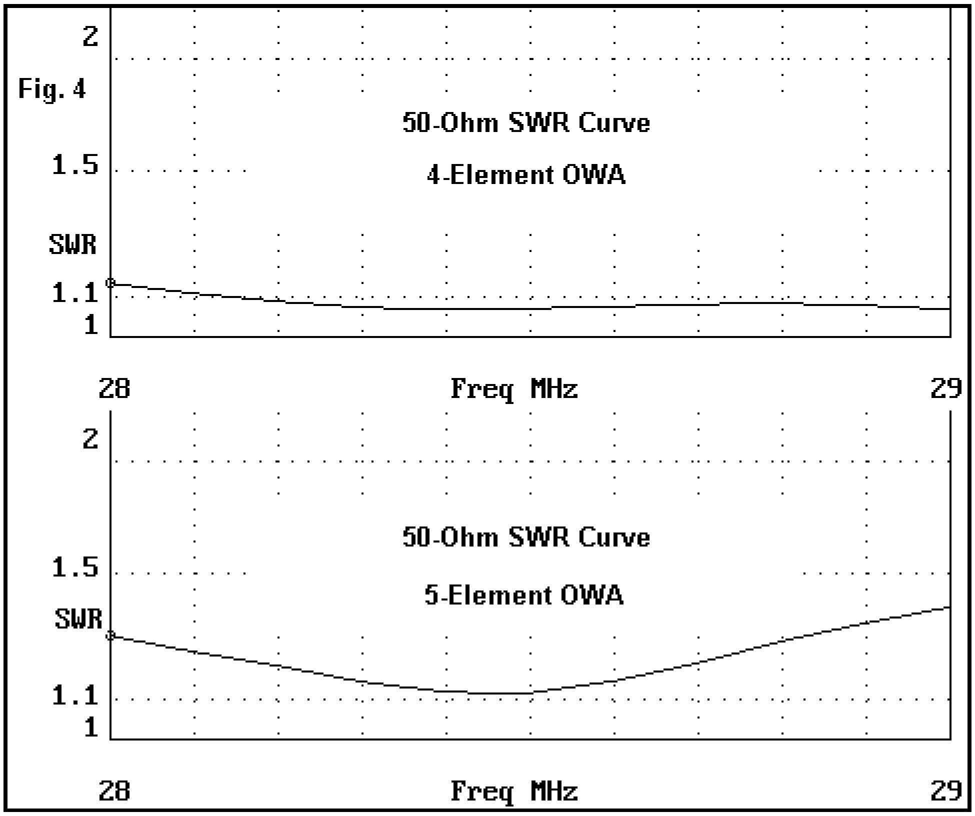


Fig. 4

For reference, **Fig. 4** shows the SWR curves for the two antennas from 28 to 29 MHz. These are for direct connection, using only a 1:1 choke or balun to move from the balanced feed element to the unbalanced coax cable. You can purchase a balun, make your own choke from coiled coax, or obtain a choke that uses ferrite beads.

Be sure to weather seal all connections. For coax connectors, a wrapping of 3-M #33 electrical tape starts the job, followed by one of the black butylate sealants. Some folks like to cover the butylate with one more #33 tape coating. Do not stint on weather protecting connections, since water leakage into the feedline can ruin the performance of an otherwise great antenna system.

In a future column, we shall go over some of the good practices to follow in building your own antenna. However, we must first finish our designs for 3/4-5/8-1/2" elements. Next time, we shall look at 6 and 7 element versions of the OWA, both with a flat 50-Ohm Feedpoint impedance, and with an extra dB or so every time we add an elements.

No. 37: 6- and 7-Element OWA Yagis

L. B. Cebik, W4RNL

Last time, we looked at some Yagi designs for fairly short-boom OWAs with direct 50-Ohm feedpoint impedances across the 28 to 29 MHz span. The 4-and 5-element designs provided about 8 dBi free-space gain and 9.2 dBi gain, respectively, which is quite good for monoband Yagis with their boom lengths.

This time, we want to look at some longer versions of the OWA with more gain, but still keep the 50-Ohm feedpoint impedance. We shall look at 6- and 7-element Yagis on 24 and 36 foot booms.

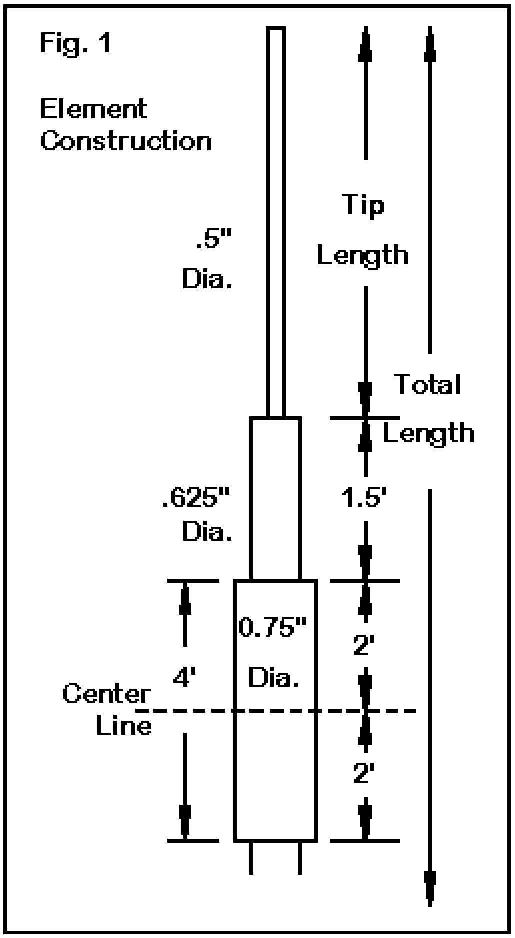


Fig. 1

Element Construction

Fig. 1 reviews the element structure that we are using in this set of designs, a combination of 3/4, 5/8, and 1/2 inch diameter aluminum tubing. One reason that we shall review the 6-element OWA, when we already did an entire column on that antenna, is the new, larger tubing sizes. As a result of changing both the tubing sizes and the taper schedule (the places along the element length where we change tubing size), the element lengths will also change. However, the end result will be very similar performance between the two versions of the antenna.

A 6-Element OWA

The original 6-element OWA is a very good antenna. So too is the new version. The only difference is in the tubing, which may be a matter of what an individual builder likes to use or has access to in his or her local area. Let's see how the new version turns out.

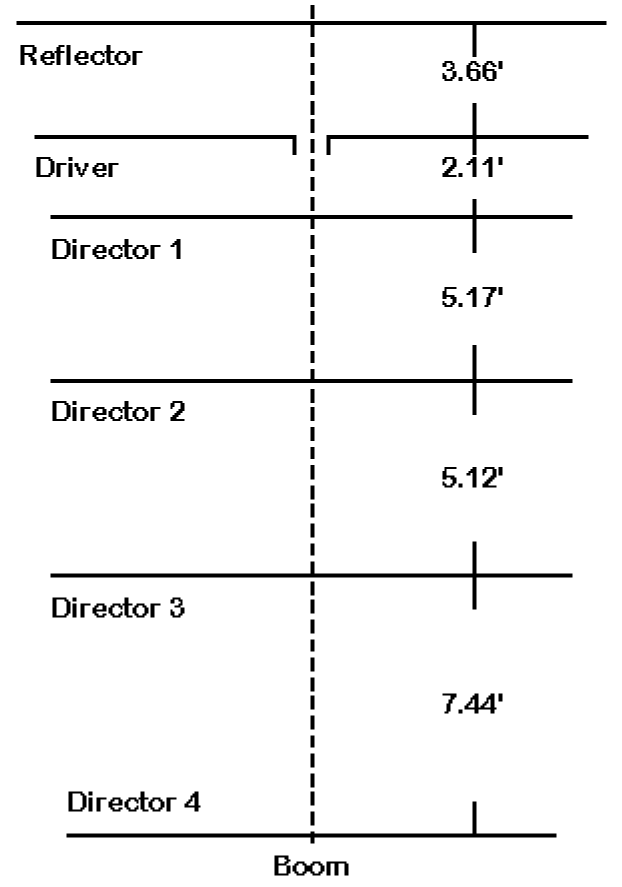


Fig. 2 Outline of a 6-Element OWA

Fig. 2 gives us the outline of the 6-element OWA, as well as the inter-element spacing. The following table provides the structural details.

Element	**Space from Reflector**	**Tip Length Length**	**Total Length**
Reflector	**0**	**5.46'**	**17.92'**
Driver	**3.66'**	**5.13'**	**17.26'**
Director 1	**5.77'**	**4.66'**	**16.32'**
Director 2	**10.94'**	**4.49'**	**15.98'**
Director 3	**16.06'**	**4.51'**	**16.02'**
Director 4	**23.50'**	**4.13'**	**15.26'**

The free-space gain of this 6-element OWA varies from 10.1 to 10.2 dBi across the band, with a front-to-back ratio that never falls below 21 dB. Only at the upper limit of the frequency spread does the SWR get above 1.25:1 with a direct 50-Ohm feed system (including the recommended 1:1 choke/balun to suppress common mode currents).

A 7-Element OWA

Adding one more element increases the boom length from 24' to 36' or so. Whether the added length is worth the effort depends on how important another dB of gain is to the operator.

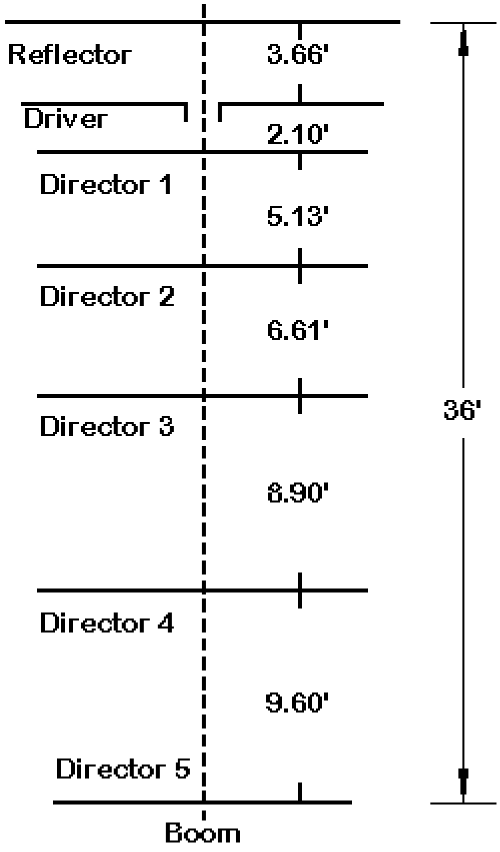


Fig. 3 A 7-Element OWA

Fig. 3 gives us the outline of the 7-element OWA, as well as the inter-element spacing. The following table provides the structural details.

Element	**Space from**	**Tip Length**	**Total**
	Reflector	**Length**	**Length**
Reflector	**0**	**5.47'**	**17.94'**
Driver	**3.66'**	**5.17'**	**17.34'**
Director 1	**5.76'**	**4.64'**	**16.28'**
Director 2	**10.89'**	**4.50'**	**16.00'**
Director 3	**17.50'**	**4.51'**	**16.02'**
Director 4	**26.40'**	**4.47'**	**15.94'**
Director 5	**36.00'**	**4.11'**	**15.22'**

The gain ranges from 11.2 to 11.6 dB across the first MHz of 10 meters, with a peak near mid-band. The front-to-back ratio is a solid 20 dB. Although the SWR curve reaches 1.6:1 at 29 MHz, it is very tame across the remainder of the band. In fact, **Fig. 4** gives us a sampling of both antenna SWR curves.

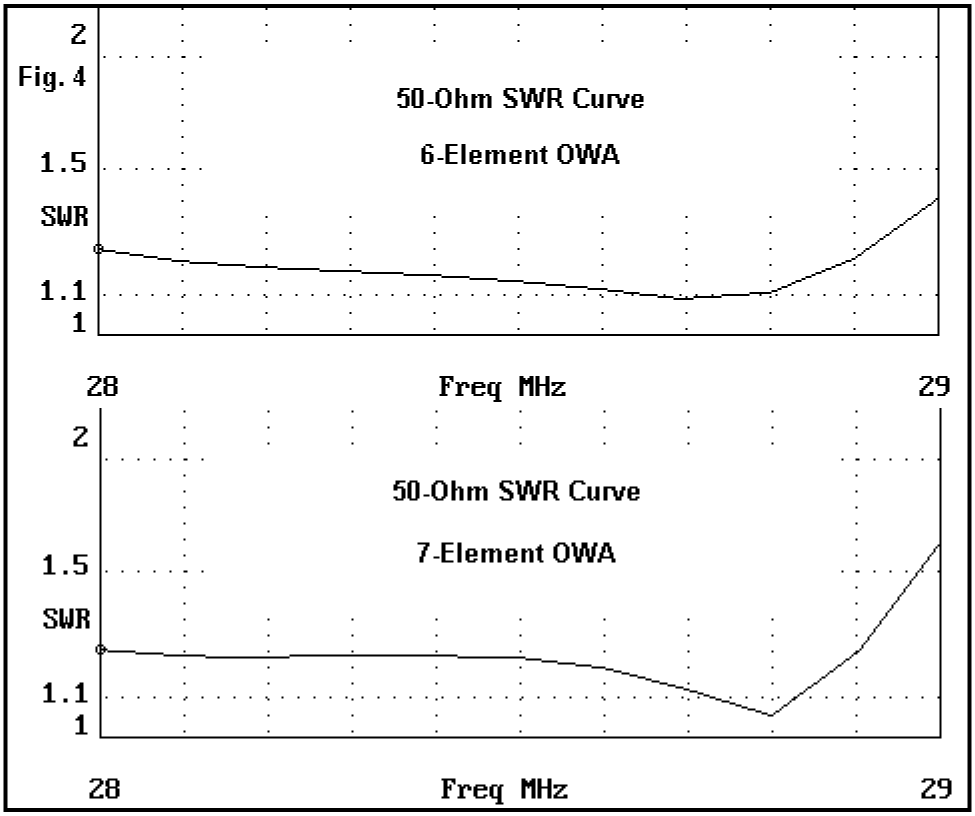
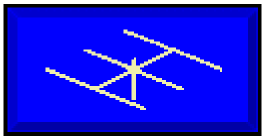


Fig. 4

Remember that these designs are specific to the tubing sizes and transition points from one size to the next. Any deviations from the prescribed tubing schedule would require refiguring the designs.

As with all OWA designs, we must have 1 extra element for the given boom length and gain in order to secure the relatively smooth 50-Ohm SWR curve across the band. The element marked as Director 1 in all of the designs does not so much contribute to the antenna gain as it functions with the reflector to establish the antenna bandwidth and feedpoint impedance.

How big do you want to go? I have seen an 8-element OWA design for 10 meters with something over 12 dB gain. But it was 48' long. The design can be found at the NW3Z web site via your search engine (search for "NW3Z"). As well, these designs might be tweaked for even better performance with an optimizing program. The versions shown here were hand-developed. If you prefer a direct 50-Ohm feedpoint impedance in a good Yagi antenna, then the OWA designs are the way to go.



No. 38: Notes on Home-Brewing 10-Meter Yagis

L. B. Cebik, W4RNL

Over the last several columns, we have examined the electrical designs of a number of Yagis ranging from 3 to 7 elements. Along the way, we have noted some construction pointers and preferences. However, let's pause a bit to see if we can pull some of those ideas together in one place--here.

1. Element and Boom Stock: For casual and portable operations, where an antenna is not going to be in the wind for long periods of time, hardware depot aluminum tubing is usually satisfactory for elements. It comes--at least in my part of the country--in limited sizes, beginning at about 3/4" diameter. So designs using this span of tubing can rely on local purchase.

6063-T832 and 6061-T6 are the more commonly used aluminum tubing for Yagi elements. Commercial houses can use thin wall versions of this tubing for lighter elements, since they have the machinery to resize the ends for perfect lap joints. However, 0.55" to 0.58" wall thicknesses are the ones used by most hams--and these are the versions carried by vendors like Texas Towers and others. Usually, for shipping ease, the tubing comes in 6' lengths, so designs need to take this into account. If you need to put two lengths together at the center of an element to get, for example, 12' of 5/8" tubing, use a short piece (about 1') of 1/2 inch tubing inside the inner ends of both 6' pieces to form a good electrical joint and stiffen the element on its mounting. For split driven elements, use a piece of fiberglass rod.

For short boom, such as for a 2-element Yagi, 1 1/4" PVC works well, but longer than 5' or so, the material sags and is heavy. Aluminum tubing makes a good boom. For modest beams up to 12 to 14 feet long, you can nest 1.125 and 1.25 inch tubing to make a very durable boom. If you have only 6' lengths, you can stagger the sections, making sure that they meet tightly at their ends.

2. Boom-to-Element Mounting: Commercial antennas often use special assemblies to join elements to the boom. Plates are bent and curved as necessary by equipment to which the average home builder has no access. However, if you like to build antennas, consider accumulating old broken beams from hams in your local area, even offering a few dollars to remove the "junk" from their yards. You will acquire a lot of unusable bent tubing and a number of quite unharmed boom-to-element plates (and also some boom-to-mast plates). Most of the junction assemblies will be reusable, even if you have to replace the original hardware with stainless steel nut and bolts from the local hardware depot. For 10-meter beams, if you have to build your own boom-to-element assemblies, it is best to design for elements that are insulated from the boom. (Directly connected elements and insulated elements usually require slightly different lengths to do the same job, so do not convert one type of assembly to the other without some redesign work.) **Fig. 1** shows a method that I prefer--meaning that it is certainly not the only method available.

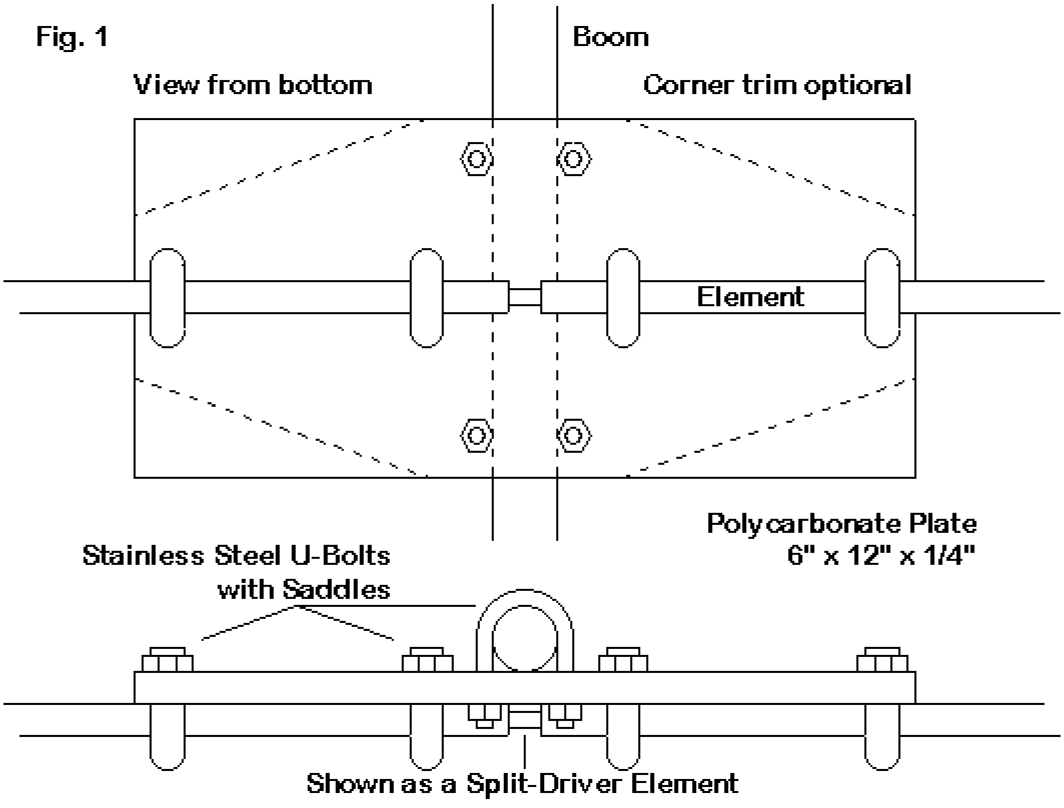


Fig. 1

Having used a lot of materials for the insulating plate, I have gone to polycarbonate, the generic name for Lexan. The material is UV resistant, has excellent RF properties, is exceptionally strong, and can be cut and drilled with woodworking tools. 6 by 12 inch plates of 1/4" material handle any 10-meter elements. Trimming the corners to save a little weight is feasible. Two U-bolts hold the boom and either 2 or 4 U-bolts hold the elements. The inner U-bolts are needed only if you have a split fed elements with no alignment rod running from end-to-end of the plate inside the aluminum.

You can replicate the plate using good outdoor plywood in 1/4 or 3/8 inch thicknesses. However, plywood requires special attention both in the beginning and every year. Initially, seal the edges with a good exterior-grade fill. Then apply several coats of good spar varnish. I normally have done this to the wood before drilling U-bolt holes and then revarnished the word, getting varnish into the holes. An annual sanding and recoating is necessary, just as it would be for a wooden boat.

Use stainless steel U-bolts, preferably with saddles. The saddles help prevent the U-bolts from collapsing the tubing when you tighten everything down. These will likely be a mail-order item. Drill the holes in the plate with precision to exactly fit the U-bolts with minimum amounts of free play (but no stress on the plate). This practice will keep your elements aligned as the wind tries to push them around.

Note also that the elements are mounted beneath the plates, with the boom on top. This arrangement let's gravity help keep the elements level.

There is a simpler method of mounting insulated elements. It involves a single U-bolt per elements that goes around the boom and through the element. It is best to use a curved plate that matches the element curve as a keeper. Between the U-bolt and the boom is a short section of split gray electrical PVC that acts as an insulator. (The gray PVC used for electrical conduit has the greatest UV resistance and hence will last longer in the sun before going brittle.) The tubing used in this system should be fairly large and should have an interior piece of tubing for reinforcement. Otherwise, the element will break off right at the U-bolt. This system requires even more careful machine work for good alignment and does weaken the element. So use the scheme, outlined in **Fig. 2**, with caution.

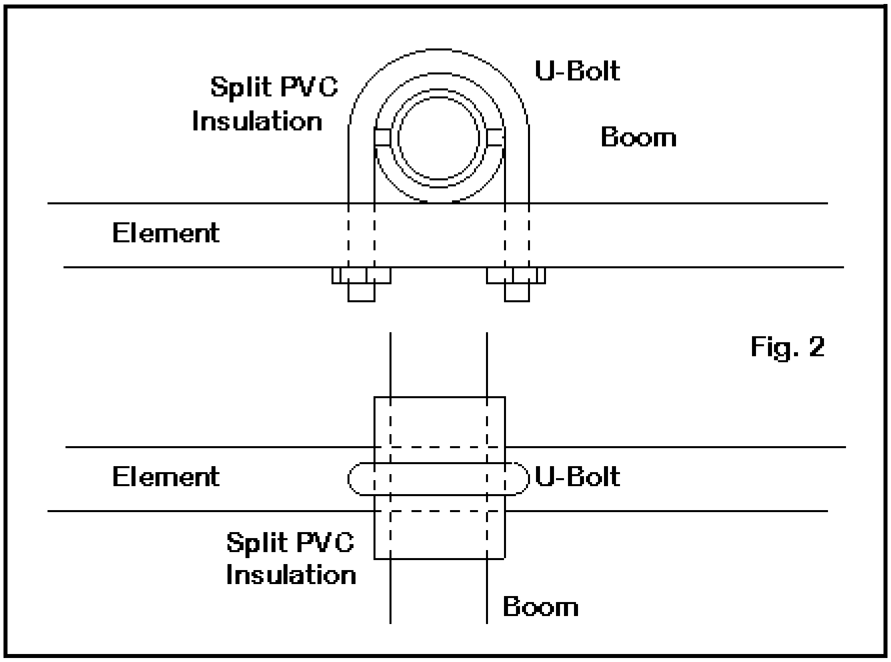


Fig. 2

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3. Boom-to-Mast Plates: For very light antennas, you can use a non-metallic plate for the boom-to-mast junction. Again, plywood--with the proper treatment--can also do the job. However, I prefer metal plates either 1/4 or 3/8 inch thick, depending on the weight of the antenna and the diameters of both the boom and the mast. Predrilled plates are available from mail order sources, as is stock that lets you drill your own custom pattern of holes. The object of using a metal plate is to ensure a good electrical bond between the boom and the mast (and downward) so that the entire assembly (except for the elements) is a ground potential for bleeding charges off the antenna support system.

For the larger U-bolts in this assembly, you can use saddle- types or you might wish to use muffler-type clamps. These U-bolt assemblies have a saddle with edges that some folks believe grips the boom and the mast better. However, if you do use these auto store components, be certain that all of the pieces are stainless steel. It will take a pair of U-bolts for the mast and another pair for the boom.

You have a choice of shapes for the plate: a square (or rectangle) of a diamond. In principle, the diamond conserves the most weight and material. However, be certain that there is enough material beyond the U-bolt holes in a diamond plate to ensure that the material will not break under stress. **Fig. 3** will reveal the areas of potential weakness.

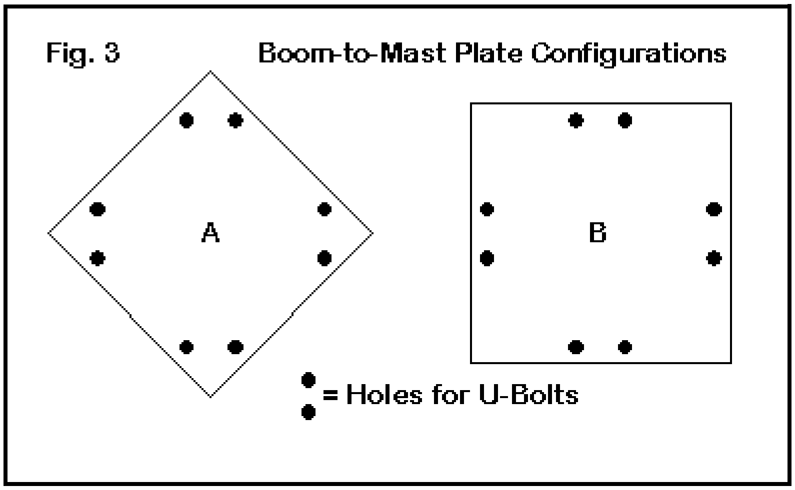

Fig. 3 Boom-to-Mast Plate Configurations

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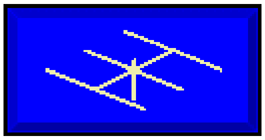
Alternatively, you might use for this assembly one of those commercially made fixtures with its complex bends and shapings to provide a maximum grip between the boom and the mast. Also, be sure the mount this fixture at the center of weight of the antenna boom.

4. **A Note About Stainless Steel Hardware**: For antenna work, use stainless steel hardware everywhere. Make no exceptions. Although once hard to find, stainless steel nuts, bolts, U-bolts, and other fixtures are easy to locate at hardware depots. Do not use aluminum hardware, as it is very weak. All other hardware will create a bi-metallic junction that will corrode one or both of the pieces joined. Stainless steel has proven to be the most successful hardware for antenna jobs ranging from joining element sections of tubing to boom-to-mast plate mountings.

The construction methods that we have noted will run the cost of a home brew Yagi only to about twice the cost of using junk-box components. However, the final cost will still be less than 1/3 the cost of a commercially made antenna--and it will last as long or longer than the commercial assembly. Even if the Yagi is home brew, if it is worth making, it is worth making well. Nothing is more frustrating than breaking a beam in the wind during a world-wide band opening.



No. 39: Frequently Asked Questions

L. B. Cebik, W4RNL

In our column for the last issue, we covered some fundamentals of the material side of beam construction. That exercise brought to mind a number of more general questions that folks have posed from time to time about antennas. So, let's try to give some succinct answer to these questions.

1. *With a wire antenna, does insulation make a difference in performance?*

This question is actually two questions in one. First, once we get the antenna set correctly, insulation makes no difference in how well the antenna performs. The gain will be virtually the same, whether the wire is bare or covered with any of the standard insulating materials.

Second, insulation will make a difference in how long a wire must be to be resonant. If a bare wire is resonant on 10 meters (actually some specific frequency on 10 meters) at a length of 200", then an insulated wire will be resonant at the same frequency at a length from about 190" to about 198". Insulation creates a velocity factor (VF) so that the required physical length is always shorter than the required electrical length. If we set the VF of bare wire to 1.0, then the VF of insulated wire will be from 0.95 to 0.99.

The nature of the insulation and its thickness determine the VF of insulated wire. The higher the dielectric constant of the material and the thicker the insulation, the lower the VF value. Unfortunately, there is no handy chart that you can consult when you buy insulated wire to tell you what the precise VF is. For dipoles, you simply prune to resonance.

If you are thinking about a wire beam, where the elements are not resonant on the design frequency, then the best policy is to use the exact wire specified in the article or handbook from which you draw the design. There are techniques for handling insulated wire in these cases, but they generally require efforts or instruments that the average backyard antenna builder does not have.

2. *Does the feedpoint gap make a difference in the antenna element length?*

If a design that you are copying calls for an element length of 200", then this length remains constant, regardless of how large you make the feedpoint gap--within reason, of course. The gap can range (at 10 meters) from 1/4" to a couple of inches without disturbing the overall length of the antenna element. The leads from the feedline to the inner edges of the gap make up the missing element section.

Remember that the feedline is in series with the antenna element. The feedline itself begins where the line is at its proper form to create currents of equal magnitude and opposite phase. When you turn the wires of a parallel feedline at right angles to the line to make the antenna connection, those wires are part of the antenna. When you separate the coax braid and center conductor to make the same kind of connection, those leads are parts of the antenna element. Even if not identical in diameter to the antenna element itself, the length is short enough at HF not to make any difference in the way the element performs.

3. *I have a multi-band doublet (or loop, etc.) that I use for all or most of the HF region. Can I connect a 4:1 balun at the antenna terminals and use coax to the antenna tuner in the shack?*

The answer to this question is yes, but there are better ways to handle the situation. The impedance presented by the antenna varies from one band to the next, ranging from very high to very low. If your coax run is long--perhaps 100' or so, your losses will climb according to the SWR on the line and the frequency. Higher frequencies and SWRs multiply natural coax losses.

Let's look at alternatives to this system. The most efficient system is to run parallel transmission line from the antenna to the antenna tuner. Parallel transmission line naturally has much lower loss than coaxial cables (except for the very low-loss hard lines used at UHF and microwave frequencies). Hence, the multiplier that comes with high SWR values on the line tends to increase the loss by only a very little. Hence, in most cases, the losses in a high SWR parallel line system will be less than the losses in a perfectly matched 10-meter coax system.

The installation rules for parallel line--whether it is 300-Ohm TV line, windowed vinyl 450-Ohm line, or open wire 600-Ohm line--differ from the rules that apply to coax. Keep the line free and clear of everything by several times the width of the line. Conductive materials--even wet wooden posts or trees--can disrupt the balance in the line and reduce its effective operation as a transmission line.

4. *If I run parallel into the house/shack, I get RF pick-up by the X (where X may equal the telephone, the TV, the rig, etc.). How can I have my parallel line and no interference?*

The losses of coax increase with line length. Hence, a short piece of coax--something less than about 20' at 10 meters--will not create significant losses. Even at a 10:1 SWR, 20' of RG-213 will have less than a 1 dB loss. Now lets assume that we can place the antenna tuner within 20' of where the coax would pass though the wall/window/etc. to reach the outside world.

We can install our parallel line from the antenna to this same wall/window--keeping it free and clear of unbalancing forces in the outdoor run. At the entry point, we can install a 1:1 bead balun. From the coax end of the balun, we run our short length of coax to the antenna tuner.

a. I specified a 1:1 balun, not a 4:1 balun. Sometimes the 4:1 balun will do the job--sometimes it will not. Since the antenna shows a different impedance on every band, it is rarely matched to the feedline headed toward the shack. At every point along the line, the impedance is transformed to a new value--and some of these values will be very low. Further transforming the impedance to a still lower value by a 4:1 ratio is likely to yield such a low impedance that the tuner may not be able to handle it. Hence, a 1:1 balun is the better choice.

b. I tend to prefer bead baluns for this transition, although other 1:1 balun types may work. Bead baluns--originated by Walt Maxwell, W2DU--are compact and inexpensive (from such sources as the Wireman in South Carolina). No balun will be lossless in this application, but the losses will be modest at moderate power levels.

c. At the coax end of the balun, run a short, heavy ground lead from the coax braid to a good ground rod. This measure helps prevent significant levels of RF from being on the outside of the coax braid and thus helps reduce coupling into conductors inside the shack.

This system is not perfect, but it is effective for using an all-band antenna with parallel feedline while suppressing unwanted RF coupling to systems other than the amateur radio equipment.

5. *I have followed all of the recommendations and my all-band antenna will still not load up properly on 1 or more bands. What should I do?*

Let's assume that your system is flawless--good connections, not opens or shorts, etc. In this case, the most likely cause of a failure of the antenna to load is the length of transmission line.

Earlier, I noted that when the antenna feedpoint impedance does not match the impedance of the feedline, the impedance is continually changing along the line. It is possible to calculate the impedance at the shack end of the line, but only if we know the impedance at the antenna feedpoint. In most cases, we do not know the impedance at the shack end of the line.

The impedance may be a complex combination of a resistive value and a reactive value. Your antenna tuner has limits to the maximum and minimum resistive value that it will accept and transform. The reactive part of the impedance is the more likely culprit, since most tuner designs will compensate for only limited reactance. Depending on tuner design, the compensation range will be better for one type of reactance (capacitive or inductive) than for the other type. In most cases of a failure to provide a good match to the 50-Ohm requirement of the rig, the culprit an impedance at the tuner terminals that is outside the matching range of the tuner.

Wait--do not throw away the tuner. Instead, change the length of the line to obtain a different combination of resistance and reactance at the tuner terminals. You can splice in a section (4 to 10 feet) of parallel line, either permanently or with knife switches. Just keep these added sections from folding over each other or coiling up. In other words, they should be free and clear like the rest of the line.

Sometimes, you can find a single length of line that allows you to tune all bands with your multi-band wire antenna. In that case, you can make the connections permanent. In other cases, you can find two line lengths that between them allow you to handle all bands. A simple knife-switching system makes quick work of changing the connections.

6. *I have the ground line at the shack entry point. Is my system safe from lightning?*

Not especially. The safest system for an amateur station that does not need to operate during a thunderstorm is one that disconnects the antenna line from the shack lead and reconnects it directly to a ground rod. Then any charges that accumulate on the antenna go to ground and not to the equipment.

In addition, set up your station so that you can do a complete disconnect in preparation for a thunderstorm. Disconnect--pulling the plug is best--the AC lines. Also disconnect the equipment from the outside ground line. Now the equipment is disconnected from every source of electrical surge.

Sensitive solid state devices do not care if the supply line has a high surge or whether the ground side of the device has a high surge. In either case, the voltage across them is destructively high. Hence, isolating the equipment from both the supply voltage and the grounding lines is necessary to prevent surge damage. Surge protectors help, but when the storm is near, nothing succeeds like isolation.

You can design your station to make all of these disconnects easy--easy enough to apply whenever you shut down after an operating session. The only step that requires a trip outdoors is changing the antenna lead from shack lead-in to ground rod. If you disconnect the antenna routinely along with the other indoor disconnects, you can save the trip outdoors for an impending storm and still be relatively safe. Of course, if you travel out-of-town, set up the station as if you will have a thunderstorm every day that you are gone.

7. *I have a beam on a tower. The base of the tower is strapped to ground rods. My coax from the antenna enters the shack, and I can change it from the rig to a second connector that goes to a ground rod outdoors. Am I safe?*

Maybe--maybe not. Experts suggests that most of the current in a lightning strike is in the coax braid. This current is very high, capable of destructively melting the insulation and arcing to other conductors. It is best if this current never enters the house at all. Hence, having an outdoor grounding system so that the coax never gets indoors during a thunderstorm is best.

There is a second move that you can make. Since your have well-grounded the tower, and since the bulk of destructive lightning-induced current is in the braid, consider this measure. Near the top of the tower, clamp a small plate to a tower leg. On the plate, install a coax bulkhead connector--a double female connector with mounting hardware. Now run the antenna lead from the antenna to the connector and a second length of coax from the connector to the outdoor disconnect near ground level. The coax braid is now at the same potential as the tower leg and connected to the ground system serving the tower. You can add a second plate and connector at the tower base for added safety.

If you maintain this system so that the connectors make excellent contact with the plates and the plates make excellent contact with the tower legs, you shunt currents on the outside of the braid to ground. However, this measure does not remove the need to disconnect the coax from the shack lead-in before it enters the shack. It just adds to the overall protection.

There are more questions on my FAQ list. But these are enough for one column.

No. 40: More Frequently Asked Questions

L. B. Cebik, W4RNL

The frequently asked questions that we shall examine in this session related to beam antennas, most of which are varieties of Yagis. On ten meters, we find a variety of beam construction methods and a variety of matching systems. So our questions tend to relate to these two topics.

1. *Which is better: elements that attach directly to the boom or elements that are insulated from the boom?*

Like many frequently asked questions, this one contains an ambiguity, since the question does not refine the idea of being better into some specific set of concerns.

a. With respect to performance, when the element lengths are suitably adjusted, there is no difference in gain, front-to-back ratio, pattern shape, or feedpoint impedance between a beam with elements directly connected to the metal tube forming the boom and a beam with the elements insulated from the boom.

However, the element lengths required for a given set of performance figures will not be the same for the two methods of construction. Elements that are fully insulated and spaced by a non-conductive plate away from the boom will be the shortest. Elements attached to metal plates that are U-bolted to the boom tend to be the longest, since the plate acts as a short, fat portion of the element.

These rules of thumb apply to elements that otherwise have the same lengths of tubing forming the element's decreasing diameter away from the element center. As we saw in a recent column, these "tapered-diameter-schedule" elements tend to be longer already than elements having a constant diameter. In both cases, the degree of length change from an ideal insulated uniform-diameter element is a complex affair to calculate, and Yagi design software is the best way to redesign one system of construction to another.

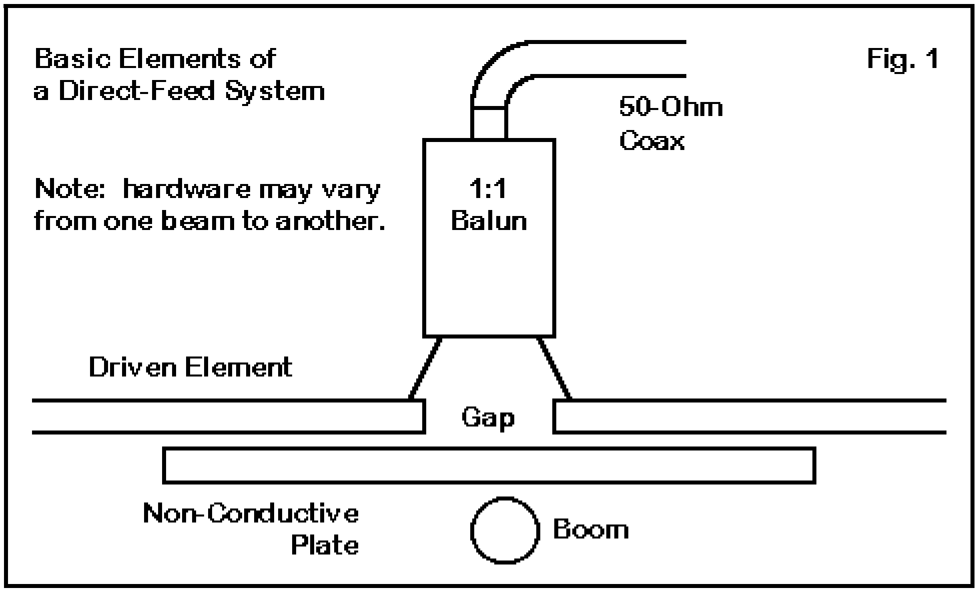
For any beam with more than 2 elements, trying to field adjust the elements to the required lengths often leads to frustrating exercises in sliding tubing and to relatively poor results. The final suggestion, then, is that the backyard builder should use the exact techniques specified in a design being copied unless the builder has considerable experience in redesigning Yagis.

b. The Yagi with element connected directly to the boom has a slight advantage in terms of noise and discharge of static build-up on the elements. The boom is connected to the mast and the mast to a grounded tower. Therefore, when the elements are connected to the boom, static charges bleed off the elements as the wind and other weather phenomena create them.

Insulated elements can build considerable static charges over time. We can discharge them by connecting a high-value resistor (about 5,000 Ohms or more) or an RF choke (100 microHenries or so) between the element center and the boom.

2. *What does it mean to say that a certain Yagi design uses "direct feed?"*

Although many Yagi designs in current use have feedpoint impedance running from 20 to 30 Ohms, it is possible to design a high performance Yagi that shows a feedpoint impedance of 50 Ohms. In this case, we do not need a matching network, since the feedpoint impedance is the same as the characteristic impedance of the most common coaxial cables.



However, we do have some constraints when using a direct feed driven element, as shown in **Fig. 1**. Regardless of the construction methods used for the other elements, the driven element must be insulated from the boom. The driven element must be split at the center to create a gap similar to what we find in a common wire dipole. The size of the gap is not critical at 10 meters and might range from 1/4" to 1".

We connect the inner conductor of the coax to one side of the element, and the braid to the other side. Hence: direct feed.

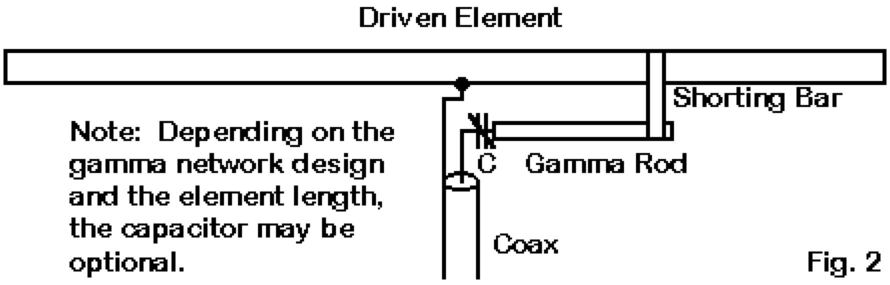
Since the coax is an unbalanced line and the Yagi driver is balanced, we can encounter radiation currents on the outside of the braid. To suppress these currents and maintain a good pattern with no radiation from the feedline, a 1:1 balun is a useful device to insert between the element terminals and the coax line. Bead-type balun chokes are the lightest and work well in this application. We can often use coils of the coax feedline to perform the choking function. Recommended coil sizes appear in The ARRL Antenna Book.

Some Yagi designs using direct 50-Ohm feed have broader operating bandwidths than Yagis with lower feedpoint impedances. As well, the feedpoint losses are often less. Every connection represents a small loss, since the connection of one part to another will not have precisely zero Ohm resistance. When we lower the feedpoint impedance of the antenna, these resistive losses will be a higher percentage of the total impedance (the sum of the natural radiation resistance and the loss resistance) than when the radiation resistance is higher. As well, direct-feed systems usually have fewer connections than low impedance systems with matching networks.

3. *Which is best as a matching system for a Yagi: a gamma, a Tee, or a beta match?*

Once more we have an ambiguous question, the simplest answer to which is this: it all depends. . . The first consideration is whether a matching system is needed. If the Yagi has a feedpoint impedance well below 50 Ohms--say in the 20-30 Ohm range, then you will need a matching system. There are many fine Yagi designs with feedpoint impedances in this range, so understanding a little more about matching systems is wise.

a. If you are determined to use a direct connection between the driven element and the boom, then you will need to use either a gamma or a Tee match. (There is also a more complex form of the gamma called the Omega match, but we can bypass it in these brief notes.)



Note: Depending on the gamma network design and the element length, the capacitor may be optional.

Fig. 2

Elements of the Gamma Match

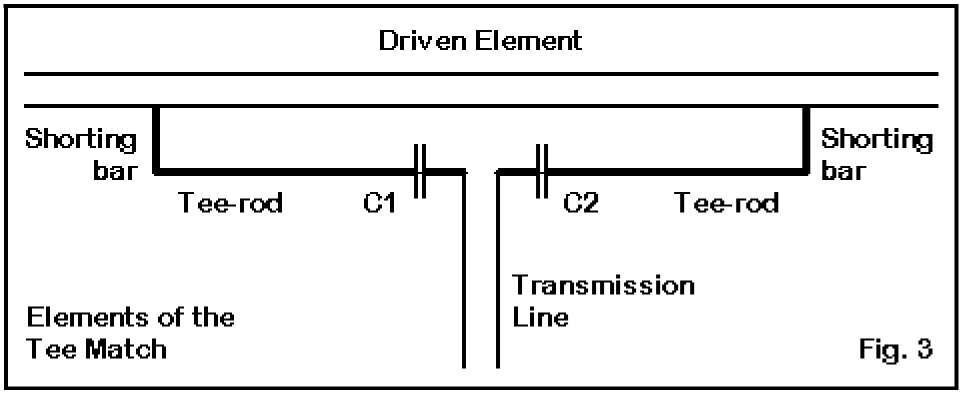
The most commonly used matching network for home-built Yagis is the gamma. As **Fig. 2** shows, it consists of a line in parallel with part of the element and connected to the element. We add a series capacitor between the coax center conductor and the gamma line. By adjusting the line diameter, spacing from the element, length, and the capacitor value, we can arrive at a good match.

The number of element playing a role in the gamma match system makes hand calculation of the dimensions very tedious. There are computer programs that can put you in the ball park and ease the adjustment. The first step is to reduce the length of the driven element to make is capacitively reactive, which often allows us to omit the capacitor.

As a starting point, make the gama rod or line about 1/3 to 1/2 the diameter of the driven element itself. Then the line can be about 0.04 to 0.05 wavelength long and spaced (center-to-center) about 0.007 wavelength from the element. The capacitor should be about 7 pF per meter (about 70 pF at 10 meters) for a resonant driven element with an impedance of about 25 Ohms.

If you use the capacitor, alternatively adjust the length of the gamma rod to the shorting bar to the main element and the capacitor until you obtain the best match. Replace the variable capacitor with a fixed capacitor. If you omit the capacitor, adjust the length of the gamma rod to the shorting bar and the length of the element until you get a perfect match.

b. The gamma match can produce some distortion in the beam pattern, since it is an unbalanced system. The distortion has shown up more at VHF and UHF than at HF, but 10 meters is just on the cusp of the VHF region. Therefore, some beam builders prefer to us a Tee match. As **Fig. 3** shows, the Tee looks like a double gamma and still permits a direct connection between the element and the boom.



Elements of the Tee Match

Fig. 3

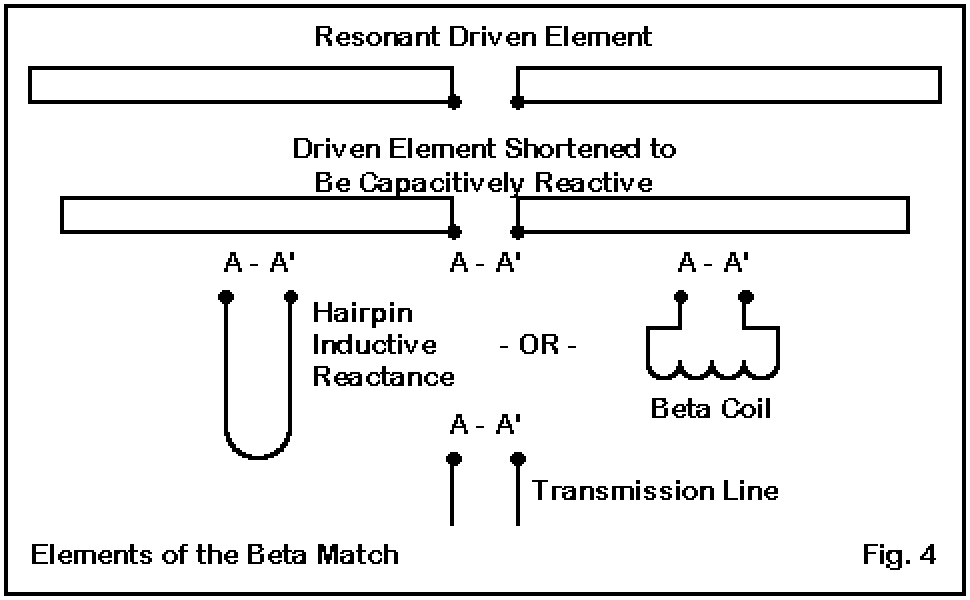
Tee match calculations are not just simple adjustments of gamma calculations. One Yagi optimizing program (YO by K6STI) has a Tee-match calculating module, and it allows you to either use the series capacitors or to omit them--although the Tee rods will be different for each case.

Some builders use the Tee match not only to obtain a good match but also to raise the feedpoint impedance to 200 Ohms. Then they place a 4:1 balun at the feedpoint to arrive at the coax 50-Ohm impedance.

As a balanced matching system, the Tee match avoids potential pattern distortions. However, it is the most complex of our matching systems and requires considerable patience to adjust.

c. The simplest balanced matching system is the beta match. We have taken a long look at the beta match in past episodes of this column. Essentially, we shall form an L-network to transform a low antenna impedance to the higher coax cable impedance.

The L-network requires a series capacitor on the low impedance or antenna side. We form this by shortening the element from its resonant length, thereby making it capacitively reactive. Then we add a shunt or parallel inductive reactance across the terminals--effectively on the coax side of the network.



Elements of the Beta Match

Fig. 4

As shown in **Fig. 4**, we can use either of two ways to obtain the required shunt inductive reactance. One method is to make a length of parallel transmission line with a short at the far end. A shorted transmission line less than 1/4 wavelength provides inductive reactance. The amount depends on the wire spacing and diameter, as well as the line length. This is the so-called "hairpin" matching device.

The other method uses a coil--wound to provide the inductance that has the required inductive reactance. Either method will do the job. The coil has slightly higher losses than the shorted transmission line hairpin, but provides a slightly wider operating bandwidth. The short at the end of the hairpin can float or you may ground it to the boom--there should be no difference in performance either way.

L-network calculations abound. One convenient program for calculating a beta match while evaluating your antenna design is YW, a program accompanying The ARRL Antenna Book.

The beta match does require that the driven element be insulated from the boom and have a center gap for the connections.

3. *What is the best way to make adjustments to my Yagi and its matching system?*

Only a few hardy folks who love working at heights enjoy adjusting a Yagi at the top of a tower. To make the initial adjustments on a Yagi, we can work closer to the ground, using a step ladder at most.

Mount the Yagi pointing straight up. The reflector should be about 5' to 10' off the ground at 10 meters for best results on the widest variety of designs. You can jury-rig an assembly to support the beam while you do your work. Just be sure to move yourself and your ladder well out of the way when making measurements to test your adjustment work. Indeed, the test site should be as much in the open as your situation permits.

Adjustments made by this system should hold if the antenna is a half-wavelength or higher in its final position. The higher the front-to-back ratio of the beam, the better the system will work, since a high front-to-back ratio minimizes interactions with the ground. This adjustment system does not give 100% assurance that you will not have to make further adjustments when you get the beam mounted at its operating height, but it should handle 90% or more of the cases and the work.

Hopefully, these brief answers to frequently asked questions will get you started toward better antenna building. As I have noted on several occasions, if you plan to roll your own antennas--whatever the type--or if you simply want to understand antennas better, make sure that you have a copy of *The ARRL Antenna Book* on your shelf--or better, on your work bench opened to a relevant section.

No. 41: A 10-Meter J-Pole

L. B. Cebik, W4RNL

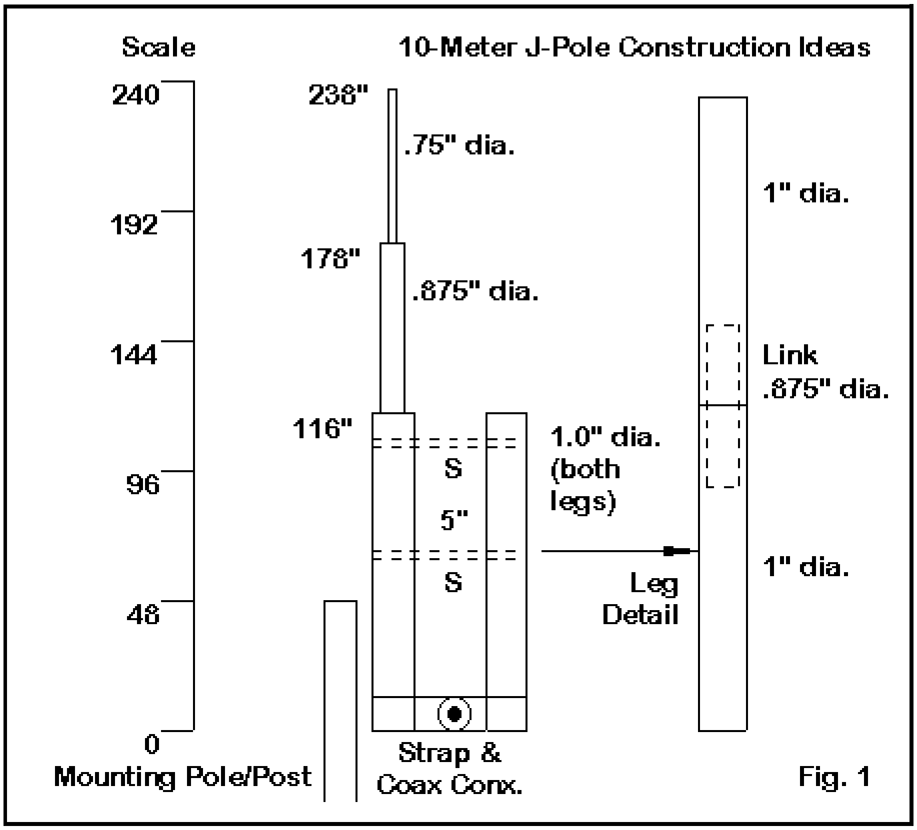
Many 10-10 operators live in restricted spaces calling for a vertical antenna. Sometimes, the roof-top is not accessible for a simple monopole with radials. However, the alternatives may also be unattractive for the situation. A vertical dipole calls for an elevated feedpoint with the feedline carried away at right angles to avoid RF pick-up on the outside of the line.

So the question that emerges is this one: is there a 10-meter vertical that will cover all of the band that I can feed from the bottom without using any radials?

The answer is "Yes: the J-pole." Ideally, a J-pole is a vertical dipole set above a quarter-wavelength matching section composed of the same materials as the antenna. The end of a dipole shows a very high impedance, unsuited for coax feedline. However, a quarter-wavelength of parallel feedline can transform a very high impedance into a very low one. With the right juggling of dipole length and matching section length, we can obtain a broad 50-Ohm feedpoint impedance.

The J-pole has another advantage: the main radiation from the antenna begins where the dipole portion is above the two-legged matching section. The main current is about half-way up the free and clear dipole section. The effect is the same as placing a ground-plane monopole at a 1/2-wavelength height in terms of added signal strength.

The J-pole's disadvantage--especially on 10 meters--is that it is a considerable structure. The version we shall examine is 20' tall. However, it does not have much side-to-side dimension. Like all vertical antennas, we should install it as far away from houses, trees, and shrubbery as our home site makes feasible. How high we should place the base of the antenna is a question that we shall look at before we are done.



I have designed an interesting variation on the usual J-pole that uses common aluminum tubing that one can obtain either from a hardware depot or from one of the usual sources of antenna tubing stock (such as Texas Towers, among others). The bottom sections are 1: diameter stock, with the dipole consisting of 7/8" and 3/4" stock nested. **Fig. 1** shows the basic details. The first thing that you will notice is that the antenna has several features unlike some of the VHF J-poles that are so common. The usual J-pole design has a shorting bar at the base and we then probe up the twin legs until we find the 50-Ohm matching point. This version has dimensions that place the 50-Ohm feedpoint at the very base of the antenna. Hence, the strap in the figure should be non-conductive (plastic, etc.), with a coax connector and fat leads to each leg. Remember that the feedline is in series with the connections. We also need to place a 1:1 choke balun at the feedpoint to suppress any RF on the outside of the coax.

This design results in upper dimensions quite different from the usual J-pole. The legs are considerable longer than 1/4 wavelength--about 10" longer. At the same time, the upper section is shorter than 1/2 wavelength, nearly 90" shorter. Why?

Essentially, the dipole leg extends well down into the double-leg region of the antenna. This does not block or cancel radiation, since the high current region is still well above the matching portion of the structure. Many J-pole enthusiasts believe that the structure should be as perfectly a 1/2-wavelength antenna + 1/4-wavelength section as possible. However, the currents in the matching section can never be equal in magnitude and opposite in phase, since one end of the matching section is open-ended and the other is continuous with the radiating portion of the antenna. Hence, such perfection is an illusion. The object is to arrive at a set of dimensions that will radiate effectively and provide a match for our feedline.

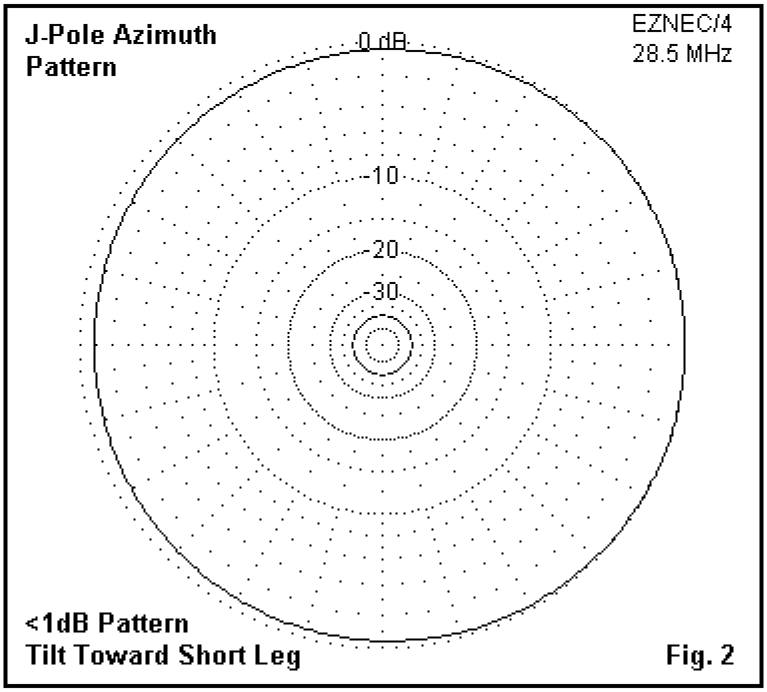


Fig. 2

The J-pole pattern is omni-directional, with only a very small offset created by the double-leg matching section. **Fig. 2** shows a typical azimuth pattern, along with the very small offset in the direction of the open-end leg of the matching section. The offset cannot be detected in operation.

Now we can see if raising the base of the antenna makes any difference to performance.

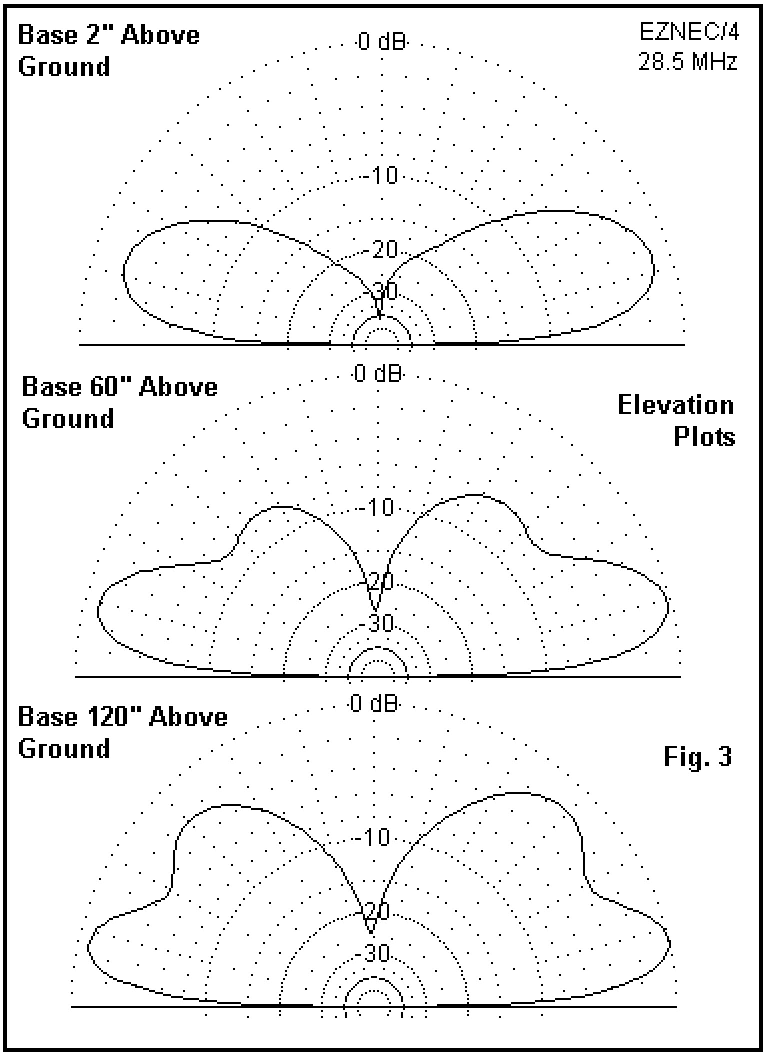


Fig. 3 gives us the answer. With the antenna close to ground, we obtain a single-lobe elevation pattern about 1 dB (hardly detectable) weaker than more elevated base positions. The antenna will be about 20' tall overall, and most installations would opt for this height as the simplest mechanically.

The middle pattern raises the base of the antenna 5' off the ground, for an overall height of 25' for the tip. We obtain close to maximum gain in the lowest lobe, along with some radiation at higher levels. Some folks prefer this height because it gives better short-skip performance without changing the DX performance.

The bottom pattern raises the antenna base to 10' off the ground, for a total structure height of 30'--almost the same as a 1/4-wavelength ground-plane monopole for 40 meters. At this height, we do not gain more than a dab of gain at the lowest level, but we do acquire even stronger high-angle radiation.

As we raise the antenna, we also acquire the need for sturdier base materials for installation. At the lowest level a buried 4x4 or PVC pipe section can support the antenna. The longer the support above ground, the longer the portion in the ground, if we wish a stable structure. Hence, most folks place the base fairly close to ground.

The other structural cautions involve stabilizing the structure itself. First, note the spacers in Fig. 1.

Any plastic material that will stand up to the sun will do to keep the matching section legs correctly spaced at 5" center-to-center. Second, the tapering diameter upper potions of the antenna will sway in the wind. Adding light rope (1/8" to 3/16" diameter) guys will limit the sway and the extend the life of the tubing.

The mounting system that you devise for the antenna will detune it from its ideal conditions. However, the design has some adjustability in it. First, the long matching-section legs are composed of two pieces of tubing, with a linking tubing piece inside. Hence, we can lengthen the legs (or shorten them if we make the 1" sections total just a little less than 116"). As well, the upper sections of tubing are each shorter than the usual 6" store lengths. Hence, we have the ability to lengthen or shorten the overall height of the antenna.

Tuning up the antenna is a matter of juggling the matching section leg lengths and the overall length of the antenna. Increasing the leg lengths while keeping the overall height constant raise both the resistance and the reactance at the feedpoint. Raising the total antenna height while keeping the matching legs constant raises reactance but lowers the resistance. Hence, by juggling the leg length and the total height, we can create an SWR curve that is less than 2:1 across the entire 10-meter band from 28.0 to 29.7 MHz. All-stainless-steel hose clamps with slots in the upper ends of the tubing make a good way to adjust and them tighten down the final assembly.

These notes have only pointed at the mechanical features of a J-pole installation. Before buying any tubing for one, be sure to plan carefully the entire mounting system. If you use metal devices to attach the antenna to the mounting post or pole, expect to spend a bit of time retuning the antenna for full band coverage. Do not use a metal pole for mounting. Instead, use a ground lead from the coax side of the RF choke balun at the feedpoint and connect it to an 8' ground rod.

If you use tubing diameters other than those listed, also expect to spend considerable time tuning up your version of the J-pole. As we raise the operating frequency, changes in element diameter of even 1/8" become larger influences on the resonant frequency of an antenna. At 10 meters, we cannot use the dimensions listed in an article unless we also use the same materials.

Avoid the cheap aluminum electrical conduit for antenna elements, whether vertical or horizontal. It is both heavy and soft. The end result is often a bent element or a broken mounting system. The lighter and harder aluminum tubing used by commercial antenna makers is still the best material for the home antenna builder.

The J-pole is not a magic antenna, but it is a useful addition to the array of verticals at our disposal. Expect it to perform like any other vertical dipole at the same top height. But if you need a vertical and want to feed it at the base, the J-pole may be a good candidate for the job.

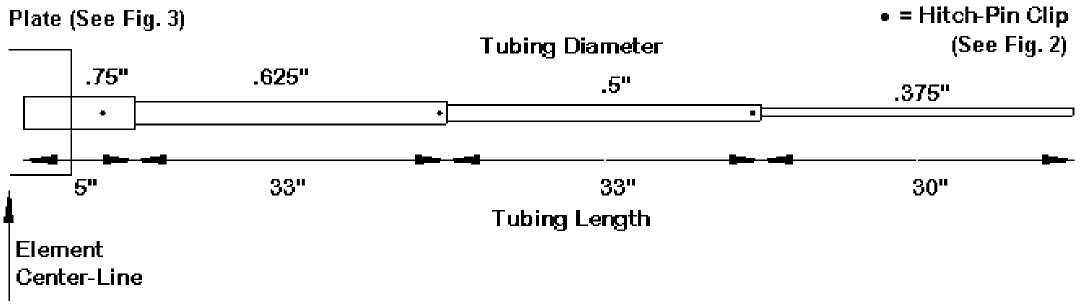
No. 42: A Hilltopper Portable Dipole

L. B. Cebik, W4RNL

A rotatable dipole is a very useful antenna for portable or hilltop operations. Unlike a vertical that should have a ground plane, the dipole is horizontal and needs none. Of course, we do have to think about a support mast. It may consist of 3-4 5' sections of TV mast or even a painter's pole--each with at least 3 guy ropes and tent stakes to stabilize the system.

But what about the antenna? We can make a dipole from wire, tubing, end-to-end whips, and a bunch of other materials. The featured system for this episode is made from tubing. We can easily obtain 3 6' lengths of aluminum tubing from sources like Texas Towers at very reasonable prices. We shall need 6' of 5/8" diameter, 6' of 1/2" diameter, and 6' of 3/8" diameter tubing. T6063-832 is the most usual tubing to use because each size nests well inside the next larger size.

A good portable antenna should require an absolute minimum number of tools for assembly in the field. How about 1 wrench to tighten the center plate to the mast. We shall need no other tools to assemble and disassemble our antenna.



General Tubing Layout for Each Half of Element

Fig. 1

Fig. 1 shows the basic tubing layout on each side of the center plate. We cut the 6' tubes in half. Then we carefully smooth the cuts so that the 3' sections will slide easily inside each other. The two larger tubes need a 33" exposure, with 3" inside the next tube. The smallest tube needs only a 30" exposure, and you can either cut off 3" or have 6" of tubing inside the next size. With 5" on the center plate (discussed a bit further on), we shall have 101" each side of center or 202" overall--a good size for the lower MHz of 10 meters.

When not in use, slide the tubes for each side of the dipole inside each other. You will end up with an easily stored 3' long set of element pieces. As well, you will always have the correct sections in place, just in case the holes for comparable pieces on each side are not perfectly aligned for complete interchangeability.

Our fastener will be the hitch-pin clip--also known as the hairpin cotter pin and some other names. For clarity, **Fig. 2** shows the shape of the clip.

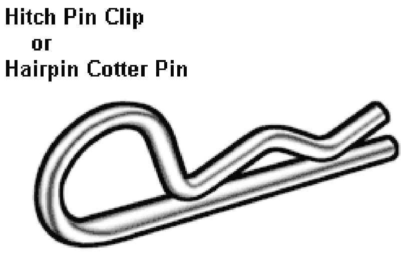


Fig. 2

We drill holes through each pair of tubes at the center of the tubing junctions all the way through. Clean the drilled holes. The hole size depends on the clip material diameter. Choose clips designed to fasten tubes of the diameters that you are using. When we assemble the antenna in the field, we simply align the holes and press a hitch-pin clip through them. The sections are secure.

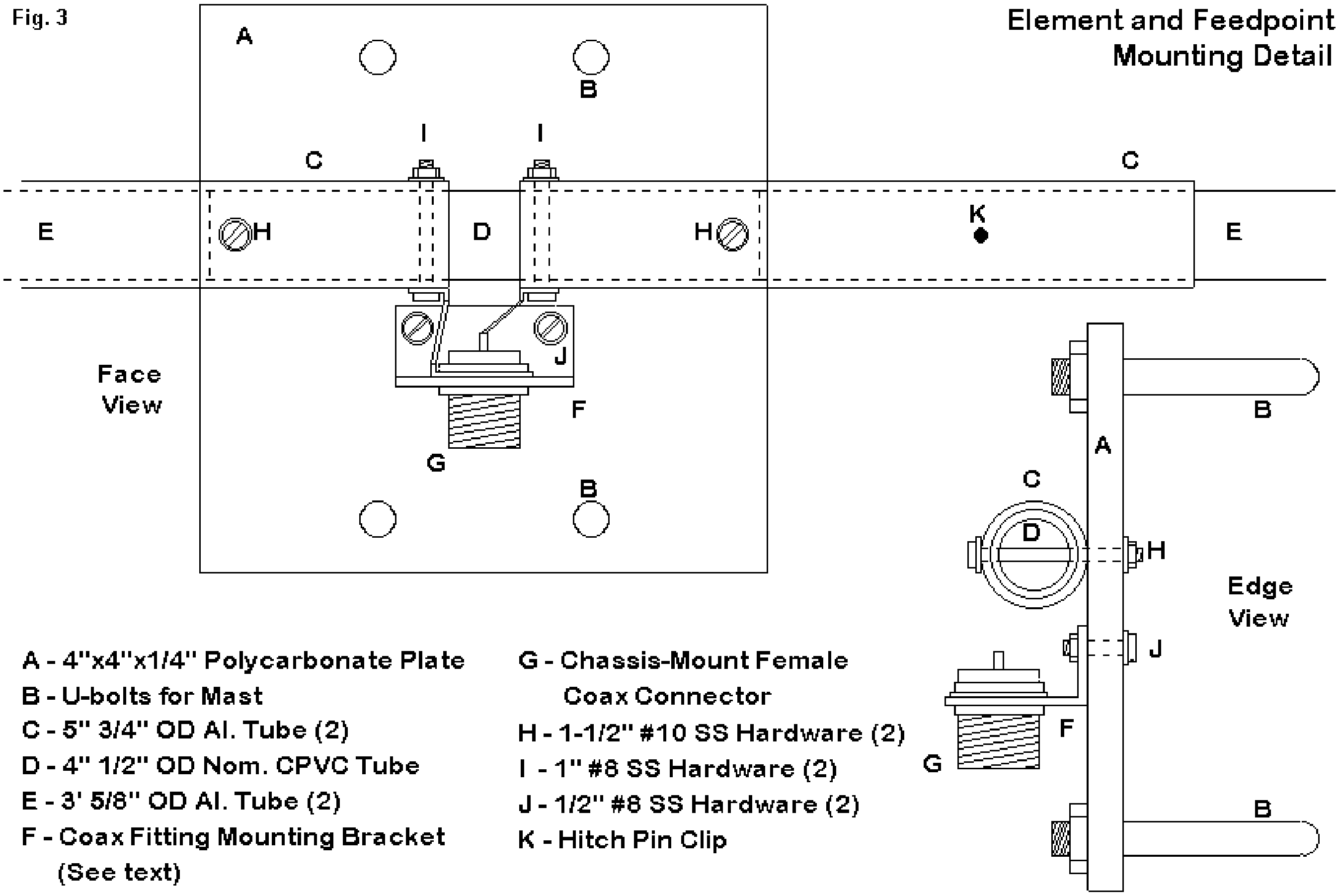
The electrical contact from one tube to the next depends on the tubes themselves. Hence, it makes sense to be sure that the tubing ends are clean inside and out before each field use. Do Not use the hitch-pin clip system for a permanent home antenna, since the tubes may accumulate dirt that may interrupt electrical contact. But for short term field use, this system work very well indeed.

To avoid losing clips in the grass or gravel of the field site, you can tie a bright ribbon to each one. For storage, you can clip all of the clips to a designated master clip.

Now all that we need is a center section so that we can assembly the elements and connect a length of coaxial cable. **Fig. 3** shows the system that I am using.

Fig. 3

Element and Feedpoint Mounting Detail



A - 4"x4"x1/4" Polycarbonate Plate
B - U-bolts for Mast
C - 5" 3/4" OD Al. Tube (2)
D - 4" 1/2" OD Nom. CPVC Tube
E - 3' 5/8" OD Al. Tube (2)
F - Coax Fitting Mounting Bracket (See text)
G - Chassis-Mount Female Coax Connector
H - 1-1/2" #10 SS Hardware (2)
I - 1" #8 SS Hardware (2)
J - 1/2" #6 SS Hardware (2)
K - Hitch Pin Clip

I had some polycarbonate (tradename: Lexan) plate 1/4" thick in the shop. However, you can use plywood or acrylic for the center plate. A 4" by 4" square will do the job. At the top and bottom of the plate, drill holes for U-bolts that are sized to the mast diameter that you will use.

Note that the elements cross the plate just above the centerline in order to leave room for a coax connector. I used a short section of 1" by 1" L-stock, 1/16" thick for my connector. The connector is the version that mounts in a chassis hole. It is useful to cut the 5/8" connector hole and screw holes before cutting the stock to its final inch and a quarter length, and a bench vise helps hold things in place during this work. The plate is a bit wide than it needs to be for the connector so that the screw holes will miss the mast behind the plate. In fact, I placed the heads of the screws on the mast side of the plate so that the nuts would not interfere with the mast.

Note that a short lead runs from the connector center pin and the ground lug to each side of the element. The element center pieces consist of scraps of 3/4" tubing lying around in the shop--cut-offs from old projects. In each 5" piece of 3/4" aluminum tubing, we need two sets of through holes. One set holds the tube to the place near the plate edge. The other set--at right angles to the first set--is at the inner end of each tube. The hardware holds solder lugs for the connector leads.

We need one more piece of material for our assembly. 1/2" nominal CPVC just fits inside of 3/4" aluminum tubing. a 4" piece runs through the inner ends of each of the plate tubes. The CPVC keeps the tubes perfectly aligned and maintains the gap between them. A gap of about 1/2" between the ends of the 3/4" tubes works well, but 3/8" to 1" gaps are fine.

Since we used about 2" of each 5" tube on the plate with the CPVC inside, we have 3" of tubing extending off each side of the plate. This is the necessary 3" overlap for the 5/8" section of element tubing. Of course, we use hitch-pin clips to secure the element section to the center plate tubes. When complete, we should never have to touch the nuts and bolts on the center plate in the field. (Check their tightness before taking the antenna to the field.) We simple hitch-pin the entire dipole together for use, connect a coax cable, and operate. Of course, fastening the plate to a mast and raising the mast will help our signals immensely.

My YL (Jean, N4TZP) stitched up an old but sturdy bath towel into a carry bag with a draw-string. So the dipole pieces are protected from dirt and bumps, but are always ready for use. In the bag, I have a dedicated wrench sized to the U-bolts ready for action. The 4" by 10" center plate assembly and the 2 3' long element assemblies make a compact package to carry. I have a bright ribbon on the center of the wrench, matching the ribbons on the hitch-pin clips. Incidentally, I store the mass of hitch-pin clips in one of the holes on the 3/4" center plate tubes. My goal is always to make everything ready to use and difficult to lose.

A little over 10 years ago, just before I started this series of antenna columns, I wrote an article for *10-10 News* about a rotatable portable dipole using some materials adapted from the ground plane radials of an old CB antenna. I think that I like the present field antenna a little bit better. It stores in a smaller space and the materials are easily obtained. As well, the total cost is in the cheap range. While the shop work requires some care, the field work is as simple as I know how to make it.

The antenna is also adaptable for use on upper floor apartment balconies. In fact, if your balcony is at least 20' above ground, you can use a horizontal mast and hand turn the antenna from horizontal to vertical polarization. It works well either way. The antenna is also usable in emergency situations, whether the emergency is a matter of community communications when other circuits are down or simply a matter of the main station beam failing just as the band opens.

No. 43: A Small 10-Meter Very-Wide-Band Yagi

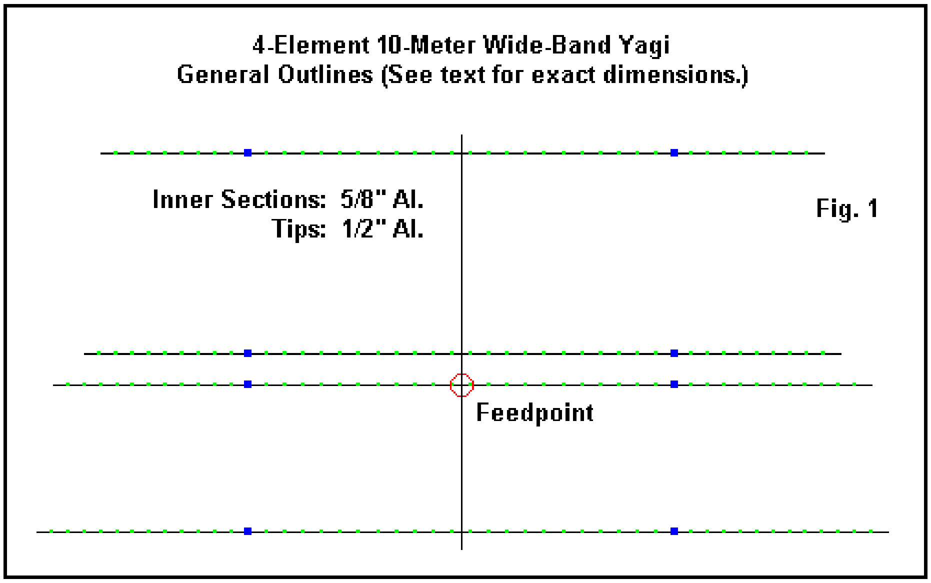
L. B. Cebik, W4RNL

Some 10-meter fans like to work not only the low end of the band for the CW, digital, and SSB activity, but also the upper end of the band, for a few rounds of nostalgic AM action. In this episode, we shall look at a 4-element Yagi that covers all of 10 meters with a 50-Ohm (direct feed) SWR under 2:1 and with at least 7 dBi of free-space gain (about the same as a narrow-band 3-element Yagi with the same boom length). The front-to-back ratio will dip below 20 dB only at the band edges. All of this will fit on a boom just over 8' long.

While we are at it, we shall look at some very sound assembly techniques for beam construction. This Yagi requires careful construction, and so we might as well use the best materials and techniques for putting it together. Even if you do not like the design, the construction methods are suitable to almost any 10-meter Yagi you might prefer.

The Basic Design

The Yagi consists of 4 elements, one of which is the 50-Ohm driver. Hence, we do not need a matching network, although a common-mode current suppressing choke--such as a 1:1 ferrite bead "balun" is always a good precaution at the feedpoint. There is a standard reflector, plus 2 directors. One of the directors is spaced close enough to the driver to count as a "slaved driver" to extend the performance of the antenna over the upper end of the band. **Fig. 1** shows the general outlines of the antenna.



The boom length, including ends to support the element mounting plates, should be about 9' long. You can make one from 6' long pieces of 1.25" and 1.125" aluminum by using a 6' and 3' section of each type, but placing the junctions at opposite ends of the boom. The elements consist of lengths of 5/8" aluminum at the center with 1/2" aluminum tips. Obtain 6063-T832 high-grade aluminum tubes (by mail order, if necessary). Do not substitute elements of other diameters in this project, since the element interactions are very specific to the performance. All inner sections extend 54" from the element centers or the boom-line. The tip lengths will change from one element to the next in accord with the following table. Be sure to add 2 to 3 inches to the tip to fit inside the inner sections.

Element Lengths and Spacing: 4-Element Wide-Band 10-Meter Yagi

Element	**Tip-to-Tip Length Inches**	**Outer Tip Length Inches**	**Space from Reflector Inches**	**Space from Preceding Element Inches**
Reflector	**215.5**	**53.75**	**----**	**----**
Driver	**207.2**	**49.6**	**37.5**	**37.5**
Director 1	**191.8**	**41.9**	**45**	**7.5**
Director 2	**182.6**	**37.3**	**96**	**51**

Construction

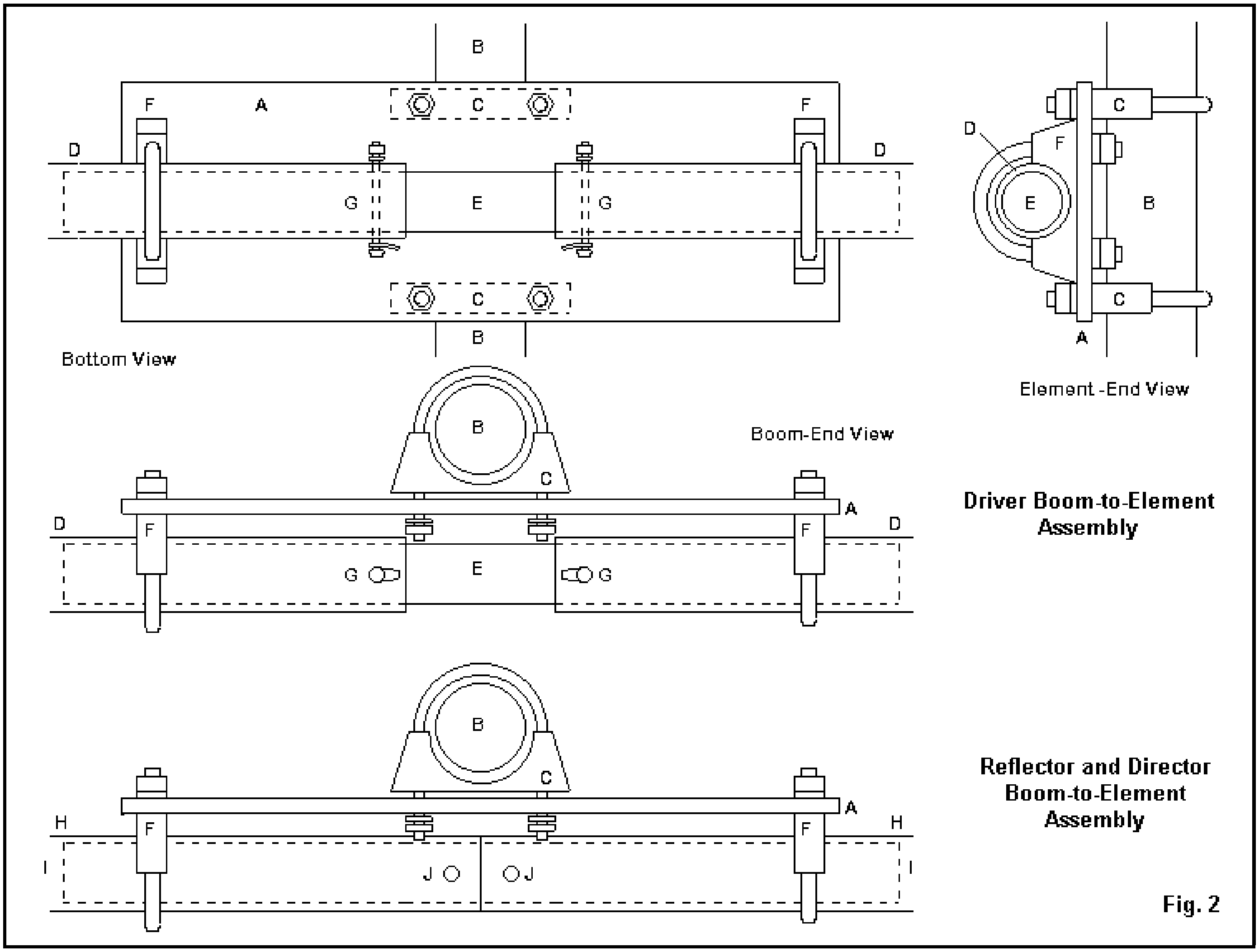


Fig. 2

Fig. 2 shows the construction of high-quality junctions of the elements to the boom (B). Item A is a nonconductive plate (polycarbonate), about 9" by 6" by 1/4". Do not use metal plates, since the dimensions shown are based on well-insulated and isolated elements, relative to the boom. The boom attaches to the plate with U-bolts equipped with saddles to reduce tube compression. The U-bolts and all other hardware, including washers and lock washers should be stainless steel. The elements are secured to the plate with similar U-bolts (F), sized to the element diameter.

The driver assembly requires a gap--which is part of the overall element length, not an addition to it. Use a 1/2" diameter tube or fiberglass rod the length of the plate (E) to align the driver halves (D). Run #8 nut-bolt-washer-solder-lug combinations one each side of the driver (G) for connections. (See below for the coax connector). The parasitic elements use a simpler mount. Use 1/2" tubing the length of the plate as a junction between the parasitic element halves (H), with sheet metal screws (J) to complete the assembly.

Fig. 3 shows one good way to add a female coax connector to the driver plate, using one set of the U-bolt nuts to hold it in place. Use a short section of aluminum L-stock, 1" by 1" by 1/16" thick (J). Cut a 5/8" hole in one side of the stick for a standard 1-hole connector (K). Use the shortest leads feasible from the connector to the element solder lugs (G). Coat all exposed soldered connections and the rear of the coax connector with a plastic insulating material, like PlastiDip. Be sure that the connector and its plate are on the mast side of the driver element for the shortest, most direct coax run.

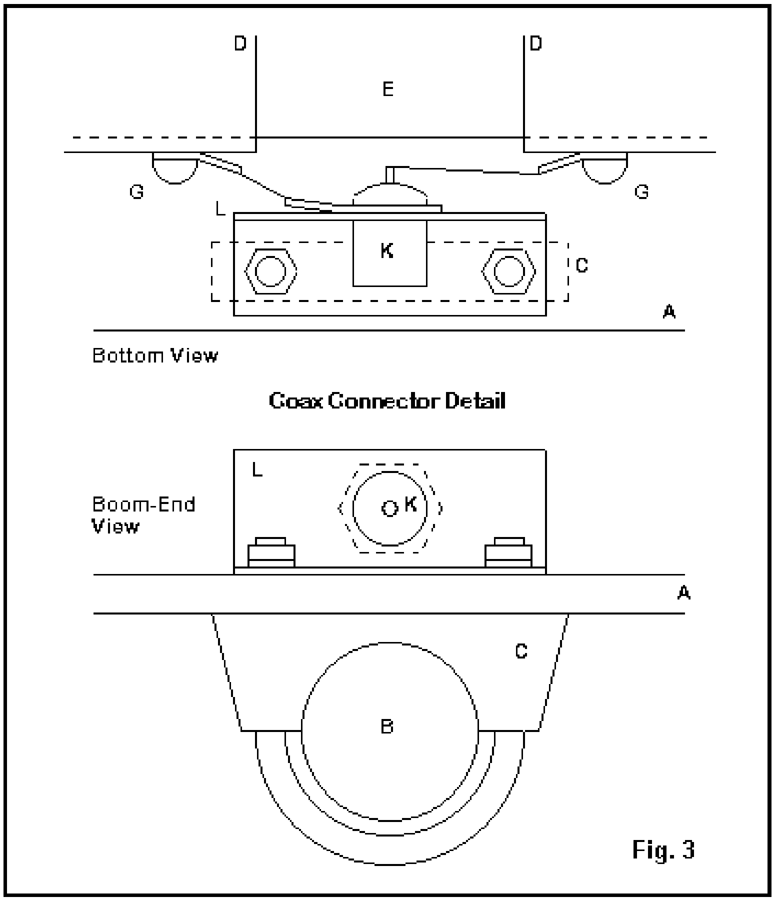


Fig. 3

Performance

How well does the antenna perform across 10 meters. The following table gives free-space figures across the band. Add about 5.5 dB to the gain for a height of about 1 wavelength.

Modeled Performance of the 4-Element Wide-Band 10-Meter Yagi

Freq. MHz	**Gain dBi**	**F-B Ratio dB**	**Impedance R +/- jX Ohms**	**50-Ohm SWR**
28.0	**7.04**	**19.2**	**49.4 - j 8.2**	**1.18**
28.25	**7.02**	**22.0**	**49.7 - j 7.7**	**1.17**
28.5	**7.04**	**25.4**	**48.7 - j 5.6**	**1.13**
28.75	**7.10**	**30.7**	**47.4 - j 2.3**	**1.07**
29.0	**7.19**	**32.8**	**46.6 + j 2.0**	**1.09**
29.25	**7.31**	**25.9**	**47.1 + j 6.5**	**1.16**
29.5	**7.44**	**21.0**	**49.2 + j 9.5**	**1.21**

29.7	**7.55**	**18.0**	**51.7 + j 8.4**	**1.18**

For a Yagi covering a 7% bandwidth, the gain is remarkably smooth, climbing gradually in the upper part of the band. The front-to-back ratio dips below 20 dB only at the band edges, but is still very good. The key to the SWR performance is the spacing and sizing of the driver and the first director. **Fig. 4** provides a graph of the 50-Ohm SWR across the entire 10-meter band. With proper construction, the 50-Ohm SWR should not rise above about 1.25:1 anywhere in the band.

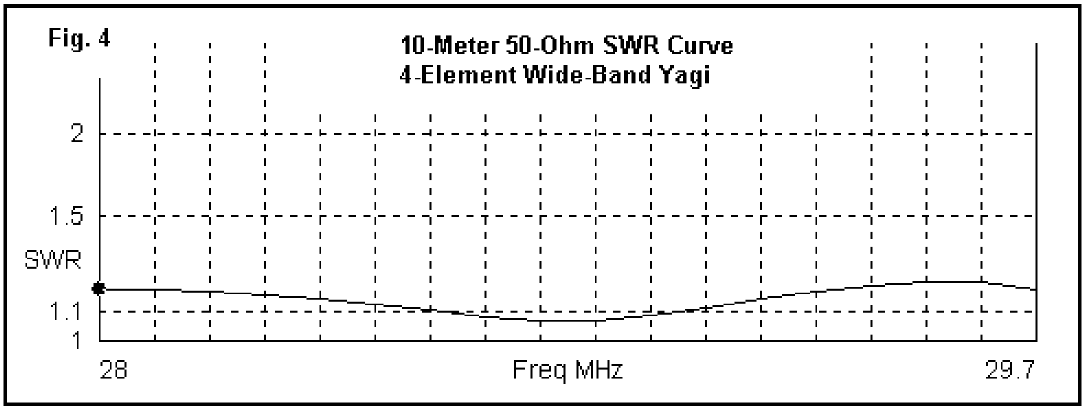


Fig. 4

Since the antenna has a 50-Ohm feedpoint impedance, you do not need any kind of matching network. Direct coax feed is preferred. However, you may wish to install a ferrite bead choke of W2DU design (available from many sources, such as the Wireman of South Carolina) in order to attenuate common mode currents on your main feedline. Sources of other components include such places as Texas Towers for the aluminum tubing and DX Engineering for the stainless steel saddle U-bolts. All of these--and other suppliers--advertise in *QST*. These supply notes are not an endorsement of any particular provider, but only represent sources that I have successfully used.

Even if you do not need a very-wide-band Yagi, the construction methods shown here are sound for almost any Yagi design. If you are copying a magazine design, look carefully at how the elements are mounted to the boom. If the elements are separated electrically, your version should also do so; and likewise for a design that specifies electrical contact with the boom. These specifications are not interchangeable, since boom contact requires a redesign of element lengths to compensate for the contact. This design uses insulated element mountings.

If you ever thought that all Yagi designs were standardized, you now know differently. This little beam is an example of how Yagis can be designed to do specific jobs, and each job carries with it its own requirements for element length and spacing. You can explore past columns, as well as the *An-Ten-Ten-nas* book, for examples of other designs and the ways in which the design specifications affect the element lengths and spacing.

No. 44: A Large 10-Meter Very-Wide-Band Yagi

L. B. Cebik, W4RNL

In the last episode, we examined a 4-element very-wide-band Yagi on an 8'+ boom. The antenna covered all of 10 meters from 28.0 to 29.7 MHz with reasonable gain (7.0 dBi free-space or about 12.5 dBi over ground), good front-to-back ratio (20 dB), and a direct-feed 50-Ohm SWR of less than 1.25:1 across the band. We also discovered that we could build such a beam using high-grade materials, if we were willing to use mail order and similar sources of supply.

This month, we shall explore a Yagi with similar coverage. The design is based on an original by Dean Straw, N6BV, of ARRL. The difference between Dean's Yagi and my smaller design last time is that his beam uses a 26' boom and has 6 elements. For the increase in boom length, we obtain an additional 3 dB of gain (10 dBi in free space or 15.5 dBi over ground), with all other operating specifications being the same as the smaller unit. The front-to-back ratio is about 20 dB across the band, and the 50-Ohm SWR does not rise above 1.25:1. If you like long-boom Yagis, you may take a shine to this one.

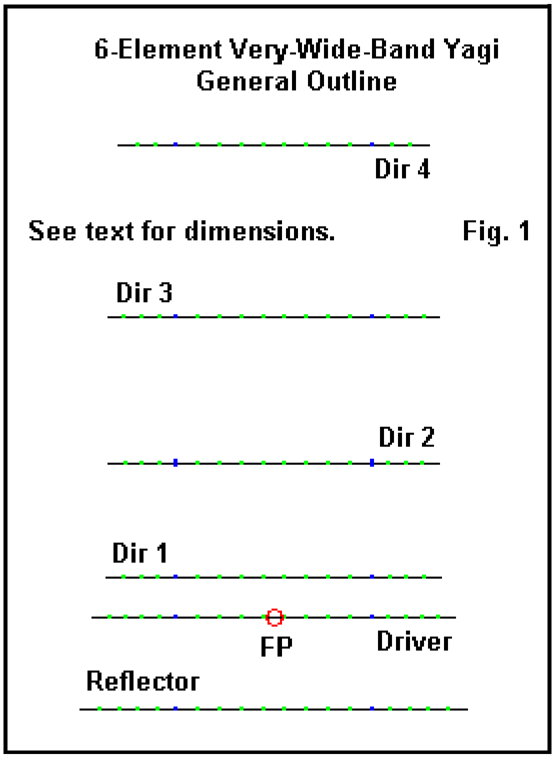
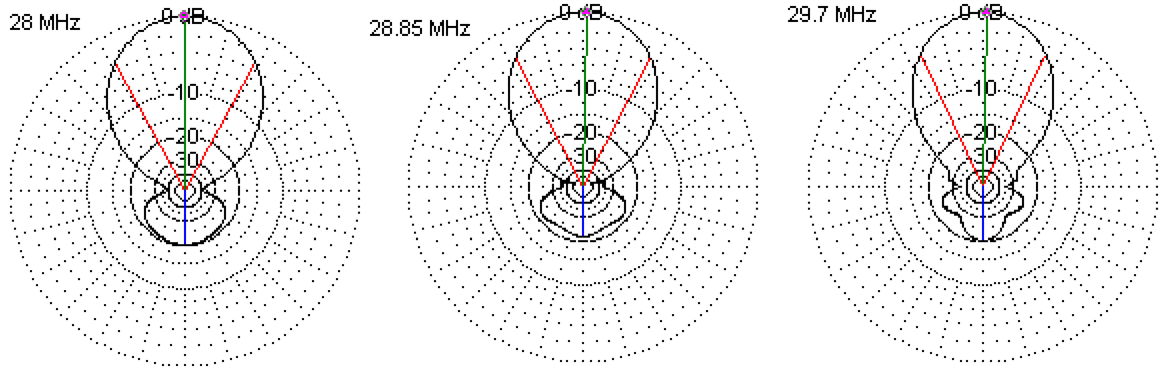


Fig. 1 shows the general proportions of the antenna. Once more, we see that the first director is

quite close to the driver, although not as close as in the short boom Yagi that we presented last time. However, this time, let's look at the performance characteristics before we examine the construction.

Performance

The very-wide-band 6-element Yagis has very clean patterns that vary only slightly as we move across the band. It is quite natural for the rear lobes to change shape across a wide operating passband, while the forward lobe tends to hold its shape from one band edge to the other,



Representative Azimuth Patterns
6-Element Very-Wide-Band Yagi

Fig. 2

Fig. 2 shows representative azimuth patterns for the antenna at the band edges and at mid-band. The overall area within the rear lobe does not change much across the band, although the perimeter does change shape. The forward lobe is relative constant, with the emergence of very slight bulges at the upper end of the band. If we could have extended the operating range any further, we would find that these bulges would develop into small secondary forward lobes. If we had added more elements for higher gain, the secondary forward lobes would have become a permanent feature of all the patterns, as they are in most VHF Yagi design of 8 or more elements.

Modeled Performance of the 6-Element Wide-Band 10-Meter Yagi

Freq. MHz	Gain dBi	F-B Ratio dB	Impedance R +/- jX Ohms	50-Ohm SWR
28.0	9.63	20.2	44.5 - j10.1	1.25
28.25	9.72	21.8	50.1 - j 5,8	1.12
28.5	9.83	22.9	52.9 - j 2.0	1.07
28.75	9.98	21.8	55.2 + j 1.3	1.11
29.0	10.09	20.9	56.7 + j 3.8	1.16
29.25	10.22	20.1	56.7 + j 5.0	1.17
29.5	10.32	19.8	53.7 + j 5.8	1.14
29.7	10.37	20.2	48.3 + j 7.7	1.18

The table of performance values from the design model shows how smooth the performance is across the band. The gain varies by only 0.75 dB in that entire span, an amount that would be completely undetectable operationally. The front-to-back ratio varies by only 3 dB, again, an amount that we would be hard pressed to detect, even in cross-town checks with a friend.

The antenna uses a direct feed and is a good match for 50-Ohm coaxial cable. As usual, I recommend the use of a means of attenuating common-mode currents on the cable, that is, a ferrite bead choke balun of the W2DU type that is readily available from numerous sources. Unlike 1:1 current balun transformers that are bulky, the ferrite bead balun is relatively thin and liner. Hence, you can tape it to the boom and it projects hardly more than the coaxial cable itself. **Fig. 3** shows the 50-Ohm SWR curves across the band. Notice that the values tend to undulate in minor ways, a feature of the driver-first-director combination.

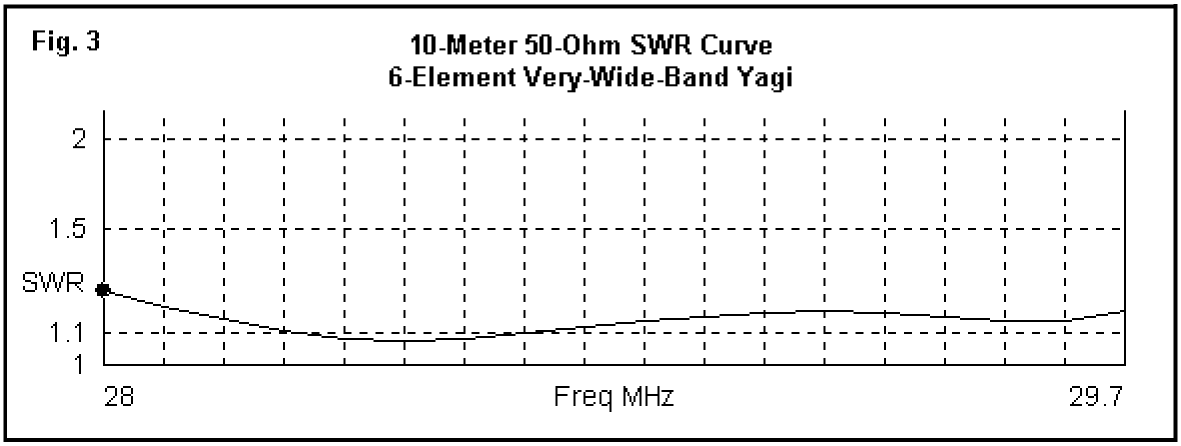


Fig. 3

10-Meter 50-Ohm SWR Curve
6-Element Very-Wide-Band Yagi

Construction

Except for requiring a very long boom, the 6-element very-wide-band Yagi uses the same construction as the 4-element version that we have already examined in detail. The elements consist of inner section of 5/8" diameter aluminum, with 1/2" tubing used for the tips. Use 6063-T832 tubing, which is available from suppliers. The design calls for elements that are well insulated from the boom, so the sketches in the last column are completely adaptable to this antenna, right down to the way of mounting a coaxial cable connector to the overall driver assembly.

The inner 5/8"-diameter tubing sections extend 54" each side of centerline. Some builders may be concerned about the wind loading capability of such long inner sections. If you wish to strengthen them a good bit, the simply extend the inner tubes about a foot or so beyond the limits of the 9-12-inch long mounting plates. For the parasitic elements, these inner tubes will be 1/2" diameter aluminum. For the driver, the inner piece will be a non-conductive tube or a fiberglass rod, either with a 1/2" diameter.

The following table provides element length and spacing dimensions. Be sure to add 2 to 3 inches to the lengths of the tips for the required overlap. An overlap under 2" is likely to be insecure, while one longer than about 3" simply adds unnecessary weight to the beam.

Element Lengths and Spacing: 6-Element Wide-Band 10-Meter Yagi

Element	Tip-to-Tip Length Inches	Outer Tip Length Inches	Space from Reflector Inches	Space from Preceding Element Inches
Reflector	214.6	53.5	----	----
Driver	201.6	46.6	50.9	50.9
Director 1	186.6	39.3	72.8	21.9
Director 2	184.0	38.0	136.2	63.4
Director 3	184.8	38.4	216.8	80.6
Director 4	174.0	33.0	312.0	95.2

Fig. 4 shows three generally accepted ways of joining two sections of elements. The easiest way is to use sheet metal screws. Most builders use two per junction, although they are divided on where to place them. Some builders place them in a line, while others place one on each side of the tube so that the points face each other. The second method uses a hole all the way through both tubes. Some builders are now using aircraft (not hobbyist) rivets, while others use a nut-bolt assembly with lock washers on each side. The third method cuts slots in the larger tube and uses stainless steel hose clamps to lock the sections together. With all hardware, be certain that all parts of it are stainless steel. Some auto hose clamps use stainless straps but plated (rustable) screws.

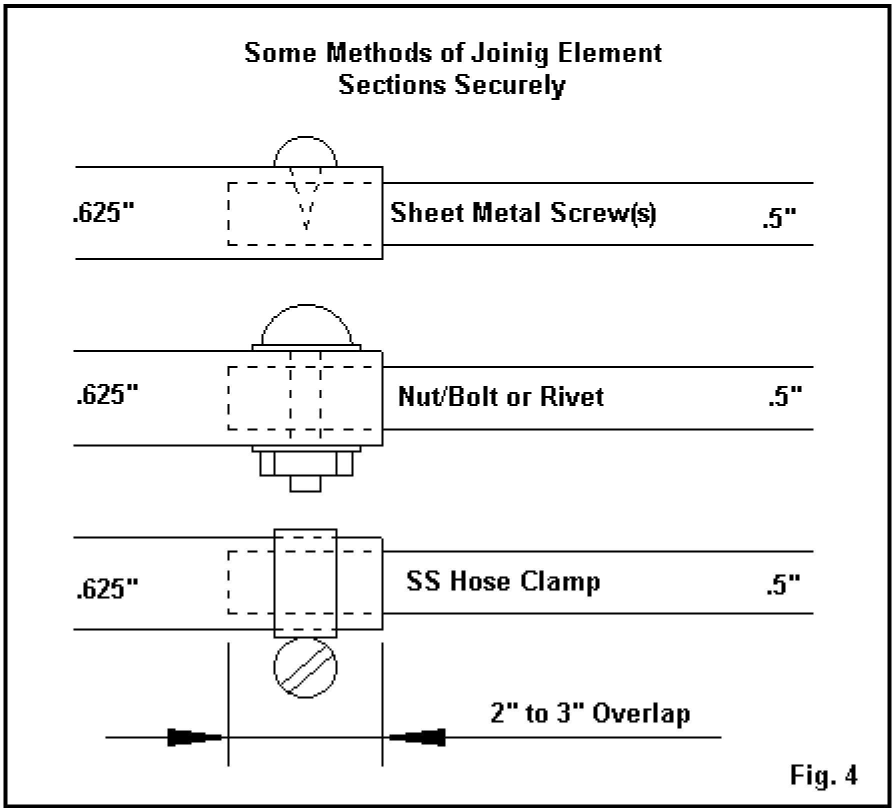


Fig. 4

Like the smaller antenna, the design uses very specific element section diameters. Even changing the relative lengths of the inner and outer element sections can change performance noticeably. Trying to change the overall element diameters to use larger or smaller tubing will throw off the design even more. A Yagi depends for its performance on the mutual coupling between adjacent elements, and changes in element diameter alter that coupling. Unfortunately, too few books and articles point out this limitation of Yagi design, and too many beginning beam builders try to substitute handy materials--usually with very frustrating results. If you do not have the means of performing the re-design work, try to replicate any design that you like as exactly as possible.

The 26' long 6-element very-wide-band Yagi is a sample of what can be done with Yagis. You may wish to compare its dimensions with designs that aim only to cover the first MHz of the band. The differences in element lengths, spacing, and overall boom length may be instructive.

No. 45: What Should I Expect from a Yagi?

L. B. Cebik, W4RNL

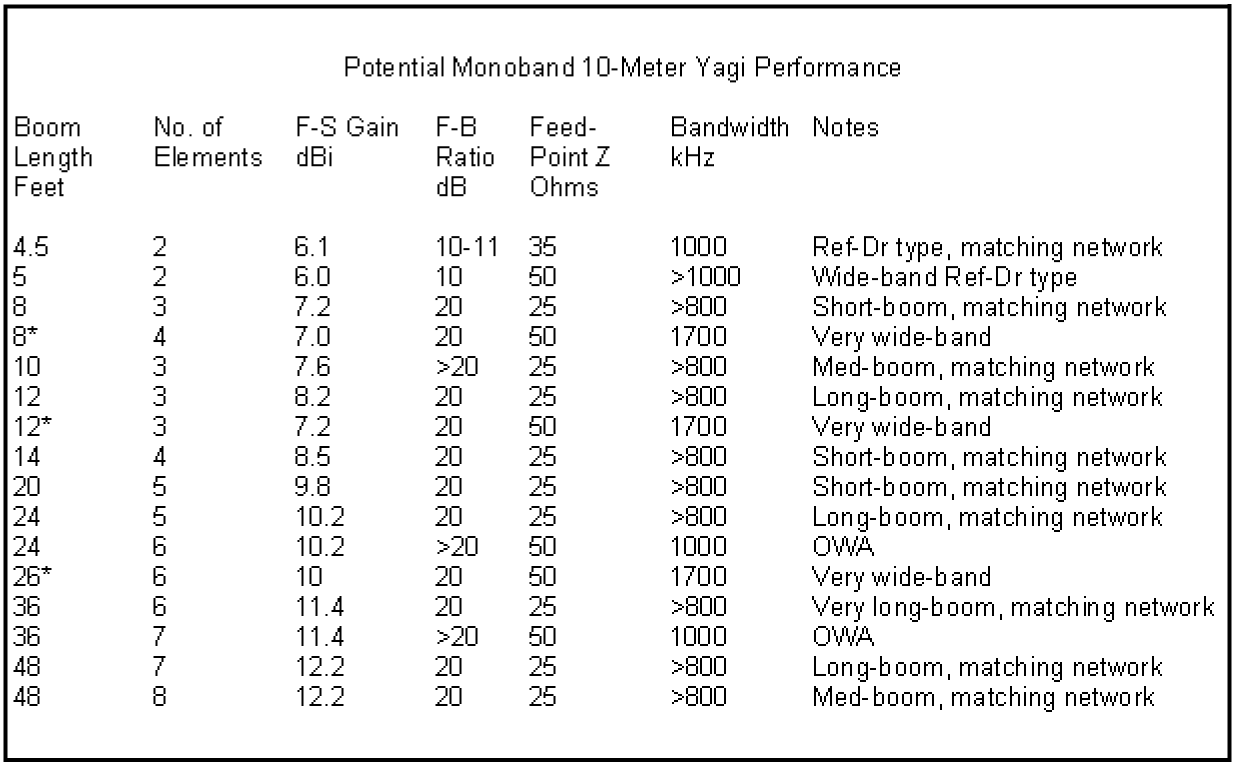
With commercial antenna makers spreading all manner of numbers around, it is difficult for the antenna buyer--or even the prospective antenna builder--to know exactly what to expect from a Yagi or similar beam. So let's take some time to survey the field and give some estimates based on many years of designing and analyzing Yagis. But first, a little terminology.

I shall specify the gain of the Yagi designs in terms of free-space values that are average across the first MHz of 10 meters. The gain numbers will be in dBi, that is, dB over an isotropic source. Gain values in dBd, that is, gain over a dipole, are 2.15 dB lower than those given in dBi. Gain over ground varies according to antenna height, but at a height of 1 wavelength above average ground the gain values (whether in dBi or dBd, will be about 5.5-dB higher than the free-space value to account for both ground reflections and ground losses. By using free-space values throughout, you can get a comparative idea of the advantages of one design over another. So if one design has a gain advantage of 3.2 dB over another in free-space, then it will have the same advantage if we specify the values in dBd or specify the values over ground--or both. However, remember not to mix fruit: we are talking only of Yagi and similar designs based on horizontal half-wavelength elements.

Unfortunately, some advertising does not give you a clear picture of the conditions for the gain specification, so that you do not know if they are citing inferior gains over ground or superior gains in free-space. Some makers only express the gain in dB, so that you do not know what the reference standard is. There is also the problem of stating only the peak value so that you have no idea of the gain across the operating passband of the antenna. Then there are antenna makers who are completely honest, even if that honesty seems to make their products inferior to those of makers who rely on one or another form of vagueness, ambiguity, or downright unsupportable claims.

Monoband Parasitic Arrays

Let's begin our survey with monoband Yagis for 10 meters.



Potential Monoband 10-Meter Yagi Performance

Boom Length Feet	No. of Elements	F-S Gain dBi	F-B Ratio dB	Feed-Point Z Ohms	Bandwidth kHz	Notes
4.5	2	6.1	10-11	35	1000	Ref-Dr type, matching network
5	2	6.0	10	50	>1000	Wide-band Ref-Dr type
8	3	7.2	20	25	>800	Short-boom, matching network
8*	4	7.0	20	50	1700	Very wide-band
10	3	7.6	>20	25	>800	Med-boom, matching network
12	3	8.2	20	25	>800	Long-boom, matching network
12*	3	7.2	20	50	1700	Very wide-band
14	4	8.5	20	25	>800	Short-boom, matching network
20	5	9.8	20	25	>800	Short-boom, matching network
24	5	10.2	20	25	>800	Long-boom, matching network
24	6	10.2	>20	50	1000	OWA
26*	6	10	20	50	1700	Very wide-band
36	6	11.4	20	25	>800	Very long-boom, matching network
36	7	11.4	>20	50	1000	OWA
48	7	12.2	20	25	>800	Long-boom, matching network
48	8	12.2	20	25	>800	Med-boom, matching network

Notes:

- 1. Ref-Dr means a reflector-driver design. Driver-Director designs are feasible, but have very narrow bandwidths.
- 2. Short-Med-Long-boom: boom length classification is relative to the number of elements in the Yagi and is based on building norms.
- 3. OWA means optimized wideband antenna design, based on initial work by WA3FET and NW3Z.
- 4. Very wide-band means the antenna will cover all of 10 meters.
- 5. Bandwidth is based on the 2:1 SWR curve after matching (if needed) with a gamma, beta, or Tee network.
- 6. Feedpoint Z is the resistive feedpoint impedance with the driver brought to resonance, and may be +/-5 Ohms from the listed value. For Yagis with more than 2 elements, making the driver impedance slightly capacitively or inductively reactive to suit a matching network does not affect performance.
- 7. Add about 5.5 dB to the free-space gain for the gain when placed about 1-wavelength (35' on 10 meters) above average ground. For a given mounting height above ground, regardless of the Yagi type, the elevation angle of radiation will be the same.

Let's notice some trends. First, the gain does not always go up with the number of elements, but it does go up with the boom length. The only exception to this trend is when we design a very wide-bandwidth beam, such as starred entries on the list. Then we may require a longer boom to achieve the bandwidth and the 50-Ohm impedance.

Second, adding an extra element on a given boom length does not usually increase gain. However, it does allow us to set the feedpoint impedance and to achieve greater control over the operating characteristics. For example, most of the Yagis with 3 or more elements show an upward gain trend across the band. However, the OWA design can center the gain curve and the front-to-back curve together so as to have more even performance across the band. As well, the OWA design allows a direct 50-Ohm feedpoint impedance and no need for a matching network.

You can generalize on these rough expectations on other bands in a very simple manner. Find the ratio of the band names, for example, 20 meters divided by 10 meters equals 2. Then multiply the boom length of the 10-meter beam of your choice by that ratio. For example, a 20-meter equivalent of larger a long-boom 24' 5-element Yagi design, will have about 10.2 dBi gain if the boom is 48' long. These ratios are significant not only in the evaluation of monoband Yagis for other bands, but as well when we try to develop some reasonable expectations of more complex designs.

The performance figures do not take into account non-electrical factors in a given beam's design. Commercial and home-built monoband designs may range from flimsy to greatly overweight, relative to the wind and ice loads at a desired operating location. The durability of both hardware and plastic fittings is an important question for both buyers and builders to address. As we look at booms that exceed about 24', we must also consider the needs for preventing excessive boom sag and stress.

Remember that all of these Yagi designs are monoband antennas. Hence, the designers were able to optimize performance. Next, we shall see what happens when we cannot fully optimize performance.

What Should I Expect of a Tri-Band Yagi?

The world of tri-band Yagi design is full of compromises. Depending on the design approach taken, the compromises may take many different forms, ranging from reduced gain on one of the bands to reduced bandwidth on another. Virtually all of the compromises result in reduced performance relative to a monoband Yagi for a given band. The design approaches are many and varied, as sampled by the diverse designs shown in **Fig. 1**. One design uses 10 elements on a shorter boom, with three of the elements serving as individual drivers for the three bands. The other design uses a reflector with a set of traps dividing 20 and 15 meters, and the forward-most director has a set of traps (shown as squares on the outline sketch) dividing 10 and 15 meters. The driver has 2 sets of traps and handles all 3 bands. These are only two of the many types of designs on today's market.

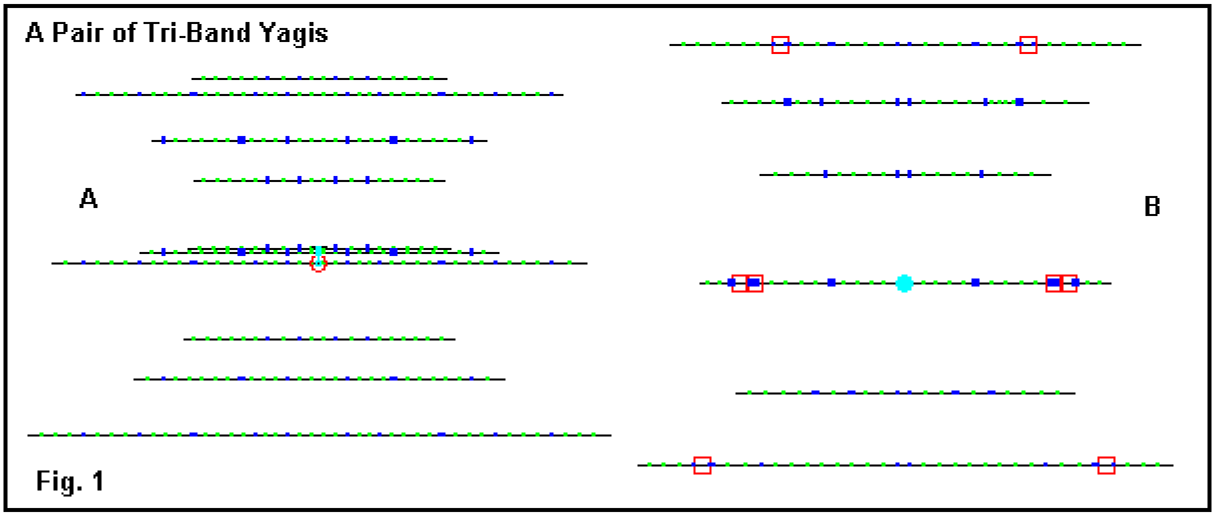


Fig. 1

The question that faces us is how we can develop reasonable expectations from a tri-band design. One approach is to pose some basic questions.

1. How long is the boom for each band, counting from the rear-most element to the forward-most element for that band?

2. How many elements are active on each band?

3. Are any elements in a given band loaded? This question can be tricky. For example, a 10-meter trap will not load the element on 10 meters, but it will form an inductive load on 15 or 20 meters. An element shortened by loading has slightly less gain potential than a full size element.

4. Do any of the elements--especially directors--perform special functions that do not contribute significantly to gain? You may have difficulty determining the answer to this question, since non-gain element functions are difficult to determine without further analysis.

Now let's apply the questions to our two subject antennas. The 10-element tri-bander at left, marked A, has a 3 element Yagi on 20 meters that occupies most of the boom. The 20-meter section of a tri-bander--if the elements are not loaded--tends to come closest to full size performance. If the boom length for the 3 elements approaches 16', then it will yield about 7 dBi of gain--about the same as the 10-meter monoband Yagi on an 8' boom. There are also 3 15-meter elements on a proportionately shorter boom. However, note that the forward director is behind the 20-meter director. This situation often reduces gain somewhat relative to placing it ahead of the 20-meter director. Hence, we can expect less than 7 dBi gain on this band.

On 10 meters, there are 4 elements, and the boom length for them is similar to that of a 4-element short-boom monoband Yagi. However, note that the two directors bracket the 15-meter and 20-meter directors. Some of the function of the first 10-meter director is to "capture" the 10-meter energy to prevent the 20-meter element from controlling it. Hence, its function is not identical to that of the first director in a monoband beam. The result is a slight reduction in our gain expectations from the 10-meter elements--perhaps a half-dB reduction to the 8-dB region.

In almost all tri-band designs, achieving a 20-dB front-to-back ratio is rare, with that value being a peak value. Values from 14 to 18 dB are more typical as averages.

Now let's turn our questions to the design marked B in **Fig. 1**. It uses 6 physical elements, but some of them--as indicated by the squares--serve multiple duty. As we examine the design band by band, we need to count the elements that are active, even if only part of the element is active.

The three longest elements--the two at each end and the driver with multiple sets of traps--form a 3-element Yagi for 20 meters on a boom that is longer than the one in our first design. The longer boom suggests higher gain, but the traps, especially in the driver, suggest some gain reduction at least due to element shortening. The net result is a gain value of about 7 dBi (free-space), since the boom length is still less than that of a long-boom 3-element monoband design.

On 15 meters, we also have 3 elements. The reflector is the inner portion of the longest elements. Next comes driver, which terminates at the outer driver traps but passes through the inner traps. The director is the element behind the forward-most trapped element. The overall boom length is proportionately longer than for the first array and longer than for 20 meters. However, since the driver is still trapped for 10-meter use, the gain will not reach peak long-boom 15-meter levels, and once more falls in the 7 dB range.

On 10 meters, we have 4 elements: the independent reflector, the inner portion of the driver, an independent director, and the inner portion of the forward element. Although as a monoband Yagi, these elements might form a good 4-element beam with a fairly long boom, the interactions with the other elements--especially those for 20 meters--will reduce the gain to about 8 dBi average. However, those same interactions have two other effects. First, they tend to make performance show sharp changes across the 10-meter passband. Second, they tend to reduce the operation bandwidth to about 800 kHz.

The two tri-band designs turn out to be very comparable to each other, with the trapped design in B having a slight advantage in gain on 15 meters. However, gain is not everything. The placement of elements in a tri-bander must be a compromise between adequate gain over a sufficient bandwidth and the front-to-back ratio that can be achieved. Most current designs sacrifice some front-to-back ratio for gain, so realistic values tend to range from 14 to 18 dB. The exact value may vary from one band to the next. Our cursory analysis does not give us good clues to front-to-back performance.

The estimates of performance for the trapped design presume very well designed low-loss traps, and my presumption is correct for some makers--but perhaps not for all. As well, traps tend to suffer environmental effects more severely than simple elements. They use a combination of materials, some of which may age faster than others in the seasonal cycles. Most have weep holes to drain accumulated humidity. The weep holes are also entries for bug nests and atmospheric particulates, either of which can cause eventual harm or lower performance. Since access to the insides of most commercial traps is difficult, routine maintenance and inspection become difficult. However, routine periodic maintenance is a key to the continued performance of any antenna, whether a monoband Yagi or a multi-band array.

These notes are not designed to give definitive analyses of any particular monoband or tri-band array. Instead, they aim to give you a starting point in evaluating antennas that you might contemplate buying or building. In ads, thinking about commercial offerings, consider what the maker does not tell you. Then ask. If you do not get straight answers, factor that event into your evaluations along with the data that you do receive.

No. 46: The Persistent Vee-Beam Myth

L. B. Cebik, W4RNL

In a jigsaw puzzle, many pieces have similar shapes. You can force some pieces into the wrong places and end up with a messy and meaningless picture. The same rule applies to antenna work. Back in the 70s and 80s, backyard antenna builders created some interesting antennas and then made all sorts of miraculous claims for them. Since I receive numerous questions from folks reading old issues of ham magazines, a good number of them have focused on these miracle beams. One of the most persistent is the so-called Vee-beam.

Right at the start, we have the seeds for a misunderstanding. There is a very legitimate use of the term Vee-beam that indicates an array with good directivity and high gain. However, this traditional beam uses wire elements many wavelengths long. The Vee-beams of the more recent vintage are Yagi size, that is, with elements about ï¿½ wavelength from end to end. However, it appears that the Vee-beam builders wanted to claim long-wire results for their short element antennas. So claims arose that a 2-element Vee-beam would give performance equal to or better than a 3-element Yagi with straight elements. (I still see such claims on the Internet.)

A second claim is that bending the elements forward will save space. If a standard Yagi is 16 to 17 feet wide, the Vee'd form will only be about 12 feet wide. So we have a seemingly compact antenna.

Let's evaluate these claims by making a series of comparisons among 3 2-element beams. All of the antennas will use 5/8" diameter elements for our modeling exercise. There is nothing in any of the designs that will even remotely approach the limits of antenna modeling software, so results will be reliable.

1. A standard Yagi: For the Yagi, I have selected a wide-band version having a natural feedpoint impedance in the vicinity of 50 Ohms. Hence, you do not need a matching network, such as a beta or gamma match. The reflector is 17.3' long, while the driver is 15.84' long. The elements are 5.5' apart. You can use closer spacing, but the lengths will change and the feedpoint impedance will go down. At 4.3' for the spacing, you will get 32 to 35 Ohms for the feedpoint impedance and need a matching network for your 50-Ohm coax cable feedline. The reduced spacing will give numerically detectable improvements in performance in modeling software, but not enough to be detectable in operation.

2. A Moxon Rectangle: The Moxon is a compact 2-element beam that uses standard Yagi parasitic coupling plus element end coupling. Its gain is almost as good as the Yagi gain. However, the front-to-back ratio is exceptionally better. At 28 and 29 MHz, you can have about 18 dB of front-to-back

ratio, compared to the 10-11-dB figure for a Yagi. More to the point is the size. The Moxon is only 12.5' side-to-side and 4.6' front-to-back. Like the wide-band Yagi, it has a natural 50-Ohm feedpoint impedance for direct connection to your coax cable.

Both the wide-band Yagi and the Moxon rectangle should use a means of "common-mode current" suppression at the feedpoint. For this purpose, you may use a bulky 1:1 balun. However, a simpler bead-type choke, as designed by W2DU and available from numerous vendors, is just as effective. Its advantage is a diameter not much larger than coax cable. Hence, you can tape it to the boom and not add significant weight to the antenna.

Structurally, the Yagi is larger overall. However, the Moxon requires a bit of extra fabrication effort. It needs 4 corners to the elements. So the space saving comes at a price, but one which many folks can pay without strain.

3. The third antenna is a 10-meter Vee-beam. Each element has a "quadrant" form, that is, a 90-degree overall bend. The open ends point in the desired signal direction on the premise that we shall get added gain from them. The bending results in an overall beam width of about 12.4'. Unfortunately, the forward bending increases the front-to-back dimension to about 11.4'. So now we have a nearly square array. **Fig. 1** shows the relative sizes of our 3 beams.

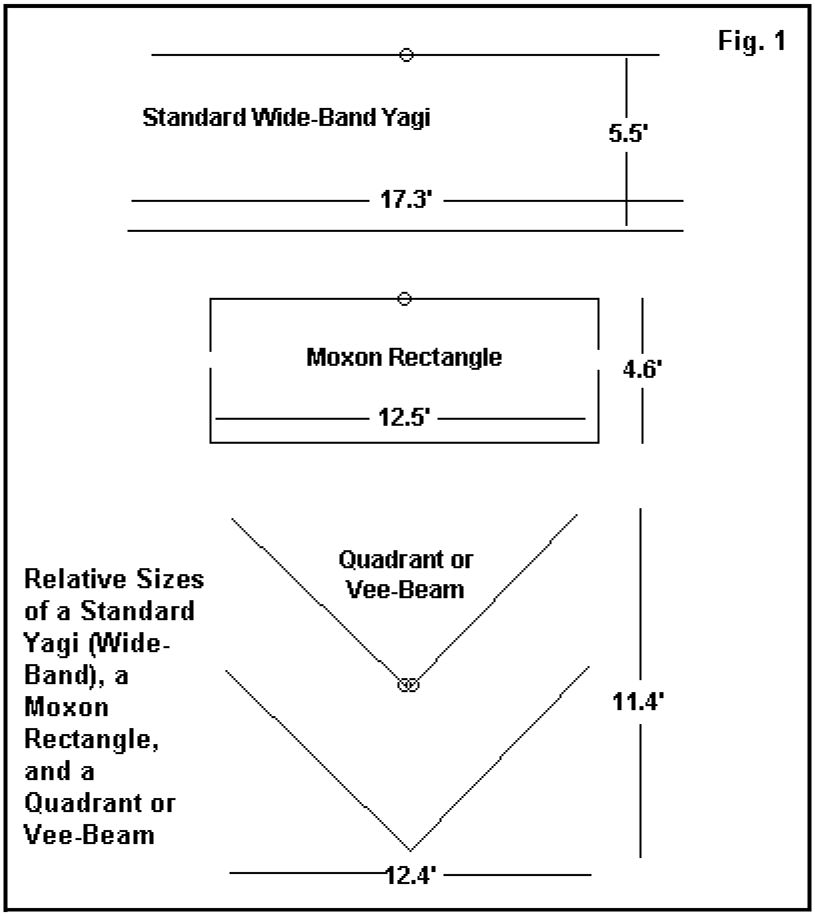


Fig. 1

Relative Sizes of a Standard Yagi (Wide-Band), a Moxon Rectangle, and a Quadrant or Vee-Beam

The next question for our comparison concerns how well the three antennas perform. We can break that question into 2 parts.

a. What kind of pattern do I get from each antenna?

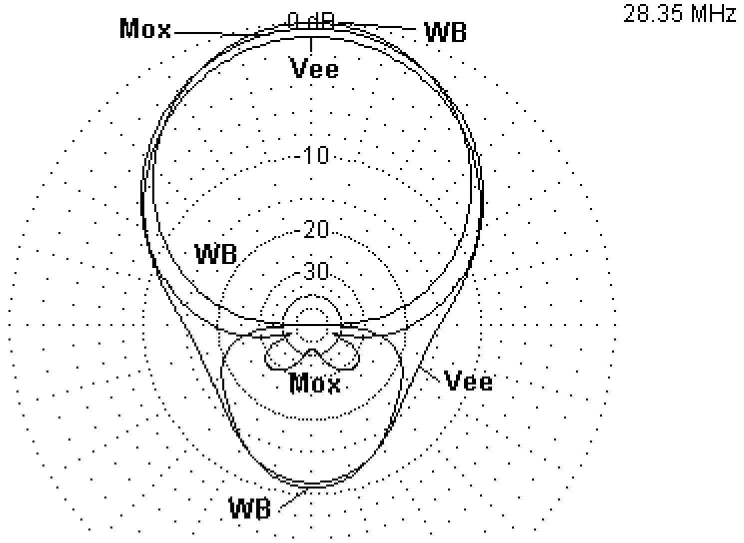
b. What kind of operating bandwidth do I get from each antenna?

The pattern question is relatively easy to answer, if we break it down into parts. The Yagi provides the most gain--about 0.2 dB more than the Moxon and about 0.7 dB more than the Vee-beam.

The Moxon rectangle has the best front-to-back performance, as noted earlier. The Yagi comes next, with a modest 11 dB front-to-back ratio. Which value is better for your operation depends on your needs. For nets, I prefer the Yagi, since I can hear--although more weakly--stations from the rear. For contests, I prefer the Moxon that quells rearward QRM very effectively. The Vee-beam is slightly poorer than the Yagi in the front-to-back performance.

See **Fig. 2** for overlaid patterns for the 3 antennas to confirm these notes.

Fig. 2

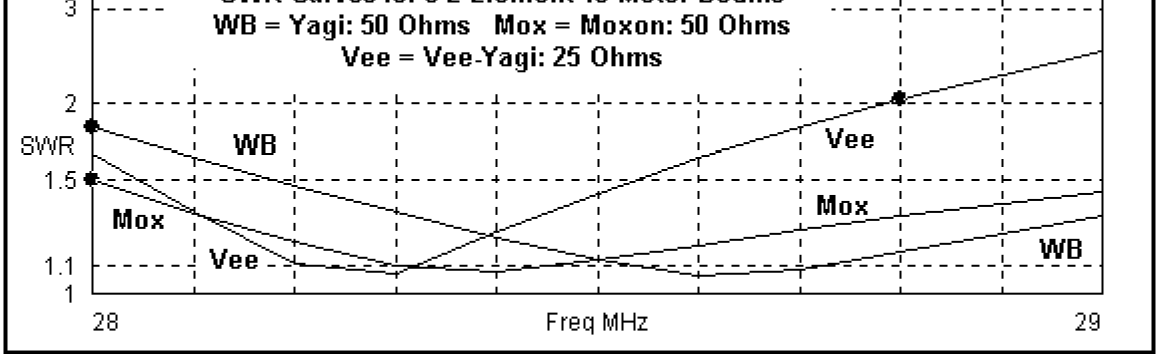


Comparative Azimuth Patterns for 3 2-Element 10-Meter Beams
WB = Wide-Band Yagi Mox = Moxon Rectangle
Vee = Vee Yagi

The patterns reveal something else about what happens when you Vee and element horizontally. The front-to-side ratio goes way down, since each half element radiates some energy to the side.

We have noted that the Yagi and the Moxon have 50-Ohm feedpoint impedances. That number applies to the design frequency (28.35 MHz for all three antennas). But what about the band edges. For this performance specification, let's look at the SWR curves in **Fig. 3**.

Fig. 3



The wide-band Yagi 50-Ohm SWR curve may start higher than the other two, but only because the antenna provides coverage of the entire 10-meter band from 28.0 to 29.7 MHz. You can lengthen the driver slightly to bring the minimum SWR value down in frequency.

In contrast, the Moxon rectangle provides a 50-Ohm SWR of 1.5:1 or less for the first full MHz of 10 meters. The rate of increase above the minimum point is slower than below the minimum point, so coverage extends to about 29.2 MHz or so before the SWR value reaches 2:1.

The Vee-beam shows an entirely different pattern. First, whenever you change a straight element into a Vee, no matter where the Vee ends point, you lower the single element impedance. Hence, a simple inverted-Vee has an impedance closer to 50 Ohms than to the straight dipole 70-Ohm value. Second, whenever you add a second element, such as a parasitic reflector, you further lower the feedpoint impedance. Straight element Yagis produce 30-50-Ohm impedances, compared to a dipole's 70 Ohms. Since a Vee'd dipole is already at a lower feedpoint impedance, adding a reflector lowers the impedance even further. Hence, the Vee-beam has a resonant driver impedance of only 25 Ohms. This value is not fatal, since we can always add a matching network to raise the impedance.

However, notice the overall SWR curve for the Vee-beam. Not only did we lower the impedance, but as well, we narrowed the 2:1 operating bandwidth. We have about 800 kHz of operating room, compared to the other beams. Although this value is adequate for most lower-end 10-meter activities, it does require that you tune the Vee-beam with great care and precision.

So the bottom line is that we do not get anything special from the Vee-beam configuration that we cannot get from simpler, smaller, or wider-band arrangements. My preference is always to keep these antenna notes on the positive side. However, the Vee-beam myth has persisted for so long that I felt compelled to provide some legitimate comparisons. May the Vee-Yagi rest in peace beside Vee'd LPDAs and other members of the family. There are better ways to meet your 10-meter small beam needs.

No. 47: What is a Balun, and Do I Need One?

L. B. Cebik, W4RNL

The term BALUN is one of the most vaguely used words in antenna work. It has different levels of specificity, but writers are not always clear on what level they mean. So let's start at the beginning and see if we can straighten out the term. Once we are clear on what we are talking about, we shall be in a better position to decide if we need one. Finally, if we do need one, we can decide on what kind we can use for a given application.

1. **What is balun?** The term balun is a contrived word composed of "balanced" and "unbalanced." In its most generic use, it indicates any device that helps us effect a transition from a balanced transmission line or circuit on one side and an unbalanced transmission line or circuit on the other side. In some of the basic materials that we studied in preparation to get our licenses, we encountered baluns, but without that name attached. Consider a standard link-coupled RF circuit composed of two coils. One side if hot at one end, but the other end is grounded. The other side is hot on both sides. It may or may not have a center ground. This circuit, whether tuned with capacitors for one frequency or left untuned for wide-band use, is a type of balun. However, the actual term grew up in relatively recent antenna work.

When the term balun arose, it was in connection with transmission-line transformers. Transmission-line transformers are specially constructed transformers composed of multiple winding where adjacent turns have a very specific spacing. The spacing forms a transmission line with a characteristic impedance. Therefore, some folks always mean a transmission line transformer when they use the term balun, while others may mean only any device that effects a transition between balanced and unbalanced circuits.

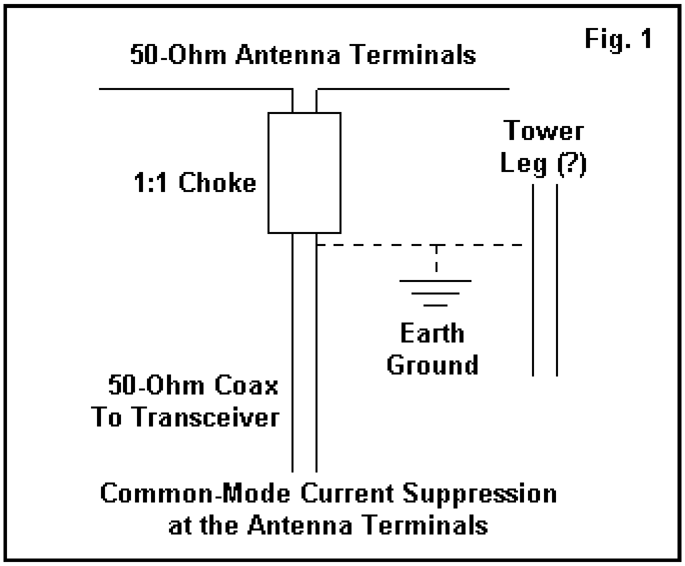
Transmission-line transformers come in many forms. One division is between linear and toroidal baluns, that is making use of transformer coils wound in a straight line or in the form of a circle. The second division is between air-wound transformers and those making use of a core that is normally composed of a ferrite material. So we find air-wound linear transformers, ferrite-core linear transformers, and ferrite-core toroidal transformers. Air-wound toroids are not normally used.

We also find other divisions to think about. For example, there is the matter of the impedance ratio. The most common impedance ratios are 1:1, which uses a trifilar winding, and 4:1, which can use a bifilar winding. 4:1 baluns normally have their high impedance side correspond to the balanced side of the device. Most baluns in the 1:1 to the 4:1 range use a low Zo for the transformer winding. For a 1:1 balun intended for use with 50-Ohm system, the impedance is as low as we can get two round wires to go (about 80 Ohms). A 4:1 balun for transforming 200 Ohms to 50 Ohms might use the geometric mean between the two target values (100 Ohms). Other impedance ratios are certainly possible. As well, there are ununs, that is, unbalanced to unbalanced transformers that designers use in conjunctions with baluns to effect odd impedance transformations.

There are also design types, such as the Guanella, but the most common distinction is the voltage vs. the current balun. For virtually all amateur antenna system applications, a current balun type is preferred. One of the guiding principles of balun design is that the device should be wide band, covering most of all of the HF region or perhaps a special design for VHF from 6 meters through at least 2 meters.

We now have at least two devices that will effect the transition: a relatively standard link-coupled pair of RF coils and a transmission-line transformer. There are other devices. Some applications call for convention wide-band transformers, often wound on iron or ferrite toroidal cores. Other applications may call for a simple choke, a device that sets up a high inductive reactance to attenuate the flow of current where we do not want it to go. One way to make a choke that is suitable for a 10-meter antenna application is to make a coil of coax. Another way is to place a series of ferrite beads over a length of 50-Ohm coaxial cable.

2. **Where Should I Use a Balun?** The most common application for a balun is at the terminals of a balanced antenna feedpoint that we are feeding with unbalance coaxial cable. See **Fig. 1**.

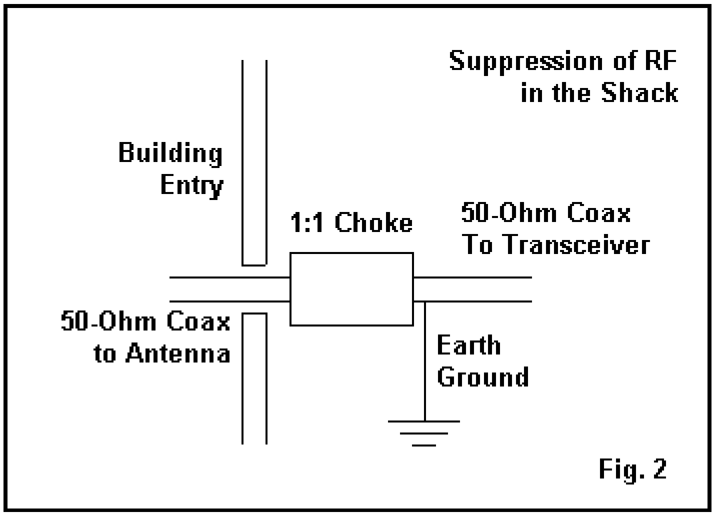


The outer braid of the coax provides an alternative path for antenna currents at the terminals. The current on the braid goes under the name "common-mode current." Common-mode currents do nothing useful for communications. Whether or not they create a problem depends on many variables, but it is always wise to place a choke at the antenna terminals. Since the antenna (including any attached matching network) and the coax are both 50-Ohm devices, we can use any of the 1:1 balun devices available.

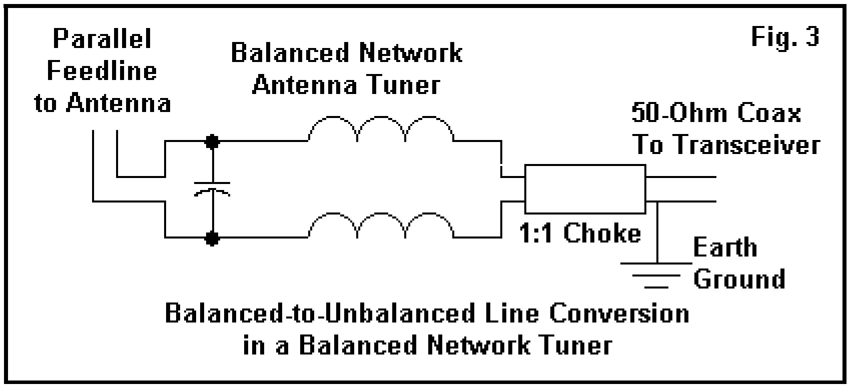
Note the special reference to a tower leg and the earth ground that it implies. If feasible, it is advisable to form a connection between the coax braid of the transmission-line side of the choke and a tower leg. I am assuming that you have your tower--if you use one--well grounded. Such a connection is protection from a number of potential problems, and giving the remnant common-mode currents a path to the earth is one of them. Charge build-up on the antenna now also has a relatively easy path to the earth.

If the coax between the antenna and the shack is long, and if the run turns enough corners, then you may still have common-mode currents in the shack due to signal coupling directly to the coax braid. If you have such a problem, it may show up as a difference between SWR reading on the rig's meter and on an external meter in the line. Or you may get a tingle or a bite from sharp corners of the transceiver case while transmitting. At its worst, it may show up on telephone lines, and it may even lock your VOX or keying circuit on some bands.

One avenue to a cure that is highly effective (but, like all things in amateur stations, not universally perfect) is to install a second choke at the shack entry, as shown in **Fig. 2**. This 1:1 choke is not doing anything but attenuating currents on the outside of the coax line (where all transmission-line currents are on the inside, between the center conductor and the inside face of the braid). Note once more the reference to an earth ground. You may wish to place the second choke on the outside wall, close to the ground, so that you can have the shortest possible distance for the lead to the ground rod.



The third major application for 1:1 baluns or choke may not involve any activity by the user. There is a new generation of balanced network tuners on the market, a partial replacement for link-coupled tuners of years gone by. The better of these tuners include on the input side a 1:1 balun. The tuner is for balanced parallel transmission lines at the output. The tuner changes the output terminal impedance to 50 Ohms, but the line is still balanced, so a 1:1 balun on the input side effects the change from balanced to unbalanced or single-ended lines to the transceiver. See **Fig. 3**.



All of these applications call for a 1:1 balun, that is, a balun that does not effect any kind of impedance transformation. We only need to effect the balanced-to-unbalanced transformation while choking out any extraneous currents that may want to exist on the outside of the coax braid.

3. **What Kind of Balun Should I Use?** Theoretically, you may use any type of 1:1 balun or choke available. In principle, any of the major types will do the jobs just described. Here are some options.

a. *Coiled coax*: The coiled coax choke can be useful at the antenna terminals. For 10 meters, you may coil about 4-6 feet of RG-8/213 or RG-58 (for lower power) into 6 to 8 turns. Do not scramble wind the turns. Instead, wind them in a coil form and tape the turns together. You may use a short piece of 4 to 6 inch PVC as a form, although some folks have used empty plastic soda bottles as a form. (Protect any form from UV, since the sun will make the form go brittle in under a year without protection.) Coax coils are quite effective on single bands, but less effective for multi-band use.

b. *Commercial 1:1 current baluns*: These devices come on many forms, usually potted inside permanently cemented PVC. Some have coax connectors at both ends, while others have wire leads on one side. A few are designed for wire-antenna center insulator/balun use, and may even have a top hanger eyebolt for inverted-Vee installations. Some current baluns are air wound, while others use either ferrite rods or ferrite toroids.

Most of these units are bulky. Their best application is usually at the shack entry point, where weight and size do not make a major difference. Some have a built-in ground strap for easy connection to an earth-ground system. Balanced network antenna tuner makers use bare baluns inside the tuner case. (If you are thinking about buying one of the new balanced tuners, be certain to find out whether the tuner includes the balun, because it is essential to proper operation.

c. *Ferrite bead chokes*: Walt Maxwell, W2DU, first devised these chokes in the 1980s, and they are highly effective. For HF use, the builder places about 50 Type 77 or type 73 ferrite beads over a length of coax. Type FB77-1024 beads fit over RG8/213 and similar larger diameter coax. Type FB73-2401 beads fit over RG58 for lower power applications. Walt's original design used the smaller beads of a length of RG-142, which appears similar to RG-58 but uses a Teflon dielectric and silver-coated wire to handle higher amateur powers. Of course, you must protect the assembly from the weather with a coating of some durable sort.

I tend to prefer the ferrite bead chokes at the antenna terminals, especially with beams. They weigh less than most current baluns and coax coils, and they are less bulky. You can usually tape them to the antenna boom. I have used them for about a quarter century with good success in both shack entry and antenna terminal applications.

So far, we have dealt with only 1:1 baluns and chokes. For coax systems, these are the ones that we need to effect balanced-to-unbalanced transitions (or vice versa) and to attenuate common mode currents that may exist on the outside of our coax braid.

Due to the history of antenna tuners in the last 3 decades, the most talked-about balun is the 4:1 variety. In fact, when many hams think "balun," they almost automatically think "4:1 balun." We find them in almost all single-ended (unbalanced) network tuners as a way to simulate a balanced tuner output. So it looks like our work with baluns is only half done. The odds are 4:1 that next time we shall look in more detail at applications--both good and bad--for the ubiquitous 4:1 balun.

No. 48: The Ubiquitous 4:1 Balun

L. B. Cebik, W4RNL

In our last episode, we introduced the idea of a balun. We noted that in its most generic use, the term "balun" refers to any device that enables us to make a transition from a balanced circuit to an unbalanced circuit--or vice versa. The most common application of the term occurs in antenna and feedline work.

More specifically, many uses of the term "balun" wish to indicate the use of a transmission-line transformer, a specialized wide-band transformer whose turns have a characteristic impedance, that is, whose turns are formed with transmission line sections. We noted that such impedance transformers come in many forms, ranging from linear air-wound versions to the more common toroidal form using a ferrite core (or cores, for high power transformers.

Balun transformers can have a large range of impedance transformations, running at the low end from 1:1 up to as much as 9:1. Perhaps the individual who has written the most on the basic balun transformer and done the most in developing versions that one can build is Jerry Sevick, W2FMI. He has several books on the subject.

In our last episode, we looked at the all-50-Ohm (or, more generally, the all coax) system. We discovered that the balun transformer is only one of the devices that we can use to effect a transition from a balanced to an unbalanced system. Besides the transmission line transformer, we could use a ferrite bead choke or even a specially would coil of coax to attenuate common-mode currents virtually anywhere along the line, depending on our needs.

In this episode, let's look at the balun transformer itself. Its purpose is to transform impedances over a wide range of frequencies--for example, the entire HF range from 3 to 30 MHz. It just happens also to attenuate common mode currents as well.

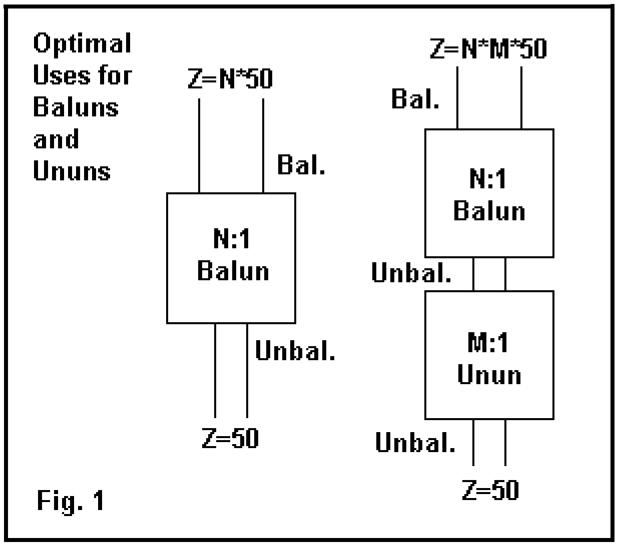


Fig. 1

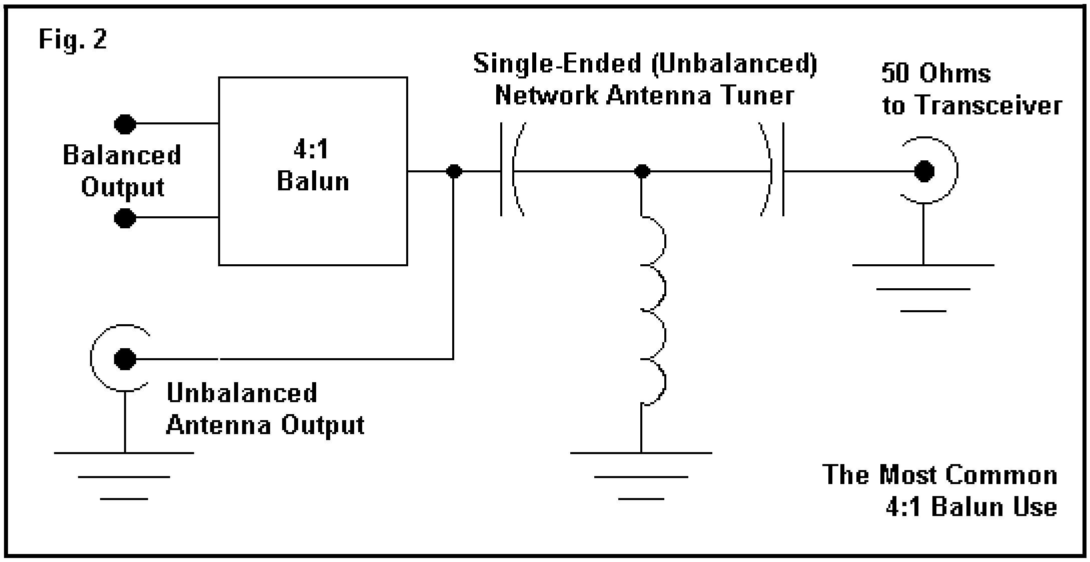
Fig. 1 shows the ideal situation for a transmission-line transformer as a balun--on the left. We buy or build a balun transformer with the desired impedance transformation relative to our 50-Ohm main feedline cable. Actually, most baluns are able to handle impedances over a range, so the 50-Ohm side can vary somewhat. If our balanced impedance is 200 Ohms, then a 4:1 balun will change that to 50 Ohms on the unbalanced side. In fact, I know of at least one contest operator who designs his beams to produce a 200-Ohm impedance in a Tee-match and then uses a 4:1 balun at the feedpoint for his 50-Ohm cable.

However, we are not restricted to a 4:1 balun. In fact, the balanced side need not have a higher impedance than the input side. There are 4:1 baluns that will transform a 12.5-Ohm balanced impedance to a 50-Ohm unbalanced impedance. We cannot simply turn the common 4:1 balun around, since it is doing two jobs at once: transforming the impedance and effecting a balanced-to-unbalanced transition.

We noted that the greatest efficiency occurs when the characteristic impedance of the balun winding is the geometric means between the high and low impedances. Sometimes, the transformation that we need is very high, for example, 16:1 in some cases (with terminated folded dipole all-band antennas, for example). In these instances, we may start with a 4:1 balun. Then we can add a 4:1 unun, that is, a transmission-line transformer designed for unbalanced input and output sides. The right side of Fig. 1 shows this option. If we must match 800 Ohms to 50 Ohms and go from a balanced side to an unbalanced side, then the dual transformer option is sometimes best.

When used properly, transmission-line transformer baluns can be over 99% efficient. However, they do have their limits. For one, they tend to become lossy when the impedance on the antenna side has considerable reactance. Sevick recommends that all matching to remove reactance be done on the antenna side of any balun transformer. It is also possible to over-power baluns so that they begin to heat before the cores reach saturation. Whatever signal energy turns into heat is energy no longer available for radiation and communication.

Fig. 2



Now let's look at **Fig. 2**, the most common application of the ubiquitous 4:1 transmission-line transformer balun. The sketch shows in simplified form the typical unbalanced (or single-ended) network tuner. The coils and capacitors in a real tuner would be variable or switched, and the unit might even have a built-in SWR meter. However, we can see, just by looking at the ground symbols, that the main purpose of the tuner is to match unbalanced antenna impedances as they occur at the output coax connector to 50 Ohms at the other coax connector.

However, the chief use for most antenna tuners is to handle multi-band wire antennas using parallel feedlines for low losses in the presence of a very wide range of antenna-terminal impedance values. Most multi-band antennas will not only show both high and low impedances, but as well, the impedances will have both resistive and reactive components, both of which may be high. The impedance at the balanced terminals of our tuner will be a function of 3 variables: the antenna terminal impedance, the characteristic impedance of our feedline, and the length of the line itself. When the antenna impedance is not an exact match for the feedline impedance, the value of impedance will undergo continuous transformation along the line every half-wavelength at the operating frequency.

To handle these impedances, tuner makers install a 4:1 balun. Depending on the tuner maker, these units may range from poor to excellent in quality. But they are still 4:1 baluns. Even at their highest efficiency, they transform the impedance at the terminals down to a value that is 25% of the tuner terminal value.

However, because the impedance undergoes continuous transformation along the way, it may already have a low impedance at the tuner terminals. If it is already 20 Ohms (a value that has occurred in many instances), then a completely efficient 4:1 balun will transform it to 5 Ohms. Most tuners will be able to transform the 5 Ohms up to 50 Ohms, but they will not do so efficiently. Considerable power will be lost, not in the balun, but in the tuner. Since the tuner components are large, you may not be able to detect the heat, but the losses will be there.

So far, we have assumed that the balun is completely efficient. However, as we have noted, the impedance at the tuner terminals may consist of both resistance and reactance. Many balun designs become lossy in the presence of high values of reactance.

The end result is a system that is lossy by design. The 4:1 balun has been added to the single-ended tuner as an afterthought, a convenient way of claiming that the tuner will handle both balanced and unbalanced antenna side loads. However, we must always ask how well it will handle such loads, and the answer is not always pleasing.

If you do use a multi-band antenna with parallel feedlines for operation on the "other" HF bands, there are better ways to handle the matching requirements. There are still a few link-coupled antenna tuners left over from ancient times, such as the Johnson Matchboxes produced from the 50s through the early 70s. European operators can still find a few good Annecke link-coupled tuners.

More recently, several makers have introduced balanced network tuners. These tuners, shown in outline form in the last episode, do their matching work while still in the balanced configuration. At the transceiver side of the unit, where the impedance is now 50 Ohms or very close to it, some builders install a 1:1 current balun to transition from the balanced impedance to an unbalanced line, namely, the coax from your tuner to the rig. (I have recently seen a low cost balanced tuner circuit that does not indicate the presence of a balun. In this case, you will have to add one.)

Balanced network tuners are not without limits. They have their widest matching range--that is, their ability to handle high impedances with relatively high reactive components) at the lowest frequencies. The matching range tends to narrow as the frequency goes up. At the high end of the spectrum, the required values of inductance and capacitance for high impedances tend to be below the minimum values that the components can achieve.

Now let's suppose that you already have a single-ended network tuner. Let's also suppose that you want to spend your money on other things than a new balanced network tuner. Is there a way to press the unbalanced tuner into service and to get reasonably good (even if not perfect) performance from it? The answer is affirmative, and **Fig. 3** shows how.

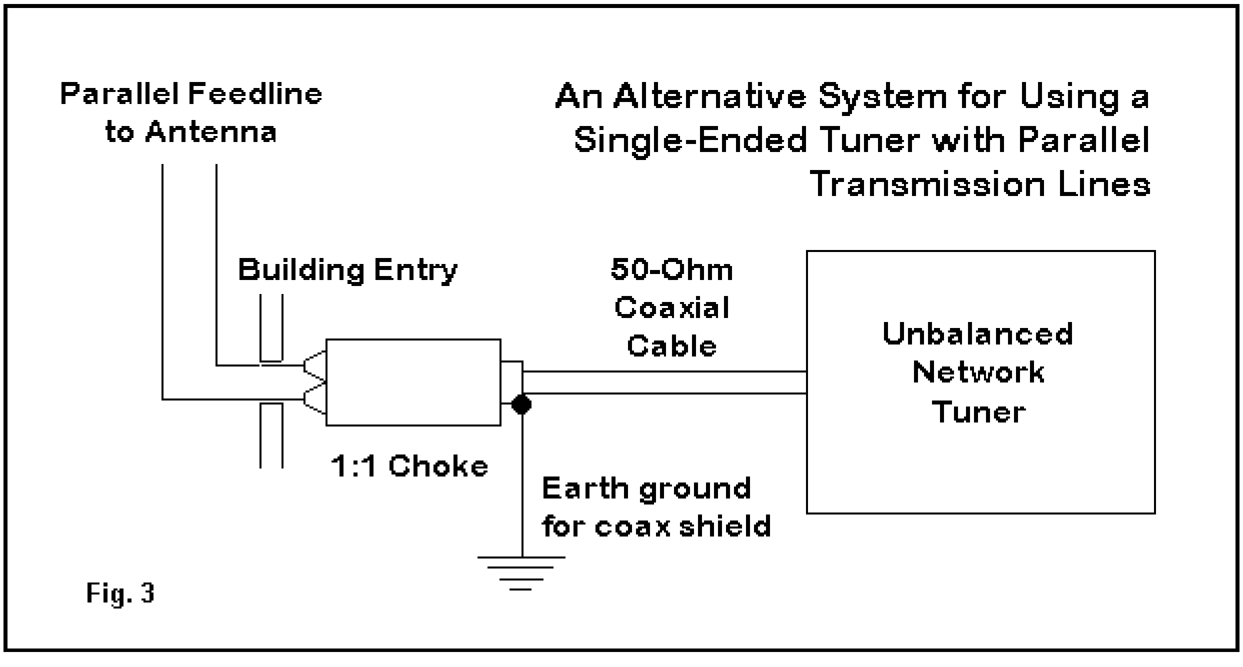


Fig. 3

First, we shall forget about the 4:1 balun inside the tuner and use the unbalanced coax connector antenna-side output. We shall obtain a short length of coax, just enough to reach from the tuner to the entry point for the feedline to our multi-band antenna. If we obtain the very lowest loss coax we lay our hands on, so much the better, and if we can keep the coax run as far under 20' as possible, so much the better to keep losses minimized. At the entry point, either indoors or outdoors, we shall install a 1:1 choke. For this application, I tend to prefer ferrite bead type chokes, since the antenna side terminals may have considerable reactance. Note that on the coax side of the choke, we run a s hort lead to a ground rod from the coax braid. The lead should be as short as feasible and the rod as long as possible. Finally, we connect our parallel feedline to the antenna side of our 1:1 choke.

In this configuration, we use our single-end tuner in the mode for which the design is most apt. We do not transform any low impedances down any further. The system will have losses. The high SWR on the coax run becomes lossier the higher we go in frequency and the longer we make the run. Hence, keeping the run very short and using very low loss coax are essential. The choke will also suffer some losses, depending on the SWR value we see there. However, the system has proven more effective in many instances than using the 4:1 balun inside the tuner. As well, because the parallel line is wholly outdoors, the system has freed many ham shacks of troublesome RF indoors. The system is not perfect, but is has proven over the last 20 years to be reasonably effective.

No. 49: The Basic 10-Meter Monopole

L. B. Cebik, W4RNL

Over the last 12 years of this column, we have pretty much overlooked one of the most basic of all 10-meter antennas: the ï¿½-wavelength monopole with a ground plane. The antenna is simple to build, fairly compact, and performs reasonably well, so we had better fill in this gap.

We shall not start with a ground-mounted antenna, simply because the losses are too high. However, when we elevate the monopole, we make a discovery. If we set the ground-plane radials at right angles to the monopole, the feedpoint impedance drops into the 20-25-Ohm range. Instead of adding a matching system for our 50-Ohm coaxial cable, we shall take a different tack. We shall let the radials bend downward at a 45-degree angle. This measure does two good things. First, it raises the feedpoint impedance to the 50-Ohm ballpark. Second, the radials, to the degree that they are partially vertical, add to the overall radiation from the antenna.

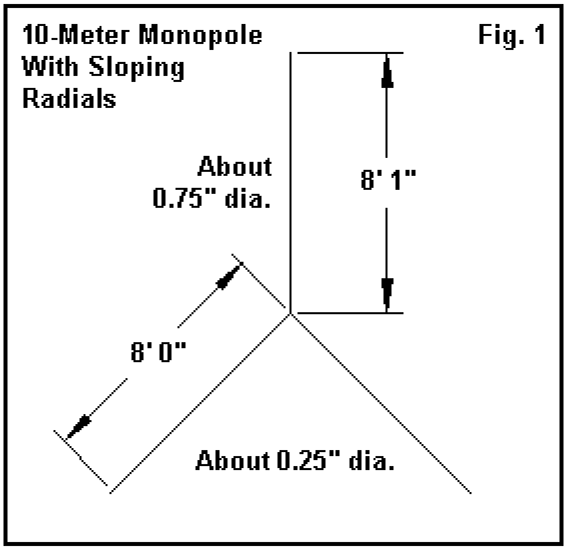
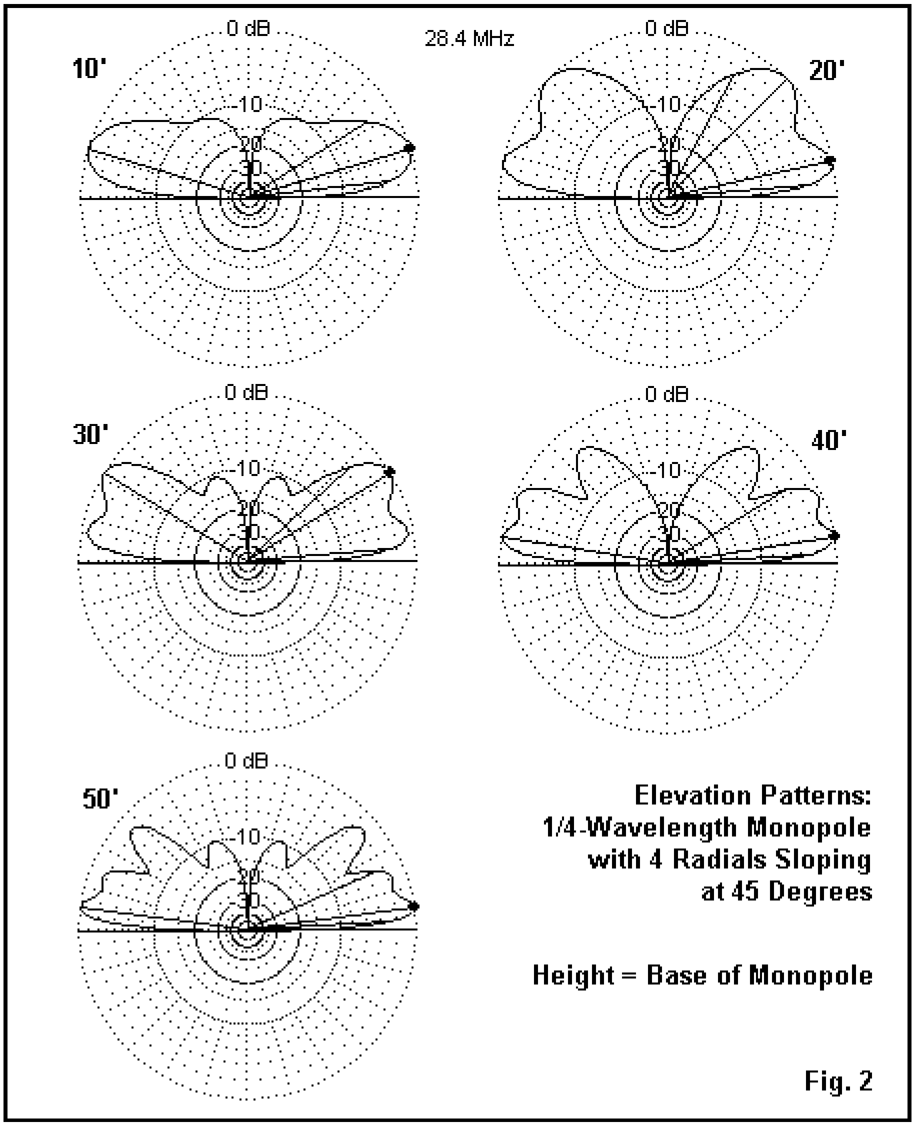


Fig. 1 shows the outlines of a same monopole with drooping radials. The vertical section is about 8'-1" long if we use ï¿½" outside diameter tubing for the element. Of course, you can combine two sizes of tubing that nest together so that you can adjust the length for the lowest SWR at whatever frequency you prefer. The model used here is centered on 28.4 MHz. However, the operating bandwidth will generally cover all of 10 meters.

The radials are 8' long when you use quarter-inch diameter rods. If you use thinner materials make them slightly longer, and if you use fatter tubes, then make them slightly shorter. Remember that you can make final adjustments to the main vertical element. The monopole uses 4 radials in a symmetrical pattern. Adding further radials to an elevated monopole will not improve performance, but it will add unnecessary weight.

I shall not give any detailed construction advice, since there are as many ways to build a monopole with radials as there are builders. Use available materials and your own skills to work out the assembly. Check various handbooks and magazine articles for construction methods that match up with your preferences. Just be certain that the radials have a common connection and that the feedline connector has its center pin going to the vertical section, with its shell going to the radials.

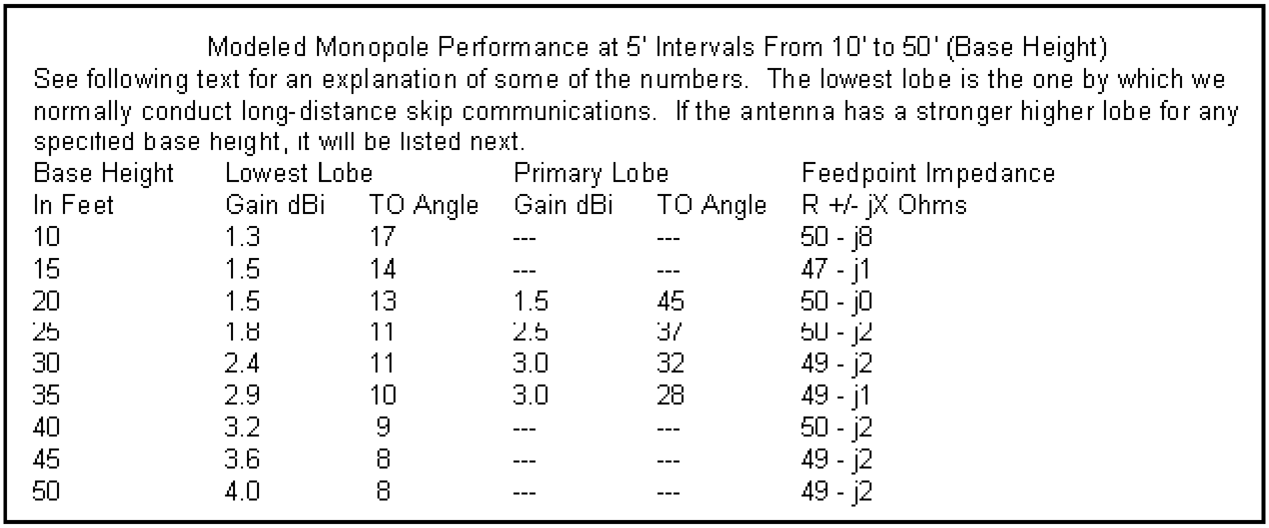
The next question is what I might mean by "elevating" the monopole. The answer to that question can be any base height from 10' on upward. We normally define the base of the antenna as the junction between the vertical element and the radials. **Fig. 2** provides some selected elevation patterns at 10' intervals. Examine these patterns together with the table that follows them. Together, they will give you some idea of what to expect from the monopole a various heights you might use.



Elevation Patterns:
1/4-Wavelength Monopole
with 4 Radials Sloping
at 45 Degrees

Height = Base of Monopole

Fig. 2



Modeled Monopole Performance at 5' Intervals From 10' to 50' (Base Height)

See following text for an explanation of some of the numbers. The lowest lobe is the one by which we normally conduct long-distance skip communications. If the antenna has a stronger higher lobe for any specified base height, it will be listed next.

Base Height	Lowest Lobe		Primary Lobe		Feedpoint Impedance
In Feet	Gain dBi	TO Angle	Gain dBi	TO Angle	R +/- jX Ohms
10	1.3	17	---	---	50 - j8
15	1.5	14	---	---	47 - j1
20	1.5	13	1.5	45	50 - j0
25	1.8	11	2.5	37	50 - j2
30	2.4	11	3.0	32	49 - j2
35	2.9	10	3.0	28	49 - j1
40	3.2	9	---	---	50 - j2
45	3.6	8	---	---	49 - j2
50	4.0	8	---	---	49 - j2

Between a base height of 10' and 20', the lowest lobe is dominant. In fact, at 10' up, it is the only lobe. However, by the time that we reach 20', the upper lobe is just as strong. It is at an angle that is good for very little but noise and possibly some sporadic E-skip.

From 25' up to 35' up, the lowest lobe is not the strongest lobe. The next higher lobe (as shown by the 30' pattern in **Fig. 2**) dominates. Nevertheless, as we continue to raise the antenna height, the gain in the lowest lobe continues to climb. Also notice that each new height shows the emergence or the rapid development of a new lobe. With vertical antennas, these lobes tend to merge so that we can only detect individual lobes by their peak values. (In contrast, a horizontal antenna would show very distinct lobes with very deep nulls between them.)

By the time we move the antenna base to a height of 40', the lower lobe once more dominates the elevation pattern. The upper lobes have significant but not overriding strength. The progression of lobe development is not an accident. It is a function of the way in which the direct radiation from the antenna mixes with radiation reflected from the ground. When the antenna base is between about 5/8 wavelength up and 1 wavelength up, the combined direct and reflected radiation favors higher angles. Above 1 wavelength up, the combination of direct and reflected radiation again favors the lower angles.

To a degree, you can translate these general pattern tendencies to almost any vertical antenna, including vertically oriented dipoles and Yagis. The key element in the translation is the height equivalence: the base height for the monopole is approximately equal to the center of the dipole and the boom of the Yagi.

The general trend of the gain and TO angles (where the TO or Take off angle is the elevation angle of maximum radiation) suggests that the higher you mount the monopole, the better the performance. Since the feedpoint impedance shows remarkable stability, you may generally adjust the antenna for best SWR at a fairly low height and then finish the installation with no further adjustments.

Not everyone has a handy tower to use for a highly elevated mount. The antenna is light enough to accept a chimney mount intended for an outdoor TV antenna (assuming in this age of cable that we remember such things). Mounting the antenna on top of your living space does call for some practical considerations.

First, it is likely that the radials may droop so that the roof comes between pairs of them. If the attic space is clear of significant metal, the roof will not usually detune the antenna. However, if the attic rafters have metal-faced insulation, it may have an affect. In such cases, you may wish to extend the mounting pole high enough to clear the roofline.

Second, the vertical element may gather static charges. **Fig. 3** shows a cure for this potential problem.

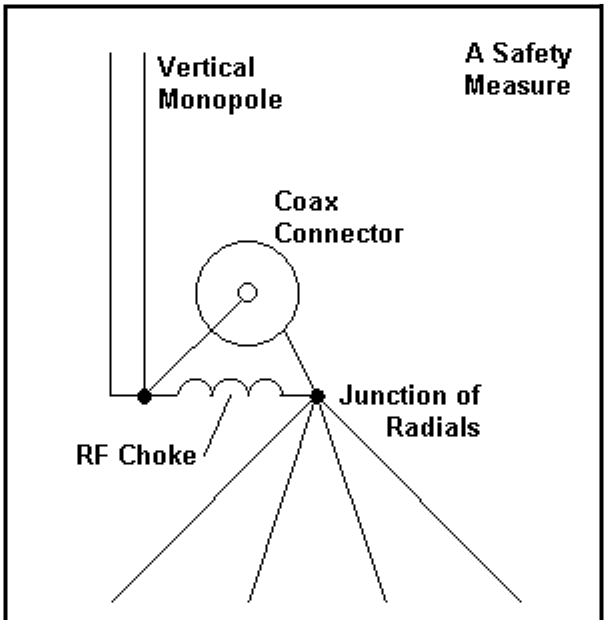


Fig. 3

Across the coax connector--or, what amounts to the same thing, between the vertical element and the junction of the radials--connect an RF choke. A value of 10 uH is usually sufficient, and 100 UH will work as well. At 10 meters, the choke blocks RF energy, so you will not be shorting out the antenna relative to operation. However, the choke does provide a DC path to discharge static energy in the vertical element as it builds. So all of the parts of the antenna will be at the same potential.

As an adjunct to this measure, where the coax would enter the house, connect a ground lead to the braid and the other end to a ground rod. Make this a stout lead and rod, since the monopole becomes a lightning rod. Remember that lightning rods tends to bring the ground potential to the rooftop, making it a less likely target for lightning than other nearby objects--such as trees--that can store and hold a charge that is more opposite to the cloud bottom charge. As a result, the other objects become more attractive than your antenna to cloud discharges. (However, if your antenna is the only tall object within a large area, then all bets are off and you need a strong discharge path for any strikes.) It is always wise when a storm approaches to disconnect your coax out of doors and reconnect the antenna lead to the earth-ground system.

The monopole with drooping radials can be an effective vertical antenna. The principles of installation that apply to it also apply to any of the commercial trap verticals that you might use for multi-band operation.

No. 50: Notes on Horizontal Antenna Height

L. B. Cebik, W4RNL

In the last issue, we looked at the simple ï¿½-wavelength vertical monopole. In the course of our examination, we paid close attention to the effects of height on the pattern of the antenna. We discovered that if we chose a height too great, we could send our signals into space rather than into the skip layers that give us long-distance 10-meter communications. Although we have touched upon the subject in the past, we should give equally close attention to the height of horizontal antennas.

One advantage that all single layer horizontal antennas share is that their behavior is very regular as we change heights. By a "single-layer" antenna, I mean a single dipole, a single Yagi, etc. The situation does change a bit when we stack horizontal antennas. But most of us are limited to single layer antennas, and that is our proper starting point.

As we raise the height of a horizontal antenna, 2 things happen. First, the lowest elevation lobe gets lower and lower. That is an advantage, because on 10 meters, most of the DX skip occurs at angles from about 5ï¿½ to 10ï¿½ or so above the horizon. The second phenomenon is that when we raise the antenna, more and more elevation lobes develop. **Fig. 1** shows the situation of a dipole at 0.5-wavelength intervals up through a 2-wavelength height.

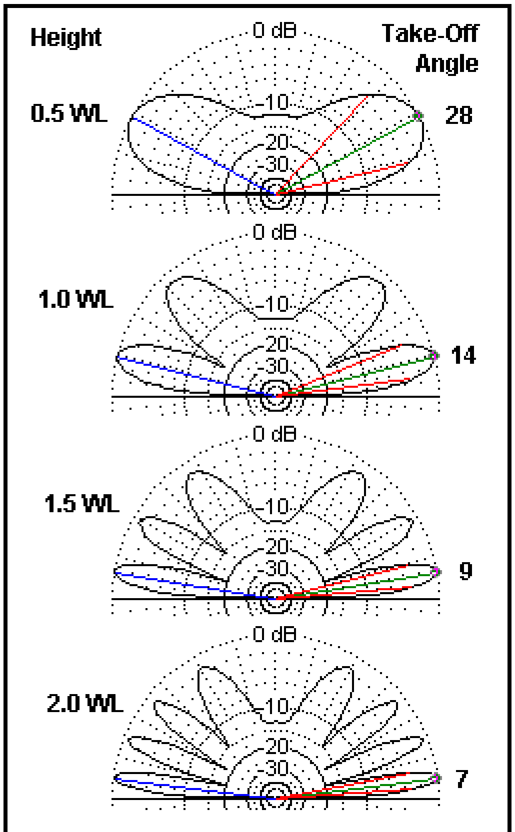
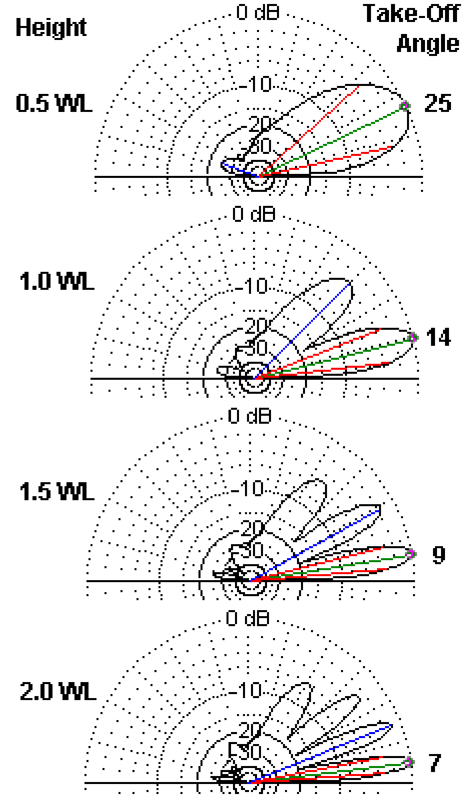


Fig. 1 Height Effects for a Horizontal Dipole

For each half-wavelength step, we find a new lobe. These lobes do not simply pop up, but develop. They first appear as a bulge straight up and then gradually split as we increase the height until they take their place in the set of lobes--with a new top bulge. Since we only have 90ï¿½ of angular room for the lobes, every new lobe results in a lower angle for existing lobes, and each of them gets a bit thinner.

Note that each elevation plot is labeled in terms of the height measured as a fraction of a wavelength. A wavelength at 10 meters is about 35', at 15 meters 44', and at 20 meters 70'. So if you use a tri-bander at 70', then your 20-meter lobes will look like the 1-wavelength picture, on 15 like the 1.5-wavelength picture, and on 10 meters like the 2-wavelength picture. In fact, we should run the same plotting exercise with a 3-element Yagi just for comparison. See **Fig. 2**.



Height Effects for a Horizontal 3-Element Yagi

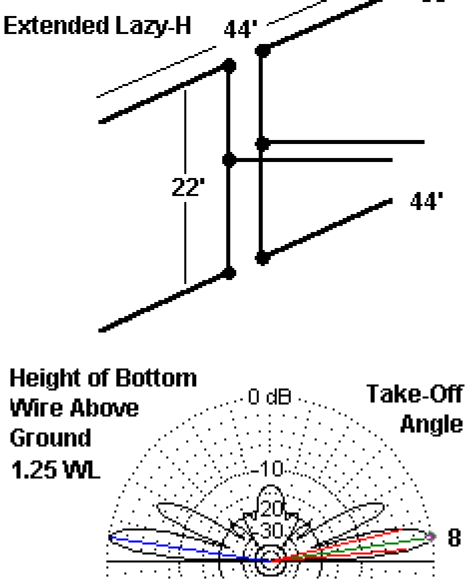
Fig. 2

Note that in the forward direction, we find the same number of lobes at each height as for a dipole. At the lowest height, the Yagi main lobe is slightly lower than for the dipole as a function of the Yagi's added forward gain. But that advantage quickly fades as we raise the antenna higher. In addition, the rearward lobes of a Yagi tend to show some erratic properties, but so long as the front-to-back ratio is high--as it is in this design--the oddities create no problems. A 2 element Yagi, with lesser front-to-back ratio will show stronger rearward lobes with more standard differences in strength. The 3-element Yagi shown in the plot has a gain advantage over the dipole about 5.8 dB, although that advantage varies with height--assuming one of each type of antenna at the same height for comparison.

How high should I place my antenna? For maximum DX, place it as high as is feasible. I have heard arguments to the effect that a half wavelength is the optimal height, because we have only a single forward elevation lobe. Unfortunately, that argument fails to account for two facts. As we raise the antenna, the gain of the lowest lobe increases. The 2-wavelength dipole is about a half-dB stronger than the ï¿½-wavelength dipole. The 2-wavelength Yagi is about 1.5-dB stronger than the ï¿½-wavelength version. The second fact returns us to the primary skip angles on 10 meters, which are very low for the longest DX (most of the time). With a height of 1.5-2 wavelength, the Yagi main lobe angles fall well into the prime skip angles. Those same angles receive about half of the available power when the Yagi is only 0.5-wavelength up. If a half wavelength is all you can manage, you will still do well, especially in strong sunspot periods. But greater height will bring even better results.

These principles apply to what I have called the single-bay or single-layer horizontal antenna. The class of antennas includes single dipoles, Yagis, and flattop horizontal phased arrays, such as the ZL-Special or the 8JK. We can modify the lobe elevation structure by using horizontal antennas that are stacked vertically and phase fed. Many such arrays are possible, but here we can bring back an old favorite of mine just to illustrate how the elevation lobes change with stacking. The array is the expanded lazy-H. As shown at the top of **Fig. 3**, we run two extended double Zepp center-fed wires, each 44' or about 1.25 wavelength long. We place them one above the other, using a 5/8-wavelength spacing or 22'. Using parallel feeders, we run lines from each wire to a mid-point between them. At this junction, we run a parallel feeder back to the shack to a balanced antenna tuner. The antenna is usable on 40-10 meters with bi-directional narrow-beam high-gain patterns. The exact gain is a function of the overall antenna height, but with the base at 44' (about 1.25 wavelength) and the top is at 66', the gain is somewhat over 15 dBi--greater than the gain of the 3-element Yagi.

Fig. 3



Sample of an Array that Modifies Horizontal Wire Lobe Structures

The lower portion of **Fig. 3** answers 2 questions at the same time. 1. Where does all the gain come from? 2. Where did all the Yagi and dipole upper angle lobes go to? (These questions will also give some work to the preposition police.) When we place horizontal antennas at a vertical spacing of 1/2 wavelength, most of the upward energy cancels out and re-appears at lower angles. In the present configuration, the spacing is about 5/8 wavelength, which does not cancel all of the vertical energy, but does yield the highest gain in the lowest lobe. Note that compared to the dipole and the Yagi, even the extended lazy-H second elevation lobe is small, releasing more energy for use in the lowest lobe.

The actual mechanics of lobe formation is a matter of complex interactions of direct radiation and reflections from the ground at a distance from the antenna. My brief description above has a few terms that will not withstand mathematical treatment. However, we have a basic fact: an antenna will radiate all of the energy fed to it. If it does not go up at high angles, then it must go elsewhere. Since the linear nature of horizontal elements prevents the radiation going to the sides (in a well-designed array), then the energy must go into the main lobe or lobes. As a general rule, the higher the gain of an array, the narrower also that the beamwidth becomes. So if you plan to use a wire extended lazy-H, aim it well so that your gain goes in useful directions.

However, our main theme this time is not beamwidth in the horizontal plane, but the elevation lobes that form the pattern of any horizontal antenna. The higher the horizontal antenna, the lower will be the lowest and strongest lobe. Hence, DXers try for the highest antenna position feasible. The higher we place the horizontal antenna, the more elevation lobes that form. Stacking antennas by the right spacing can increase gain in the lowest lobes and reduce relatively useless very high angle radiation.

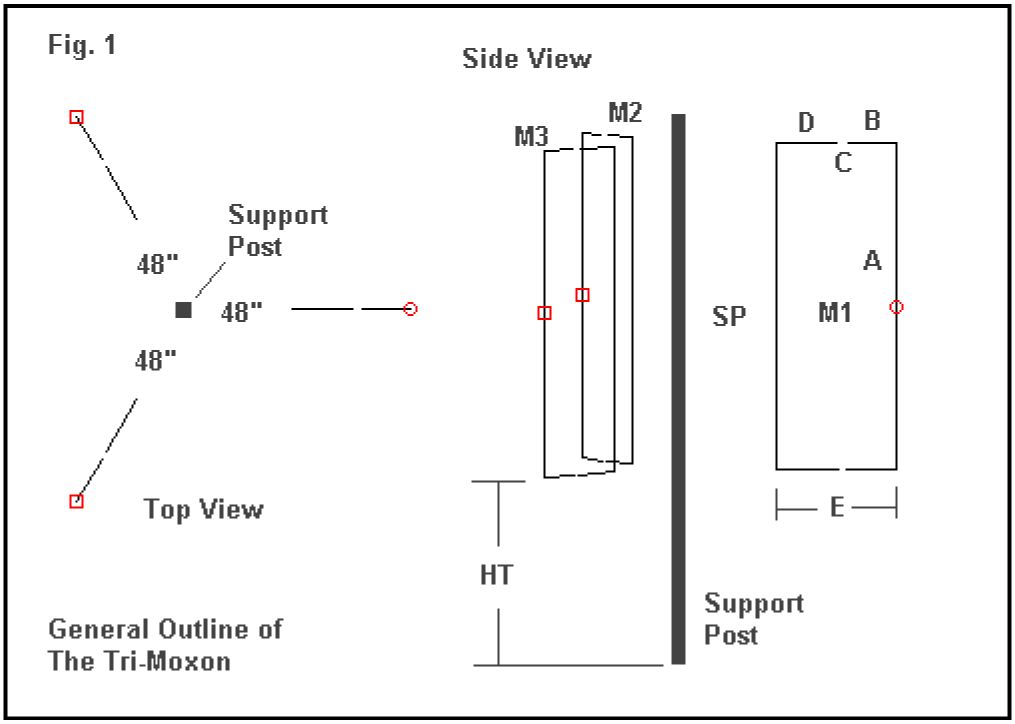
Finally, note that I always qualify my recommendation for height with the words "as feasible." There are questions of cost, maintenance, regulations, and simple family comfort that form part of our decision on how high to place an antenna. Higher is better, but only if you can handle it. My tower is only 35' tall, but my hill is nearly 100' above surrounding terrain. Mother nature has saved me a bundle of money and worry.

No. 51: The Tri-Moxon Switched Vertical Array

L. B. Cebik, W4RNL

Site and budget restrictions often rule out a rotatable Yagi as out 10-meter antenna. However, the basic dipole is bi-directional, denying us the full horizon. A simple vertical often lacks some of the gain we want. Suppose that we could come up with a vertical array with gain and front-to-back ratio and cover the entire horizon with a switch instead of a rotator. If we set three individual small antennas vertically, we can cover the horizon. If we select the right antennas, we can use a single support post about 35' tall and set the antenna in the form of a Y, switching to the unit that covers the relevant 1/3 of the field. Also, selecting the right antenna will let us make a Y that is less than 10' in radius.

The right antenna is a vertically oriented wire Moxon rectangle. Using AWG #14 wire, we can string 3 of them in Y-formation, keeping each one 4' from the post. That distance will reduce interaction to acceptable levels. Each rectangle will cover 28-29 MHz with less than 1.7:1 SWR using 50-Ohm coax as the feedline. **Fig. 1** shows the general outline of the system from the top and the side. We shall look at supporting the antenna before we finish.



The right-most part of the sketch shows the general outline of each of the 3 Moxon rectangles. We have examined this array in past columns. As well, the design of Moxon rectangles has been reduced to a set of true equations that will reliably yield the dimensions of the antenna for any reasonable element diameter (using wire or aluminum tubing) for any design frequency from 3 to over 300 MHz. See my web site (..) for more detailed information on the antenna and links to downloading small design programs.

SP is the 48" spacing of the reflector from the post, and the 3 antennas are at 120ï¿½ angles to each other. The dimensions are the same for all 3 rectangles. They will work for AWG #12 wire as well as AWG #14.

Dimension	**Feet**	**Inches**
A	**12.63**	**151.5**
B	**1.90**	**22.8**
C	**0.35**	**4.2**
D	**2.36**	**28.3**
E	**4.61**	**55.3**

Each vertical rectangle covers about 125ï¿½ of the horizon. So by switching from one to the next, we can cover the full horizon with only minimal decreases in gain at the overlap points. See **Fig. 2** for overlaid azimuth patterns.

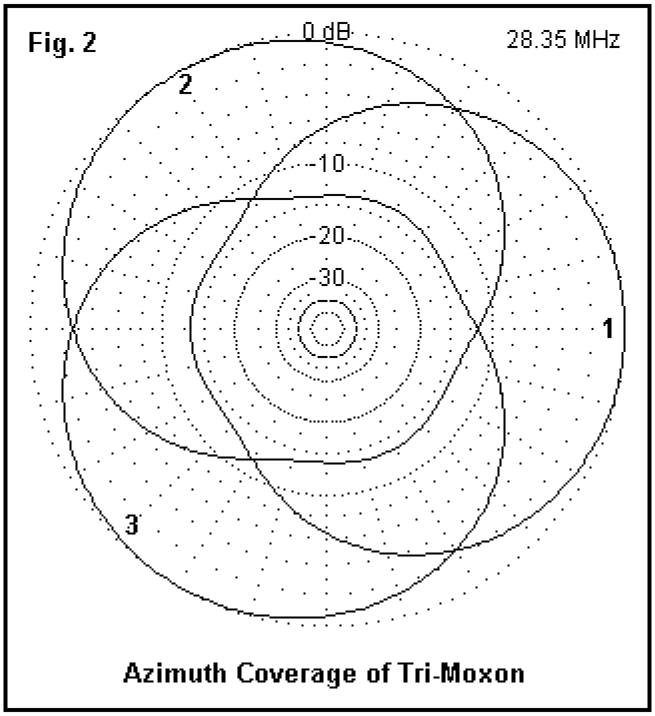
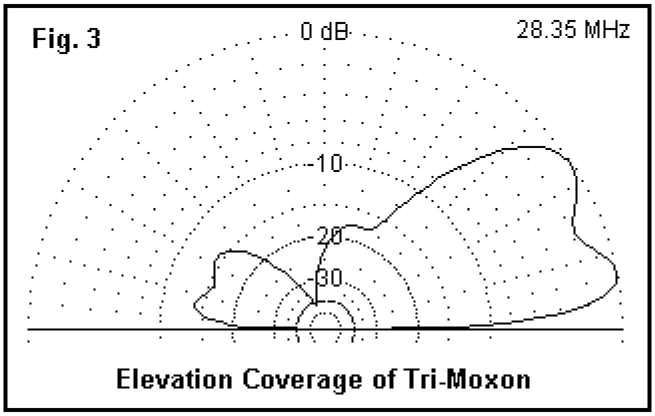


Fig. 2

Azimuth Coverage of Tri-Moxon

The front-to-back ratio is about 13 dB, in the range of a 2-element Yagi. The gain at the 11ï¿½ elevation angle of maximum gain is about 6.6 dBi. The system has been designed for a top height of about 34-35', which places the lowest point of each rectangle just above 22'. The height selected is not accidental. At this height, each rectangle produces a broad vertical pattern suitable for both short- and long-range paths, with peaks at 11ï¿½ and at 34ï¿½. **Fig. 3** shows a typical elevation pattern.



Any triple array of beams will interact. The advantage of using the tri-Moxon design is that the interaction is minimal due to the high front-to-back ratio of each rectangle. However, since they are not purely back-to-back, but at angles, we can only minimize the interaction. The Moxon allows a reduction in the needed spacing from each other relative to other antennas that we might similarly arrange--for example, three 2-element Yagis. The spacing shown allows an adequate front-to-back ratio and a smooth 50-Ohm SWR curve. **Fig. 4** shows the SWR curve for a coaxial cable feed system. Wide spacing would further reduce interactions, but would take up more backyard space and complicate the support system.

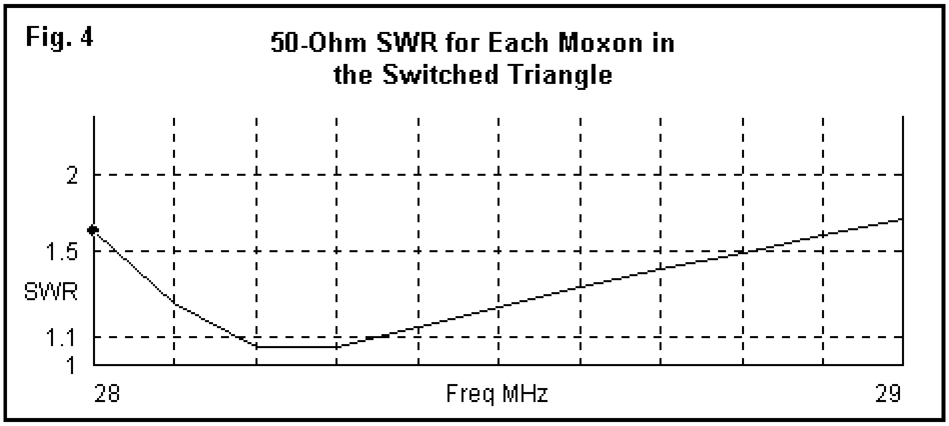
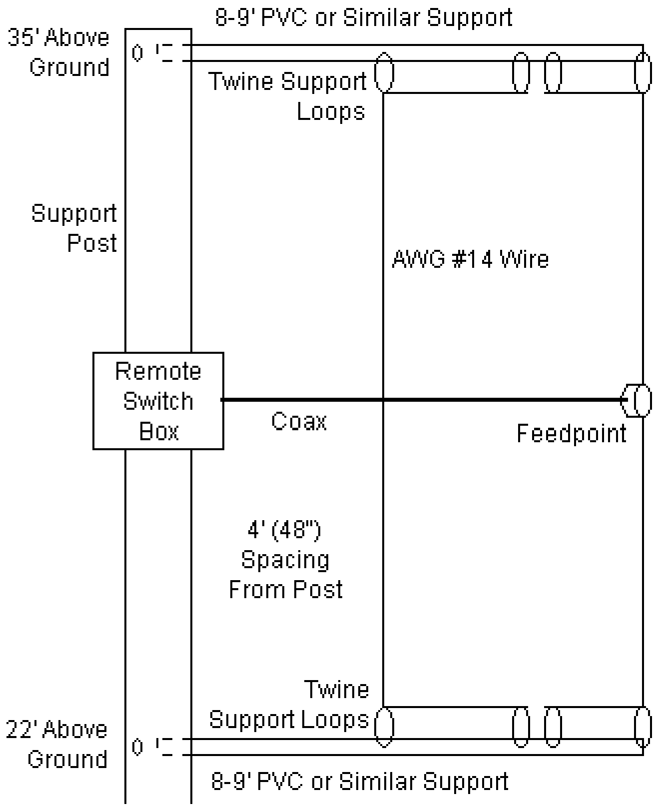


Fig. 1 carries the suggestion of supporting the entire set of 2 wire Moxon rectangles from a central support post. **Fig. 5** shows one way to achieve this goal.

Fig. 5



Support System for One of 3 Moxon Rectangles in the Tri-Moxon Vertical Array

First, all support elements must be non-conductive. A dead tree or a telephone pole that extends 35' above ground makes good central support posts. The sketch shows 1 of 3 rectangles supported by top and bottom horizontal "limbs." The limbs can be PVC or similar material capable of self-support for about 8-9 feet away from the central post. You can drill through the central post, and vertically displace each rectangle by a few inches so that the support "limbs" do not meet in the middle of the post. Set the top and bottom horizontal supports a little above and a little below the ends of the rectangle.

Use synthetic twine or thin rope to keep the rectangle under tension between the horizontal supports. This technique keeps the wires from resting on the PVC or other material, which might change a dimension along the rectangle ends. As well, loops allow room for small adjustments to the rectangle dimensions to arrive at the most perfect passband. Although the sketch shows vertical corner supports, placing them at an angle will hold the corners taut. With a piece of twine filling the gap, you can hold the rectangle in perfect shape, even if PVC or similar limbs sag a bit along their length.

Feed each Moxon rectangle with a 50-Ohm cable. You have two main choices for feeding the array. First, you can bring coax lines from each one all the way to the shack and switch them indoors. Second, you can obtain a remote coax switch and place it on the support post as shown in **Fig. 5**. Modeling shows that you get slightly better performance if the unused rectangles show an open circuit. So if the lines from the feedpoints to the remote switch are either 1/4-wavelength or 3/4-wavelength, the unused ones should be shorted at the switch end to yield an open circuit at the actual feedpoint. If the lines are 1/2-wavelength long to the switch box, the switch ends should be open to show the same condition at the feedpoint. However, the difference between the 2 conditions does not create enough difference to be called critical. If the lines go all the way to the shack, use the simplest switching feasible.

The Tri-Moxon vertical array is not an answer to all situations. But it is a workable system using light wire individual antennas set to cover the entire horizon with gain, a reasonable front-to-back ratio, a good range of elevation angles, and direct 50-Ohm feed. It requires only 1 central support and standard construction techniques for the rest of the support structure. As well, it saves the cost of a tower and rotator. Hence, the array is worth adding to our collection of 10-meter antenna ideas.

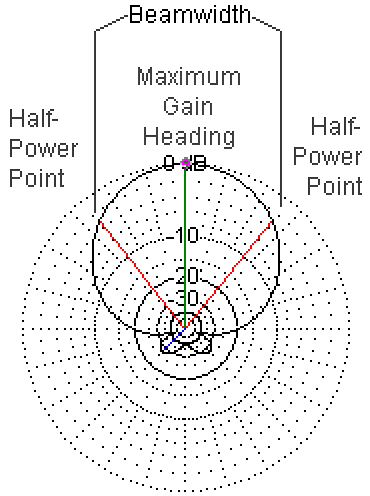
No. 52: Gain vs. Beamwidth

L. B. Cebik, W4RNL

Antenna ads are long on gain numbers, but woefully short on other important data. One of the major absences is a beamwidth specification. Omitting this information has led some wire antenna makers to advertise their wares as having on some bands more gain than a 2-element Yagi. They do not say in what direction the gain occurs relative to the fixed-position wire antenna and they do not say for how much of the horizon the gain number holds true.

If you use a rotatable Yagi or similar array, beamwidth has only secondary importance. For the size beams that are practical on 10 meters, the beamwidth will vary from about 65ï¿½ for short-boom arrays to about 50ï¿½ for long-boom Yagis. What these number tell us mostly is that super-precise aiming is not too important, since the gain variation from mis-aiming will not be detectable within about +/-10ï¿½ of the target bearing. However, if we have a fixed-position antenna that is horizontal, then beamwidth takes on added significance.

Fig. 1



Azimuth Pattern and Beamwidth

Fig. 1 shows a typical azimuth pattern for a 2-element Moxon rectangle only to show what we mean by beamwidth. The vertical centerline on the plot shows the direction of maximum gain. At some angle on either side of this line, the gain level will be 3-dB lower than maximum gain. These two points are called "half-power points." The angle between the half-power points defines the antenna's beamwidth.

If we cannot rotate or switch our antenna to place the main beam where we wish it to be, then beamwidth becomes an important consideration in selecting an antenna for 10 meters. In general, we want to be able to communicate over more of the horizon than we want to leave unattended (because no one lives in those directions). To ensure that we cover the complete horizon, many operators with limited space use vertical antennas and accept the reduced gain as the cost of coverage.

There are too many different antennas to explore beamwidth factors in this short column. So let's take the extreme cases. One of those cases concerns 80- and 40-meter wires, about which manufacturer advertising tends to make misleading statements. The product is usually a 135' (or thereabouts) wire which is resonant on 80 meters and usable on all bands--a very old antenna indeed. The antenna in principle can be fed at the center, at one end, or at a position between, called off-center-feed.

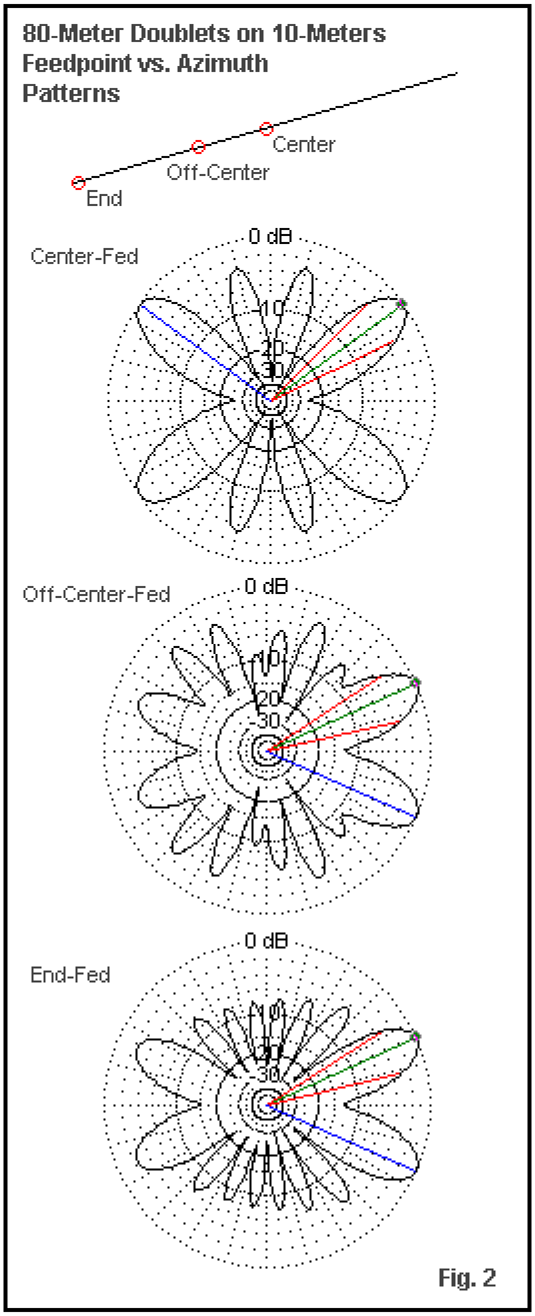
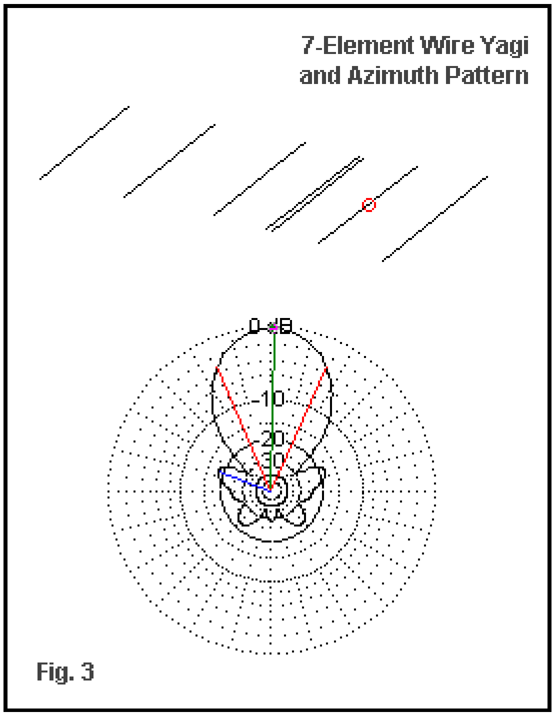

80-Meter Doublets on 10-Meters
Feedpoint vs. Azimuth
Patterns

Fig. 2

Fig. 2 shows what happens when we take any of these three feed systems and run the antenna on 10 meters. The maximum 10-meter gain runs between 10.5 and 12.3 dBi, depending on the feed system. However, as the half-power lines on the strongest lobes show, the gain applies only to selected lobes at a wide angle from broadside to the wire--which runs left to right across each pattern. The beamwidth for any of the feed systems is only about 20ï¿½ wide. In many parts of the US, a 20ï¿½ beamwidth will not cover all of Europe, assuming that you set up the antenna in exactly the right way. If we factor in wire sway during brisk breezes, we may find that signals vary widely in strength without any changes in the propagation.

There are a number of fixed wire antenna designs that offer considerably more gain and a predictable direction for it. Many operators with budget constraints feel drawn to such antennas because they are cheap, fixed, and relatively easy to build. For example, we need not use aluminum tubing for Yagi elements. With proper design, we can have a high-gain 10-meter Yagi made from wire. Suppose we could have nearly 15-dBi forward gain with a high front-to-back ratio with an antenna that uses very little more wire than the 80-meter doublet.



7-Element Wire Yagi
and Azimuth Pattern

Fig. 3

Fig. 3 shows the outlines of a 7-element wire Yagi with the desired gain. Note that the side and rear lobes have very low strength, giving us excellent forward performance. However, the beamwidth is only 47ï¿½. This antenna is for special purposes, for example, if we desire to communicate regularly in only one direction. There are numerous operators who maintain regular schedules with family members or colleagues. Others specialize in contacts with only one part of the world. For such folks, this type of antenna may be ideal. However, for the general operator, the antenna gives up over 85% of the horizon.

I recently saw on the Internet some hype for a 10-meter Sterba curtain. The antenna was promoted as having very high gain and also as having multi-band capability. Unfortunately, on all bands other than the one for which the antenna is designed, the patterns, elevation angles, and gain are mediocre. The Sterba curtain arose in the early days of short-wave broadcasting as a bi-directional array with high gain on a selected frequency. In commercial and government circles, the array has fallen out of use in favor of arrays that show a single directional pattern and some frequency nimbleness (such as the LPDA). An alternative is the electrically steerable array.

However, suppose we build the complex array composed of phased sections and end half-sections for only 10 meters. The question is what we may have if we successfully construct a Sterba curtain. The answer is two main lobes broadside to the wires. Each lobe shows a maximum gain of over 15 dBi. However, the beamwidth shrinks to 26ï¿½. The general arrangement of the antenna appears in **Fig. 4**. Invisible in the outline sketch is the fact that each vertical length of wire (except the end wires) is actually a phasing line consisting of two wires with a constant but relatively close spacing, that is, a transmission line. The pattern shows the main lobes and the narrow beamwidth. If you happen to live directly between two stations with which you wish to communicate regularly, a Sterba curtain might be useful. However, the cost is 85% of the horizon.

10-Meter Sterba Curtain and Azimuth Pattern

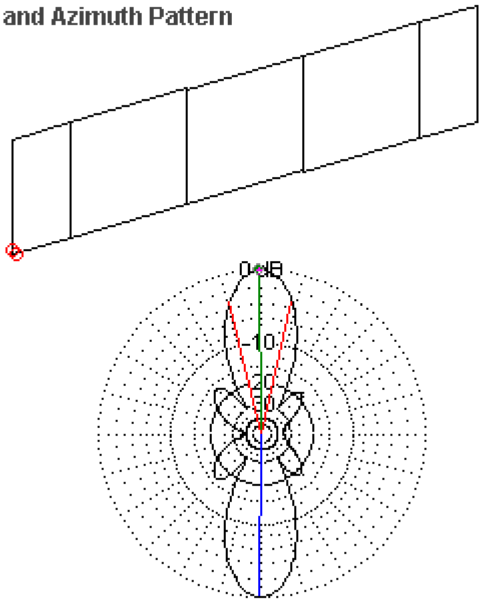


Fig. 4

Perhaps the king of all directional wire arrays by reputation is the rhombic. **Fig. 5** shows the outline and the pattern. Each leg of the rhomboid is multiple wavelengths long, and the designer carefully calculates an angle between legs to yield maximum gain. Called a "traveling wave" antenna, the point furthest from the feedpoint has a terminating resistor, ordinarily about 600-800 O and capable of dissipating at least half the power supplied to the antenna.

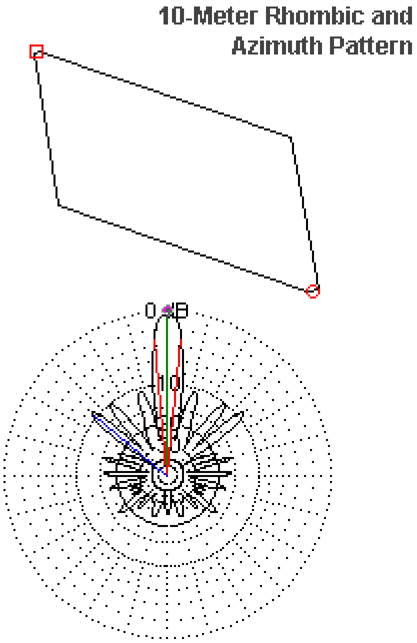


Fig. 5

The rhombic's pattern shows very high gain, almost 18.5 dBi in this design case. For the SW broadcaster or special communicator of the 1930s, the antenna allowed a very narrow beamwidth for point-to-point fixes. In fact, the beamwidth is under 11ï¿½. If I had the space and desired to communicate with a single city (or perhaps the city and its suburbs), the rhombic might be the antenna of choice. However, for the general operator who wishes access to the entire world, the rhombic is one of the poorest choices possible. The only way to use a rhombic for horizon-wide communications is to mount it in an ocean on a rotatable island.

These notes are designed to alert you to the temptations of gain at the expense of other important specifications that affect our operations. If you cannot install a rotatable antenna due to rotator/tower costs or deed restrictions, then perhaps a vertical or vertical array may be in order. Alternatively, you might be able to manage a TV mast to 20' or more above ground and mount a self-supporting dipole at the top. Then, you may hand rotate the dipole to be broadside to the desired communications path. With its 80ï¿½ beamwidth for each of the two lobes, you would not have to move the antenna direction very often during the day, and you might lower it out of sight when not in use. (Hang some flags, pennants, or mock laundry from the element to disguise the antenna's true function.) The idea is to swap gain for a wide beamwidth to gain access to more of the horizon and hence more communications targets. Beamwidth does make a difference.

No. 53: A Short-Boom Wide-Band 3-Element Yagi

L. B. Cebik, W4RNL

In the course of these episodes, we have examined a fairly large number of Yagi designs. They include short beams with only 2 elements up to long beams with 8 elements. Some have used matching networks to raise their low feedpoint impedances to 50 Ohms, while others used a direct 50-Ohm feedpoint connection. A few designs just barely managed to show SWR values of under 2:1 across the first MHz of 10 meters, while other have been wide-band designs. So why should I add another Yagi to the collection?

The simple answer is that the design in this episode is a bit different. A normal wide-band 2-element reflector-driver Yagi is about 5.5' long. A wide-band 3-element Yagi with a direct 50-O feedpoint is close to 11.5' long. There is considerable difference in the performance. The 3-element Yagi provides about 7.1 dBi free-space gain (add about 5.5 dBi when 1 wavelength above ground) and manages about 20-21-dB front-to-back ratio across the band. In contrast, the 2-element beam manages about 6.0-dBi gain across the band with only 10-12 dB front-to-back ratio. Now suppose that we could find a way to achieve about 6.7 dBi gain with about 16-17 dB front-to-back ratio and still keep the beam only 5.5' long. That beam would be worth at least a second look.

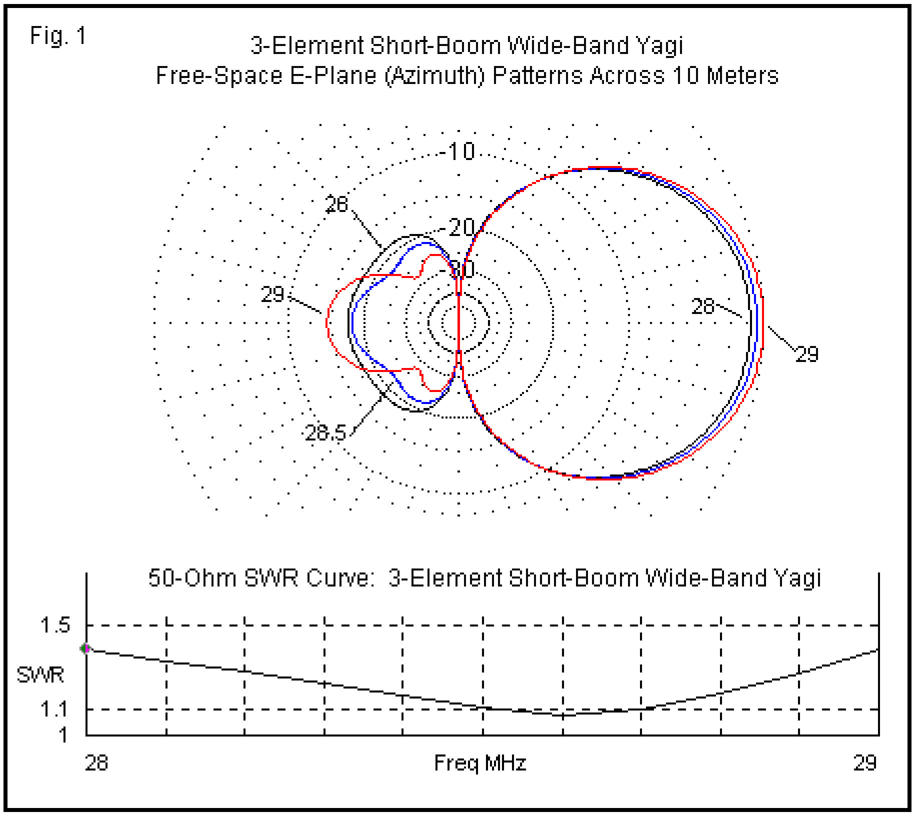


Fig. 1

Fig. 1 shows 3 overlaid patterns for the beam to cover the low, middle, and top parts of the usual 1 MHz region of 10 meters. The patterns show very little gain change (about 0.7 dB), and the front-to-back ratio holds up very well until we reach the very top of the band. The antenna uses a direct 50-Ohm feedpoint connection, and the lower part of **Fig. 1** shows the SWR curve. Ideally, the SWR does not reach 1.4:1 anywhere within the 1 MHz of 10. In fact, we might redesign the antenna slightly and cover the entire 10-meter band with under 2:1 50-Ohm SWR.

The performance improvement over a standard 2-element wide-band Yagi with the same boom length comes at a price: an extra element and a phase-line. The array that we are exploring has 2 driver elements spaced 25" apart with a single director 39" forward of the first driver. The total length is 64" plus a few inches at the boom ends. A 6' boom would serve very well. Let's take the structure in small steps.

1. The Elements: We can build beams to be light or to withstand heavy winds. To give you a choice, I shall give 2 sets of dimensions. One set uses heavier elements for wind loads up to about 90-100 mph. The lighter version might be rated to the 60-70-mph level. **Fig. 2** shows the way in which we construct the two types of elements using common aluminum tubing with 1/16" walls.

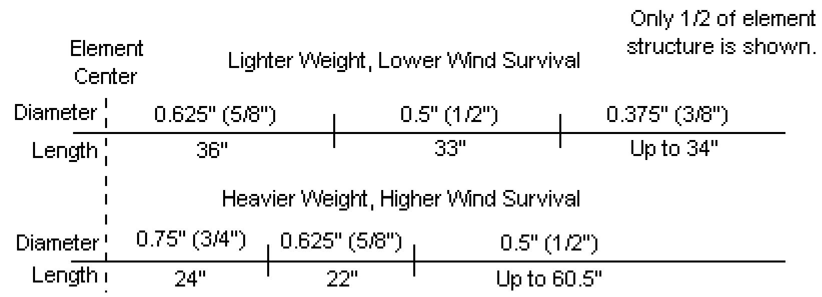


Fig. 2 2 Possible Element Structures for the Short-Boom 3-Element Yagi with Phased Drivers

The following table of dimensions applies only to these two element-diameter taper schedules. If you change the material diameters or the interior lengths of wider tubing, the beam may not perform as advertised. Remember to add about 2-3 inches to the lengths of the smaller tubes to provide a secure overlap.

3-Element Wide-Band Short-Boom Yagi with Phased Drivers: Dimensions

Heavy-Duty Version using 0.75"/0.625"/0.6" elements

Element	**Total Length**	**Tip (0.5") Length**	**Spacing from Rear Element**
Rear Driver	**205"**	**60.5"**	**-----**
Forward Driver	**193"**	**54.5"**	**25"**
Director	**190"**	**53"**	**64"**

Medium-Duty Version using 0.625"/0.5"/0.375" elements

Element	**Total Length**	**Tip (0.5") Length**	**Spacing from Rear Element**
Rear Driver	**206"**	**35"**	**-----**
Forward Driver	**194"**	**28"**	**25"**
Director	**191"**	**26.5"**	**64"**

Both versions provide essentially identical performance across the band. The free-space gain varies from 6.4 dBi at 28 up to 7.1 dBi at 29 MHz. (Yagis with directors show a rising gain with frequency increases, while 2-element Yagis with only a reflector show a decreasing gain with rising frequency.) The front-to-back ratio peaks at almost 18 dB at mid-band. Its lowest value is about 14.5 dB at 29 MHz.

2. The Overall Design: The general layout of the beam appears in **Fig. 3**. The top portion shows the relative position of the elements. In this design, I have started with a simple narrow-band driver-director array (and all 2-element driver-director Yagis have a very narrow beamwidth). I then changed the driver system to a pair of phased drivers in order to broaden the antenna's operating bandwidth. By the judicious selection of element spacing, element length, and the phase-line characteristic impedance, I ended up with a beam that spread the relatively good driver-director performance across the entire 1st MHz of 10 meters.

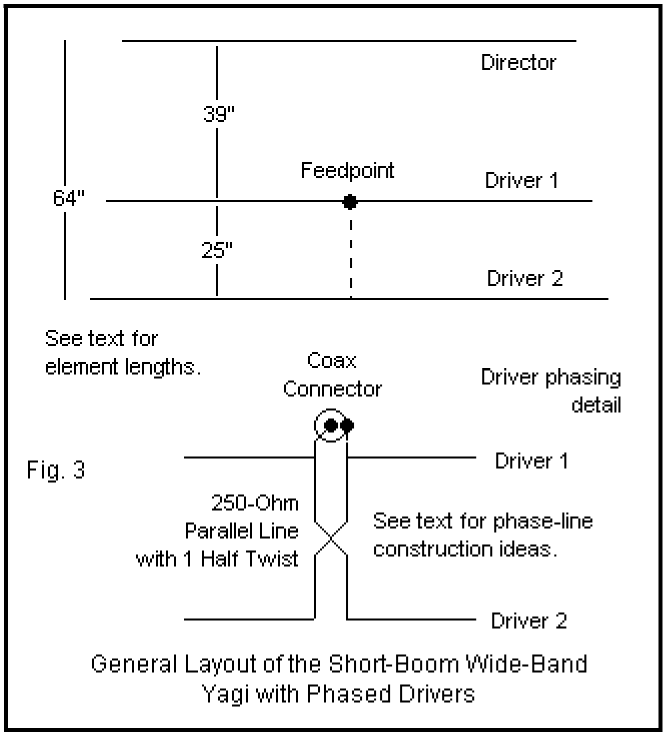


Fig. 3

General Layout of the Short-Boom Wide-Band Yagi with Phased Drivers

The lower part of **Fig. 3** shows the general layout of the interconnection of the 2 driver elements. The phase-line consists of a parallel transmission line with a 250-Ohm characteristic impedance. The line requires 1 (and only 1) half twist between the 2 drivers in order to provide the correct phasing for broadband service on 10. The coax connector--that is, the feedpoint for the main transmission line--goes on the forward driver. This position is convenient, since the position is fairly close to the mast.

3. Making Your Own Phase-Line: Since you need only 25" of phase-line (plus a bit of extra for connections to the elements), you likely should make your own. The following table lists the center-to-center spacing for 250-Ohm lines using some common bare copper wires, listed by AWG size.

250-Ohm Transmission Line Dimensions

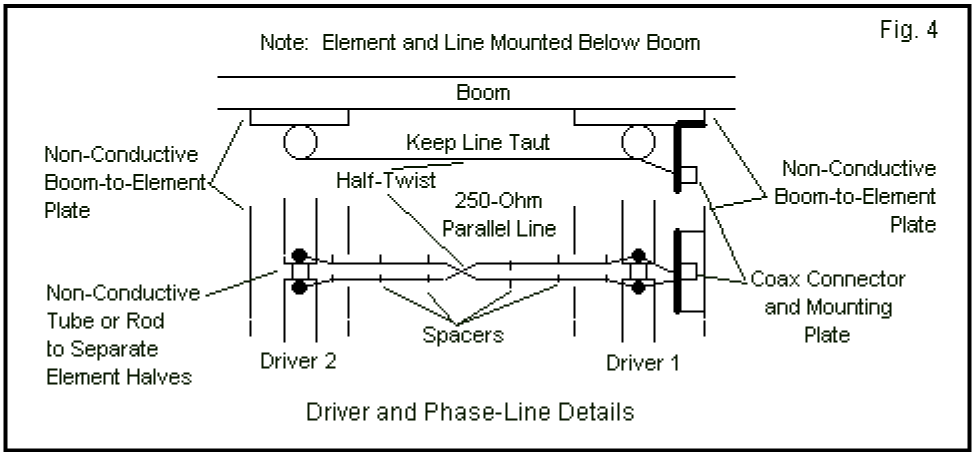
AWG Wire Size	Wire Diameter	Center--to-Center Spacing
#14	0.0641"	0.262"
#12	0.0808"	0.330"
#10	0.1019"	0.416"
#12	0.1285"	0.525"

You will need spacers about every 3" to maintain the wire spacing accurately. The best way to make spacers is to drill the wire holes in a long strip of plastic (such as polycarbonate or similar). Then cut the spacers to size after you complete the drilling. Do not make the holes too large; you want a tight fit. If you do not de-burr the holes, the spacer will tend to stay in place through all kinds of weather.

You may already be tempted to substitute 300-Ohm TV twinlead for the specified homemade line. I do not recommend the substitution. Even high quality 300-Ohm line has a velocity factor of about 0.8. Using a taut line will make the TV phase-line about 25% longer electrically than the value needed to create the right conditions for the drivers to operate well. Two elements with a phase line use a fairly critical combination of element dimensions and spacing--along with a fairly critical phase-line characteristic impedance and electrical length--to get the job done. The job involves dividing the current at the feedpoint so that each driver element receives the correct current magnitude and phase angle for maximum gain from the pair (in the presence of the director element).

4. General Assembly: There are many ways to construct Yagis. In this design, all of the dimensions apply to elements that are well insulated and isolated from a conductive boom. If you use a 6' section of aluminum tubing as a boom, you will need polycarbonate or similar non-conductive plates for the boom-to-element junctions. I prefer to use stainless steel U-bolts with saddles to grip the boom and the elements without crushing them. Saddled U-bolts with solid or cast saddles are available by mail. I prefer them to the typical muffler-style fixture with a U-shaped saddle that contacts the tubing in 2 lines.

The director will be a continuous element, with no break in the center. So double the length of the largest tubing in **Fig. 2** to arrive at the center-section length. Both drivers require a small gap (1/4" is fine) for connections. I tend to prefer fiberglass rod inside the largest tube and extending to the ends of the plate. This system has 2 advantages. First, it places an extra support under the element U-bolts and also aligns the whole element with only 2 element U-bolts near the outer edges of the plate. Second, the rod allows good support for #6 or #8 stainless-steel hardware for making the connections to the phase-line and to the coax connector leads. **Fig. 4** shows the general scheme without the U-bolts.



The side view shows the element below the boom for best stability. As well, the boom helps to keep ice and snow off the phase lines. The bottom view shows the phase-line and coax connection points. Keep the phase line taut. The sharp twist in reality will become a gradual twist along the line length. Using ï¿½" thick insulation plates and saddle U-bolts will provide enough spacing from the phase-line to minimize interaction with the boom.

The coax connector can sit on a small metallic plate attached to the forward edge of the forward-driver plate. Just be sure that the screws you use to secure the coax connector plate do not contact the boom. Of course, all hardware should be stainless steel, which you can obtain from most home centers these days. For other construction ideas and methods, you can check any number of antenna books, along with past episodes in the series.

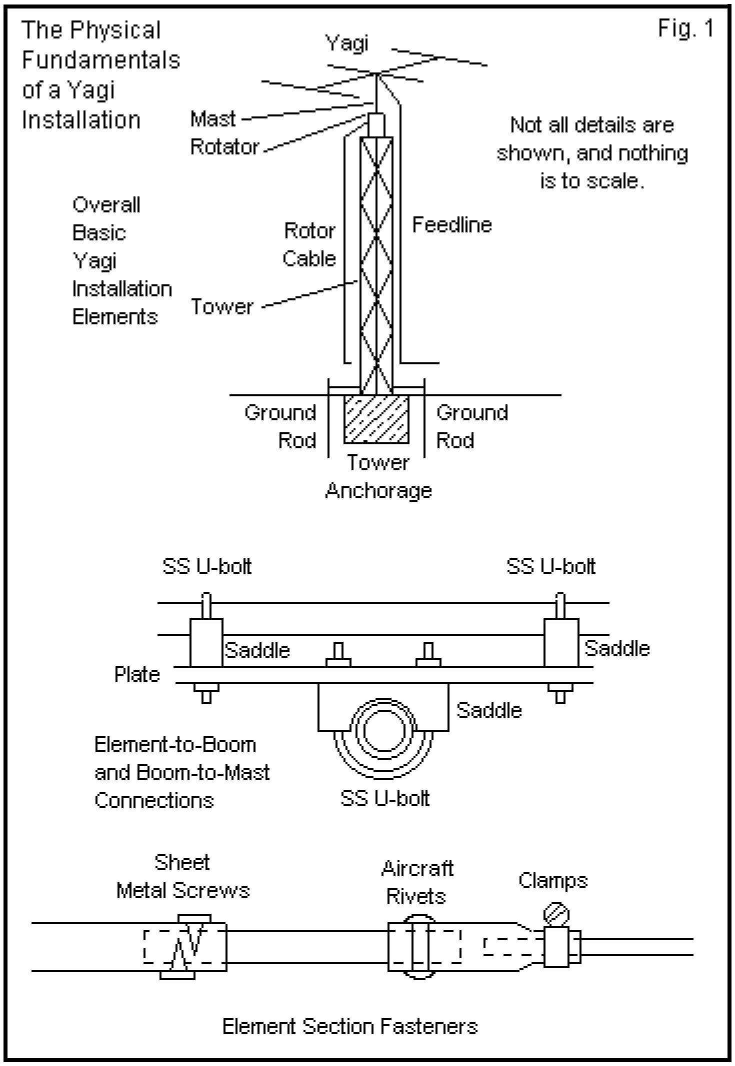
The short-boom wide-band 3-element Yagi with phased drivers is one more design in the arsenal of directive beams for the 10-meter operator. If you have followed these columns for the 13 years in which I have been producing them, your design notebooks should have a large collection of potential designs for the new sunspot cycle.

No. 54: An Orientation to Reasonable Yagi Expectations

L. B. Cebik, W4RNL

Sometimes, purchasing a Yagi can be as daunting a task as building one. The advertisements use a bewildering array of incompatible terms and specifications that often result in more confusion than information. In this episode, I shall introduce some of the most important ideas to consider when purchasing a Yagi (or similar) directive array. I cannot single-handedly change the ways of advertisers, but I can alert you to a few things to examine carefully along the way.

1. The Physical Fundamentals: Even before you look at the specification sheets from various antenna makers, you should think about the physical requirements of a good, solid antenna installation. **Fig. 1** shows some, but not all, or them.



The upper part of the graphic shows the bare outlines of a strong installation, included a tower (with guys omitted), a rotator, feedline, rotator cable, anchorage, and ground rods. All of these items must make a coherent package so that the system will withstand the stresses placed on it by the antenna at the top. If you are aging as fast as I am, or if you live in an area with a regular threat of very severe weather, then you should consider the added expense of a system that let's you lower the tower or the antenna in a storm or when periodic maintenance is due.

The antenna itself presents a number of physical concerns. We find 3 main construction philosophies in the world of Yagis. Some makers, like Force 12, use the willow theory of construction to produce light but flexible antennas. The American standard theory underlies most U.S. Yagis and uses fairly standard components, such as aluminum tubing with 1/16" walls. Most European-made Yagis subscribe to the oak theory, using aluminum with much thicker walls. In the end, their antennas tend to be 1.5 to 2 times heavier than U.S. beams with the same number of elements and wind-survival rating.

Beams present the wind with a certain area. Rotators usually carry two important ratings: the maximum antenna weight and the wind area. We need to match the latter figure with the antenna, since it is a measure of the maximum rotating stress that a rotator will withstand. Antenna themselves have a wind survival rating--usually in miles per hour. If you expect winds higher than the antenna rating, then be able to lower the antenna in a windstorm or check with the maker for the same antenna built to a higher wind survival rating.

The lower part of **Fig. 1** suggests a few construction details to examine. How do the elements connect to the boom (and how does the boom connect to the mast)? Is all hardware stainless steel? Do clamps and U-bolts hold the elements and the boom without deforming them? Are all non-conductive (plastic) materials UV-protected for long life (or will a fixture become brittle and break in a few years)?

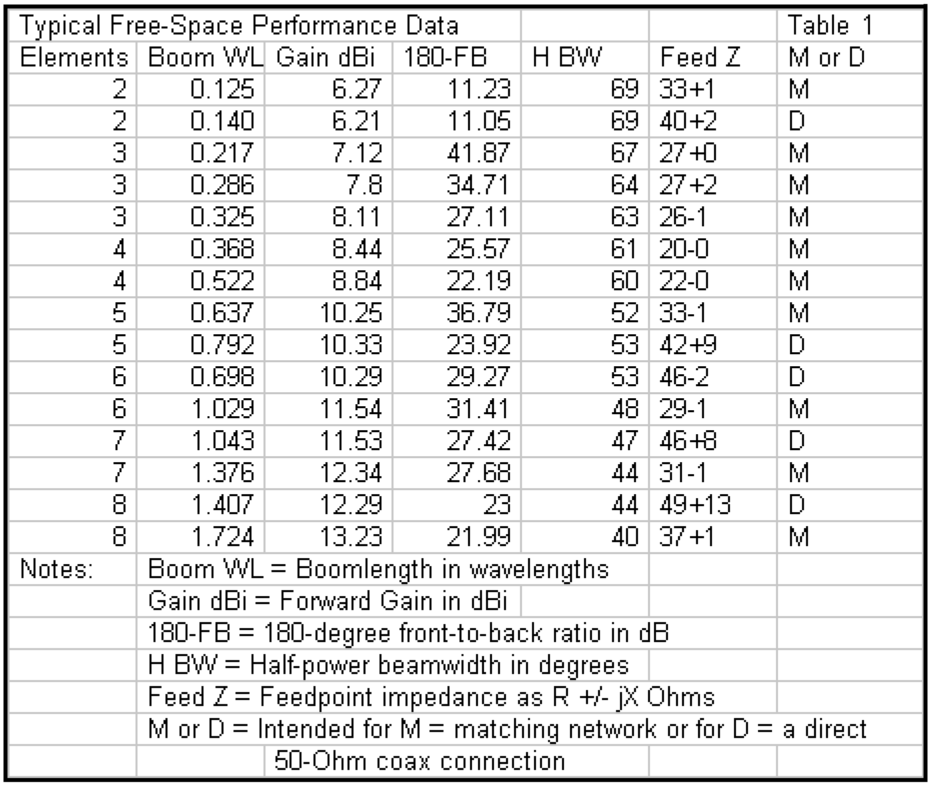
HF elements normally use a collection of tapered diameter tubing sections. The graphic shows 3 general ways in which makers secure the sections together. All three methods have proven track records if the hardware is non-rusting and strong. If a connection requires a special tool, be certain that the maker supplies the tool.

There are a few matters that the sketches cannot show. Be sure that the antenna fits inside your property. Find the distance from the mast to the tip of the longest element: that is the antenna turning radius. Be sure that it is well inside your property line with enough to spare to satisfy your insurance agent. If you antenna and tower fall, will they land completely on your property? Also be sure to adhere to any applicable laws, regulations, or covenants governing antennas in your area.

2. The Electrical Properties: The radiation properties of Yagis are designed to confuse you to the point of buying into whatever a given maker tells you. Consider the forward gain number. Some makers use a free-space value in dBi, based on computer modeling of the antenna. This figure avoids the variations in gain that occur over ground. Some makers cite values at a certain height in feet or meters above ground. Of course, this figure changes height as measured in wavelengths as you change the operating band. Still other use a figure based on the antenna 1 wavelength above ground. This value changes in feet or meters depending on the operating frequency.

Still other makers give gain figures in dBd, where the gain in dBd is 2.15 dB lower than the gain in dBi. When you combine these practices with the variations that I just cited, the gain values for seemingly similar Yagi designs can look very different. There is no solution to this morass except to perform calculations galore until you work through the specifications and come out with compatible figures for each candidate in your selection process.

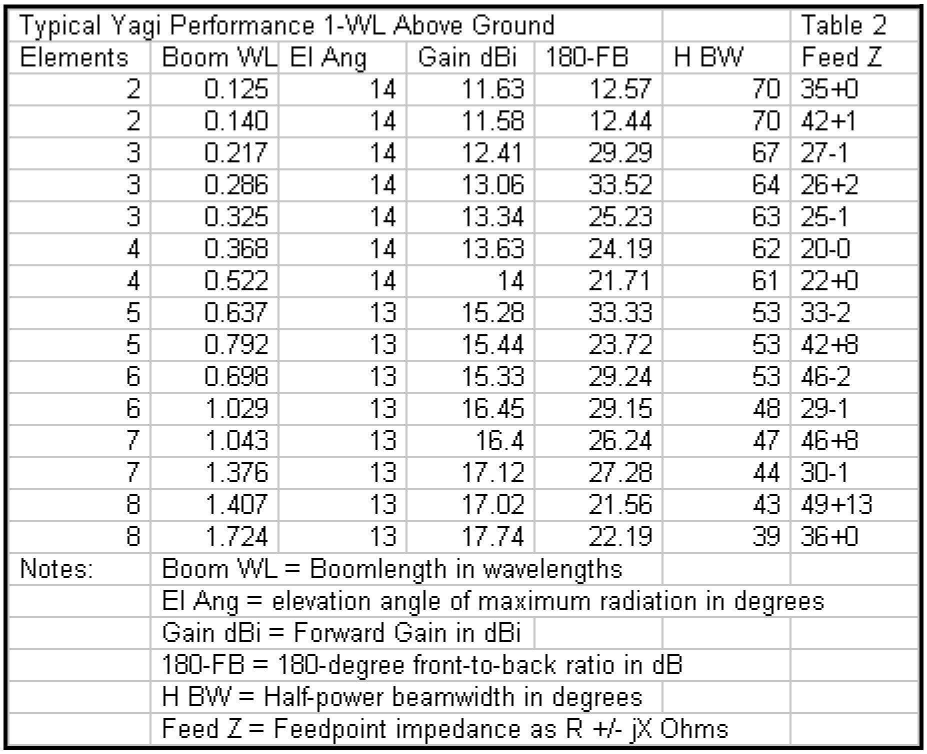
To give you some guidance, I have compiled some (but not all) of the 10-meter Yagi models in my collection from 2 to 8 elements. **Table 1** gives the free-space specifications at 28.5 MHz for each design. The gain is not dependent on the number of elements alone, but also on the total boom length. Therefore, a short-boom (8') 3-element Yagi may shows a little over 7 dBi free-space gain, while a long-boom (12') version with the same number of elements may have about 8 dBi gain. However, once we reach the long-boom size for any given number of elements, we may see one of two phenomena. First, the operating bandwidth of the antenna may be narrower. Many 10-meter antennas are rated only between 28 and 28.8 MHz, while versions with one more element in the same general boom length may be rated for the entire 1st MHz of the band. Second, we may find a lower feedpoint impedance. With good matching systems, impedances in the 20-25-Ohm range are fine, but below that level, losses begin to increase.



Typical Free-Space Performance Data						Table 1
Elements	Boom WL	Gain dBi	180-FB	H BW	Feed Z	M or D
2	0.125	6.27	11.23	69	33+1	M
2	0.140	6.21	11.05	69	40+2	D
3	0.217	7.12	41.87	67	27+0	M
3	0.286	7.8	34.71	64	27+2	M
3	0.325	8.11	27.11	63	26-1	M
4	0.368	8.44	25.57	61	20-0	M
4	0.522	8.84	22.19	60	22-0	M
5	0.637	10.25	36.79	52	33-1	M
5	0.792	10.33	23.92	53	42+9	D
6	0.698	10.29	29.27	53	46-2	D
6	1.029	11.54	31.41	48	29-1	M
7	1.043	11.53	27.42	47	46+8	D
7	1.376	12.34	27.68	44	31-1	M
8	1.407	12.29	23	44	49+13	D
8	1.724	13.23	21.99	40	37+1	M
Notes:	Boom WL = Boomlength in wavelengths					
	Gain dBi = Forward Gain in dBi					
	180-FB = 180-degree front-to-back ratio in dB					
	H BW = Half-power beamwidth in degrees					
	Feed Z = Feedpoint impedance as R +/- jX Ohms					
	M or D = Intended for M = matching network or for D = a direct					
		50-Ohm coax connection				

Except for the 2-element reflector-driver Yagis, most commercial monoband Yagis manage to achieve at least 20-dB front-to-back ratio over most of the band. Do not let peak values, such as the nearly 37 dB value of one 5-element model, fool you. Very high values like these only occur at a specific frequency, and there are usually quartering rear sidelobes with a more normal value close to 20 dB.

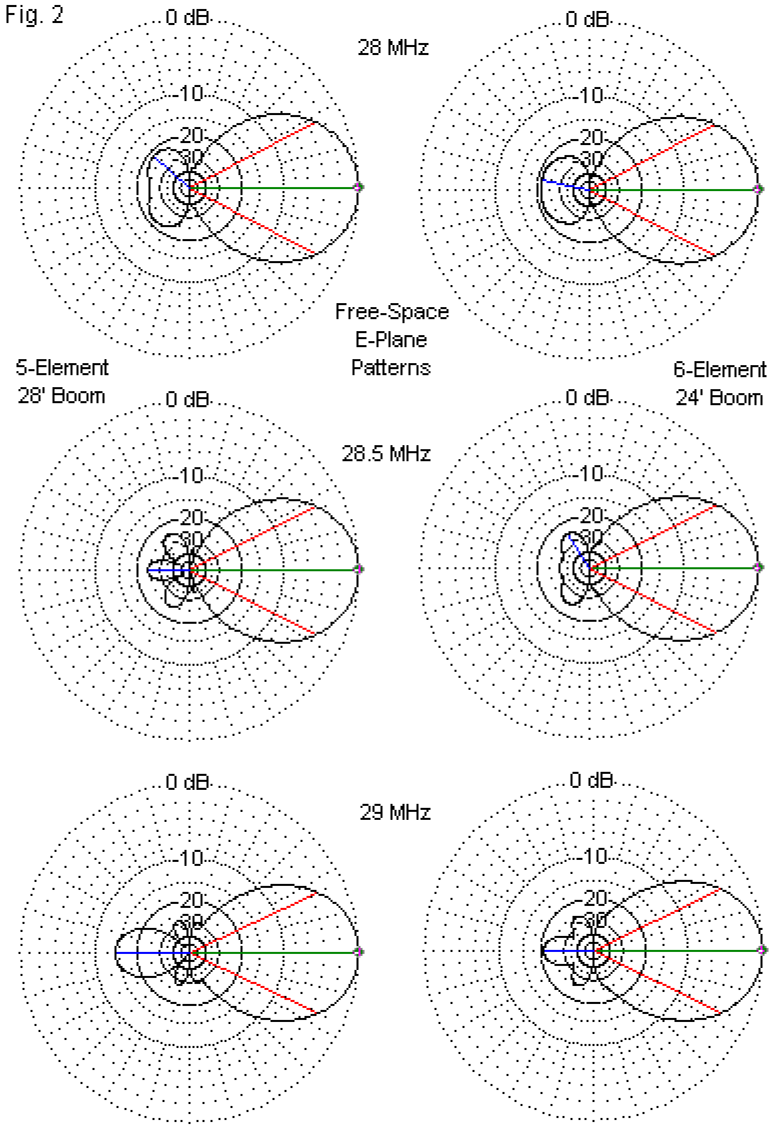
Table 2 shows the performance of the same beams 1 wavelength above ground, about 35' at 10 meters. Compare the gain values to those for the free-space models. As the beam gets longer and has more forward gain, the amount of increase provided by the ground reflections with a moderate height gets smaller. As well, the TO angle, that is, the elevation angle of maximum radiation gets a bit lower. As you raise the antenna height, these differences tend to diminish until they virtually disappear.



Typical Yagi Performance 1-WL Above Ground						Table 2
Elements	Boom WL	El Ang	Gain dBi	180-FB	H BW	Feed Z
2	0.125	14	11.63	12.57	70	35+0
2	0.140	14	11.58	12.44	70	42+1
3	0.217	14	12.41	29.29	67	27-1
3	0.286	14	13.06	33.52	64	26+2
3	0.325	14	13.34	25.23	63	25-1
4	0.368	14	13.63	24.19	62	20-0
4	0.522	14	14	21.71	61	22+0
5	0.637	13	15.28	33.33	53	33-2
5	0.792	13	15.44	23.72	53	42+8
6	0.698	13	15.33	29.24	53	46-2
6	1.029	13	16.45	29.15	48	29-1
7	1.043	13	16.4	26.24	47	46+8
7	1.376	13	17.12	27.28	44	30-1
8	1.407	13	17.02	21.56	43	49+13
8	1.724	13	17.74	22.19	39	36+0
Notes:	Boom WL = Boomlength in wavelengths					
	El Ang = elevation angle of maximum radiation in degrees					
	Gain dBi = Forward Gain in dBi					
	180-FB = 180-degree front-to-back ratio in dB					
	H BW = Half-power beamwidth in degrees					
	Feed Z = Feedpoint impedance as R +/- jX Ohms					

The final recommendation that I would make is to insist on seeing either the antenna patterns (such as in **Fig. 2**) or the gain, front-to-back, and impedance curves across the entire 10-meter band. In the figure, both antennas have about the same boom length. However, the 5-element antenna shows a relatively mediocre front-to-back ratio in the upper part of the band. If we had room for the graphs, we would also find that the 5-element antenna changes gain by about 1 dB across the band, while the 6-element design changes gain by only 0.2 dB. In terms of even performance across the band, the slightly higher element population of the 6-element design is superior, even though its peak gain does not match the value achieved by the 5-element beam at 29 MHz. You cannot reach your own conclusions about the antenna performance without the data for the antenna across the band. Do not be fooled by citations of peak values. As far as I am concerned, if a maker will not reveal all of the information about the performance of his antenna, he has lost me as a customer.

Fig. 2



Comparing Azimuth Patterns of Competing
Yagi Design Across 10 Meters

These all-too-brief notes provide the starting point for what you should consider when deciding on which commercially made monoband Yagi to purchase. Once you start learning about what to consider, you will think of equally important points to ponder and questions to ask. Note that I specified monoband Yagis. If you want to consider multi-band Yagis, you will enter a very different ballpark.

No. 55: What to Expect from Multi-Band Yagis

L. B. Cebik, W4RNL

In the last episode, we examined some of the physical and electrical factors that go into setting up a Yagi. For that exercise, we reviewed a large sampling of monoband beam designs for 10 meters. Our goal was to set up some reasonable expectations of Yagi antennas considering both the boom length and the element population. We discovered a number of factors that might influence our decision about which beam to purchase. The factors included the weight, the wind-survival rating, the gain and other pattern features, and the operating bandwidth of the antenna.

However, many 10-meter operators wish occasionally to use other bands. Hence, they are more interested in a multi-band Yagi, specifically, a beam covering 20, 15, and 10 meters. The effort to develop high-performance multi-band Yagis is many decades old. It has made very great strides since the advent of computer-aided antenna design. Nevertheless, the market today is filled with both modern and older designs. **Fig. 1** compares in outline both types of tri-band Yagis.

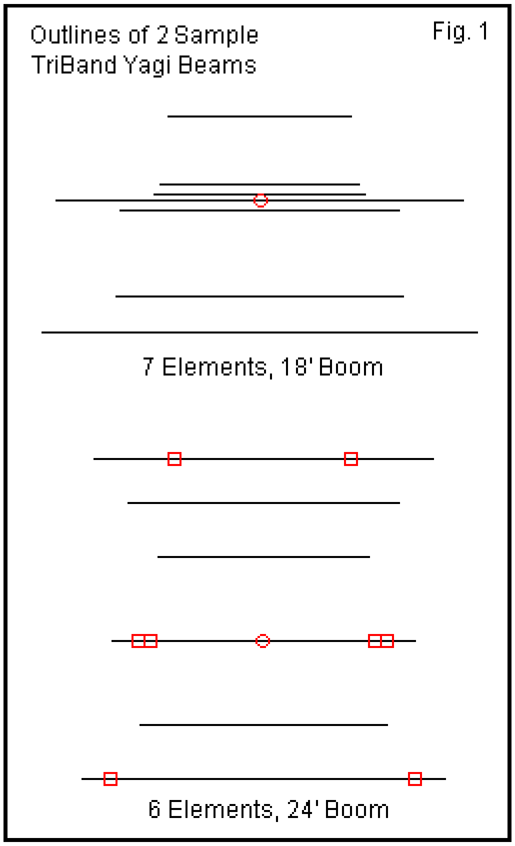
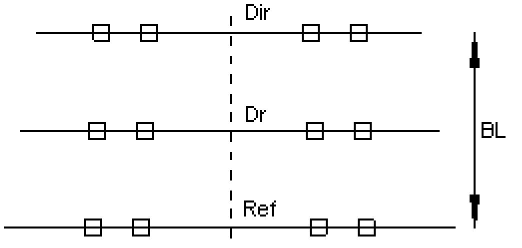

Outlines of 2 Sample TriBand Yagi Beams

Fig. 1

At the top is a more modern design. It uses 7 elements total, but each individual element has primary utility on only 1 of the 3 bands. The element lengths are clues to the band of primary use. This particular beam uses a master-slave driver assembly, as indicated by the 2 elements very close to the long (20-meter) driver with the circle indicating the feedpoint connection. The lower tri-band beam is a hybrid. It uses some dedicated elements (without square boxes). Other elements serve more than one band, as indicated by the square boxes that mark the location of traps. Advertising hype tends to either oversell the losses of traps or to remain silent on their losses, depending on which kind of tri-band Yagi we are trying to sell. Therefore, let's pay a little closer attention to tri-band Yagi design to see if we can develop some reasonable expectations of these antennas.

1. The Earliest Tri-Band Yagis: **Fig. 2** shows in outline form the general configuration of tri-band Yagis in the 1970s. These relatively early beams emerged from simple experimentation until the maker decided that the design was good enough to sell. The outline shows us two major factors to consider.

Fig. 2



One of the Oldest Types of
Tri-Band Beam

First, we find only 3 elements. From our exploration of monoband beams, we might conclude (validly) that the boom length and the element spacing are optimal on only 1 of the 3 bands--at most. Therefore, on the other bands, performance is likely to be lower than on the most optimal band. In many designs, the goal on the non-optimal bands was first to produce an acceptable feedpoint impedance for the coax feedline and second to develop at least a fair front-to-back ratio. Users who graduated from dipoles and doublets to the beam often mistook the reduction of rearward QRM for forward gain--and they still do today. Both factors are important, but they are not the same.

Second, we find traps in each element. Each trap (or equivalent device) terminates a higher-band length. On lower bands, it functions as a loading reactance. On 10 meters, the beam has no loading within the lengths for that band. However, the spacing is likely too wide for optimum 3-element 10-meter performance. On 15, the 10-meter traps load and shorten each element relative to its full trap-less length, but the spacing is likely closer to optimal. On 20, we have 2 loads per element side in each element. So the 20-meter elements are well below full size. In addition, the spacing is likely too short for full performance. Hence, in these designs, 20-meter performance tended to suffer most. (Incidentally, some tri-band designs appeared to have only one trap canister on each side of each element. However, each canister contained two traps, and the outer surface of the trap enclosure served as the intervening element section.)

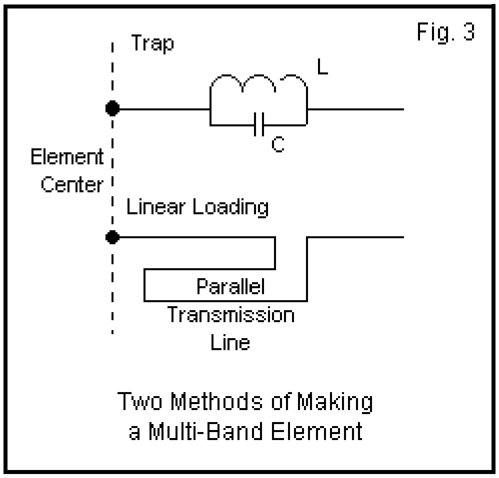


Fig. 3

Two Methods of Making a Multi-Band Element

Traps are not the only way to terminate an element at some specified frequency. **Fig. 3** shows the schematic of a trap and its equivalent linear-loading substitute. Ordinarily, we tune a trap to a frequency at or just below the lowest frequency on the band that it terminates. So we might use 27.8 MHz as the resonant frequency of a trap for 10 meters. Now consider the linear load. It is a section of shorted transmission line that the designer has folded back toward the center of the element. Ideally, at about 27.8 MHz, the line would be electrically ï¿½-wavelength long, forming a very high impedance, just like an ideal trap. Like the trap, at lower frequencies, the linear load was an inductive reactance that allowed us to shorten the overall length of the element on the lower frequency. The earliest linear-loaded element designers claimed that they had no losses and hence formed ideal ways to terminate or shorten an element. Unfortunately, those claims have not proven to be correct. The fold-back construction is one reason for less than perfect performance. The 2 lines interact with the apparent main element, so the linear-loading section rarely shows perfect transmission-line currents that are equal in magnitude and opposite in phase.

The Q of a standard trap ranges up to about 250--a good value but not a perfect value. Each pair of traps in an element--when they function as loading devices on lower frequencies--tends to reduce the element's gain by about 0.5 dB. We cannot eliminate the loss with an ideal trap--such as a perfect linear load--because part of the gain loss comes from the shortening of the element. Hence, even ideal traps, of which there are none, would create some gain loss. (Unfortunately, many trap-haters attribute all of the gain loss to power dissipation, which is not true.) In our aboriginal tri-band design, 15 meters would show losses associated with a pair of traps in each element. On 20 meters, the losses would amount to the sum of 2 sets of traps in each element and the double shortening of the overall element length.

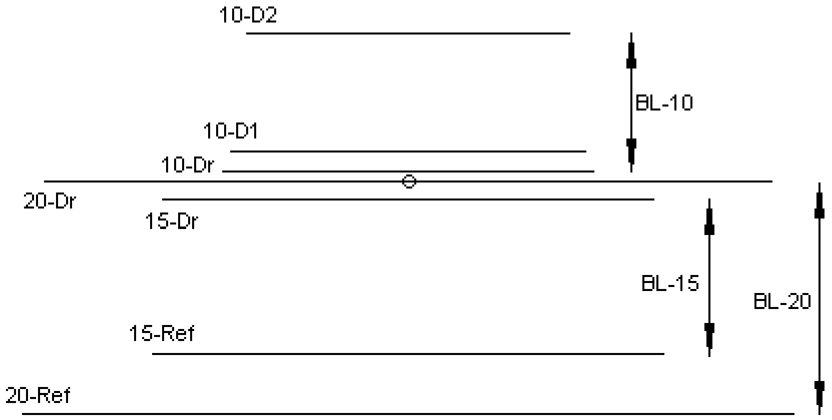
There is no easy way to estimate accurately the gain of the early 3-element designs. You might use the monoband performance table in the last episode and compare the boom length and associated gain. But remember that on 10 meters, the boom length might be too long for 3 elements. Then you can come up with an estimated gain on that band. Next, for each trap that is active as an element-shortening load on one side of each element, subtract 0.5 dB. On 15 meters, we shall subtract about 1.5 dB. On 20, we might subtract as much as 3 dB from the potential gain. Since 20 meters is already short in boom length, we would wind up with very little forward gain (perhaps 2 to 2.5 dB) over a dipole at the same height. However, the front-to-back ratio might be useful to us.

You can perform the same exercise on the hybrid beam shown in **Fig. 1**. However, only count the most active elements on each band. On 10 meters, we have 4 elements. To estimate the baseline potential gain, use the actual distance between the 10-meter reflector and the forward-most element. Since no trap loads the element, gain should be close to an optimal value for the boomlength. On 15 meters, the boomlength is between the rear-most element and the next-to-forward-most element. We find 1 trap on each side of 2 elements, the driver and the reflector. So we might reduce the potential gain by about 1 dB relative to what the boom length and 3 elements suggests for a monoband beam. (Remember to adjust the boomlength for the frequency change.) On 20 meters, we find 4 traps on each side of center for the full array. So we would subtract about 2 dB from the potential gain of a monoband 3-element beam with the same boomlength.

These estimates are very rough and ready, but they prove out in all too many cases. Advertisers tend to make claims that cite the peak gain of the array on its best band for gain and let the buyer assume that they apply to all bands. So if you count traps and estimate the boom length on each band, your revised likely gain figure will in most cases be close to correct.

2. Modern Tr-Band Yagis: Modern designs, like the upper sample in **Fig. 1**, do not use traps. Hence, we do not need to make adjustments for them. Each element serves a single frequency band. These designs have more elements and more aluminum tubing to bend or break in bad weather. However, their performance tends to be closer to monoband beams, if we know how to estimate it. **Fig. 4** enlarges the small graphic of **Fig. 1** and identifies each element. Note that the boomlength is different for each band of operation. We have a 2-element driver-reflector Yagi for 20 meters and another separate one for 15 meters. The 10-meter beam consists of a driver plus 2 directors.

Fig. 4



Analyzing a Modern Tri-Band Beam

Since the element spacing on 20 and on 15 is close to optimal for these bands, we can expect fairly standard 2-element Yagi performance on these bands. Although we do not have a 10-meter reflector, we can expect 3-element short-boom performance on that band, or close to it.

Element interactions will moderate these numbers to some degree. On larger modern tri-band Yagis, some 10-meter elements may be very close to 20-meter elements. They prevent the 20-meter elements from shifting the passband lower and hence add very little to the 10-meter gain. Element interaction also tends to reduce the front-to-back ratio relative to what we expect from 3-element or larger Yagis. Anticipate a front-to-back ratio of 12 to 17 dB from 3 or more elements on a band, rather than the standard monoband minimum value of 20 dB.

All multi-band Yagis are compromises. We pay for the convenience of having 1 beam for 3 bands by obtaining lesser performance on many bands compared to monoband Yagis with relevantly similar boom lengths. If we know how to adjust our performance expectations, we shall end up neither overly disappointed nor overly enthused.

In our exploration of tri-band Yagis, we have largely bypassed all of the physical considerations that go into a Yagi installation. Be sure to fully inform yourself about all of the important data so that your installation will be effective, secure, and safe.

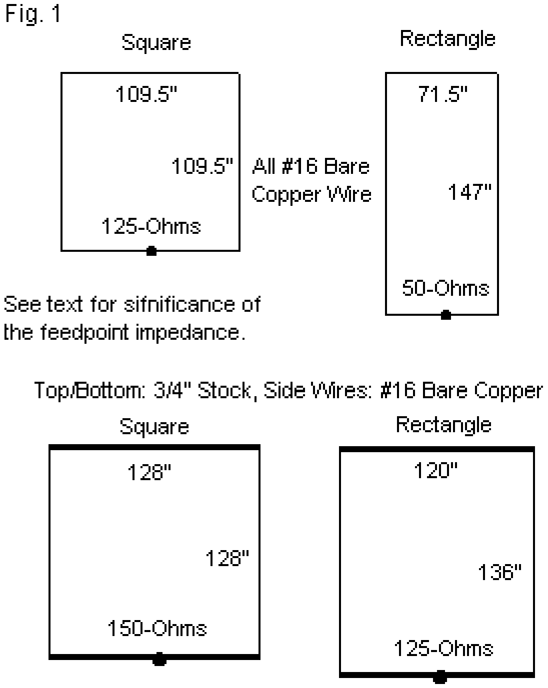
No. 56: Some Ideas for Quad Loops in the Field

L. B. Cebik, W4RNL

As the sunspots slowly return to improve 10-meter propagation, some operators begin to think of picnics, accompanied by a rig and a portable antenna. In episode 42, we examined a simple 10-meter dipole that consisted of nesting 3' sections of aluminum tubing. With about 20' of mast, the antenna is capable of very good performance, and one can hand-turn it to broadside the desired station. We can do similar things with a simple quad loop with about half the side-to-side spread. As a bonus, we acquire just a little more gain, but not enough normally to make the difference between a go and a no-go contact.

In this episode, we shall look at several configurations of the quad loop, some of which may be more useful to individuals, depending on local materials and construction preferences. **Fig. 1** shows square and rectangular quad loops. The top pair use all-wire elements. I have selected AWG #16 as a compromise size that is quite strong but lighter than house wiring. If you change the wire size, you will have to refigure the loop sizes or experimentally find the length of wire that gives a resonant feedpoint at 28.4 MHz (our design frequency). In general (and unlike the case of dipoles), closed loops require longer wire circumferences as the wire gets fatter and smaller circumferences as the wire gets thinner.

Fig. 1



See text for sifnificance of the feedpoint impedance.

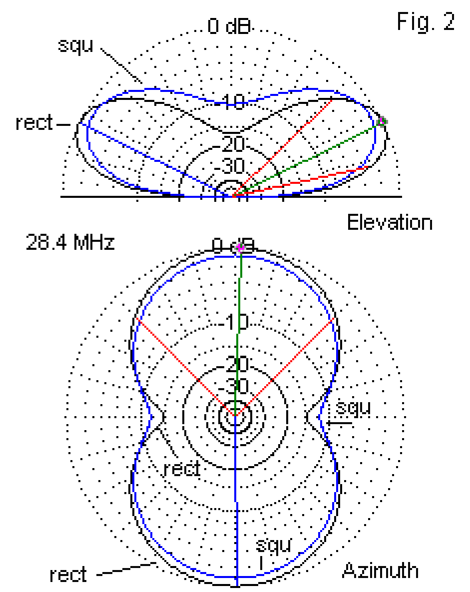
Top/Bottom: 3/4" Stock, Side Wires: #16 Bare Copper

Some Possible Configurations for 10-Meter Field Quad Loops

The lower pair use a hybrid construction method, with horizontals consisting of ï¿½" aluminum. You may use tubing, but L-stock is easier to manage for field assembly and disassembly. The side wires are AWG #16. All wires in these antennas are designed to be bare. If you use insulated wire, shorten the wires by 2% to 5%. Thicker insulation calls for the greater amount of shortening.

Let's start with the all-wire quad loops. A standard square loop, fed at the center of the bottom wire, will have a resonant feedpoint impedance of about 125 Ohms. To create the simplest match to a 50-Ohm feedline, insert a ï¿½-wavelength section of 70-75-Ohm coax. The electrical length will be just under 104". However, you must multiply this length by the velocity factor of the line that you use. Most solid dielectric lines have a velocity factor of 0.67, resulting in a 70" length. Most foam dielectric lines have a velocity factor of about 0.8, resulting in a matching section length of 83". Both the square and the rectangular loops will cover from 28.0 to about 28.7 MHz with under 2:1 SWR. Since the total feedline length will be short compared to the amount used in a home station installation, you can extend the operating span by using an internal or external antenna tuner--with no significant losses.

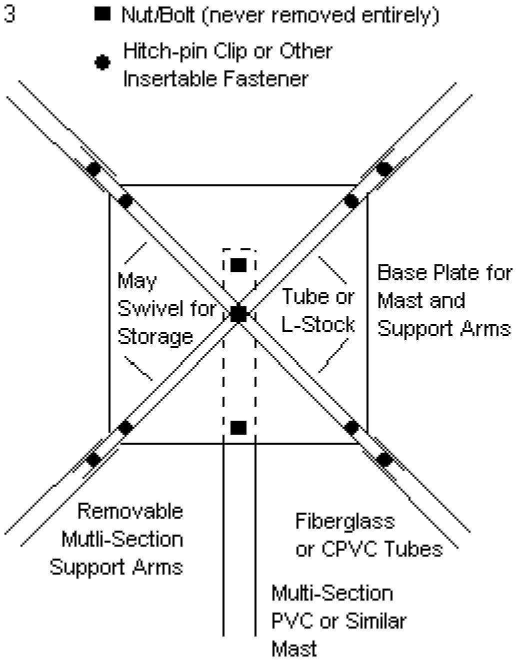
Fig. 2



Comparative Patterns:
Square and Rectangular Quad Loops
Bottom = 10' Above Ground

One reason some loop users prefer the rectangular shape is that it provides a direct 50-Ohm impedance and therefore requires no matching section. As well, if we place the bottom horizontal wire of both antennas at the same height--for example, 10' above ground in the field--we obtain slightly more gain and a slightly lower elevation angle due to the higher top wire. See **Fig. 2**. In most cases, the variables that field operations inevitably involve will wash out the small differences in the performance numbers. So the main reason for using the rectangular shape is to achieve a direct feed that requires no matching section. However, the resulting tall loop can be somewhat ungainly in the breeze.

Fig. 3



Basic Ideas for Supporting
an All-Wire Field Quad Loop

Let's consider how to construct both types of all-wire quad loops for field use, using **Fig. 3** as a rough guide. We can start with a support mast. Unlike the dipole mast that had to reach the ultimate height of the antenna element, the quad loop mast only goes to the level between wires plus a little margin. PVC sections in 5' lengths (or whatever length fits the trunk or truck-bed) make a good mast, especially when the ends have threaded couplings cemented in place. Be sure to use some rope and long spikes (tent pegs or garden timber spikes) to set up a guying system. At the top of the uppermost section, we can install a plate with 4 stubs to receive the X-braces or support arms. If we use pressure insert fasteners for the outer pinning devices, we can fold the assembly to reduce its width during transport. The anchor plate can be almost anything from plywood to plastic.

The support arms should be light, flexible, and strong. CPVC is useful and available at home centers. Fiberglass is perhaps better, but it may require mail order to obtain it. Assemble the entire support structure to string the wire initially. Be sure the wire is equally taut on all four sides of the loop, but not so taut that it stresses the support arms. Stress will likely result in a warping of the frame to one side or the other--and the warp may change in a stiff breeze. For permanent installations, I would normally suggest slip tubes at the corners, but for this antenna, I recommend that you fix the corner in place. Use non-conductive cable ties or similar, and add some epoxy after you are satisfied with the structure. The wire will help prevent the arms from sagging. For the square quad loop, the arms should be a minimum of 77.5" from the plate center to the tip. The rectangular loop requires arms that are minimally 82" long. You will have to solder in a coax connector at the center of the bottom wire, and you may wish to use a small plastic plate as a mounting.

Using the lower quad configurations involves having thick horizontal element sections and wire vertical sections. ï¿½" L-stock makes a good horizontal element section. Note in **Fig. 1** that the combination of thick and thin materials raises the impedance of a truly square loop to a very inconvenient value. A 150-Ohm impedance is somewhat low for a 4:1 balun, but too high for a 75-Ohm matching section. Therefore, if you prefer this configuration, try a slightly rectangular shape, as shown in **Fig. 1**, to obtain 125 Ohms. Then you can use a 75-Ohm matching line to good effect.

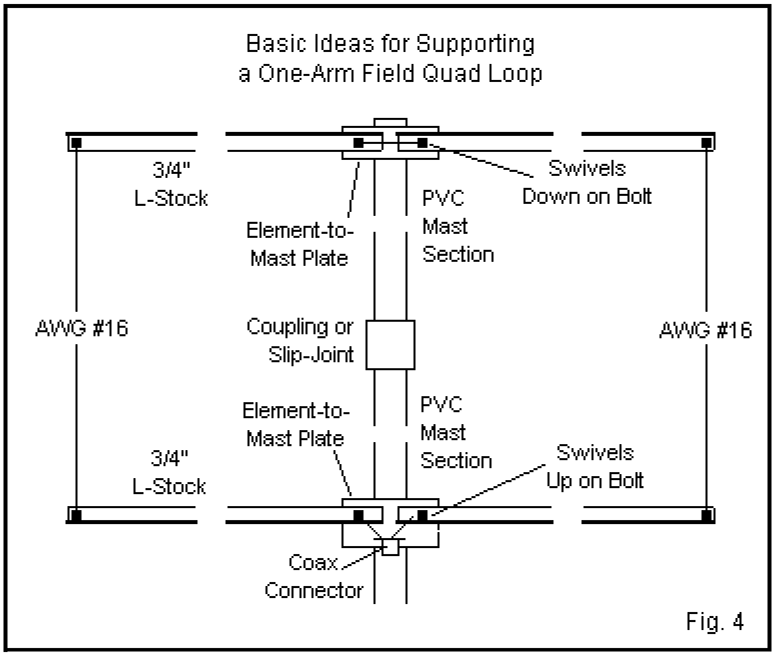

Basic Ideas for Supporting
a One-Arm Field Quad Loop

Fig. 4

Fig. 4 shows why some field operators prefer the thicker horizontal element sections. If we carry the mast up to the top element, we no longer need the 4 X-brace support arms. The horizontal L-stock supports the side wires with ease. Since the loop is over 9' tall, the central mast above the lowest element section should be in 2 sections. To each section, we can attach a small plywood or plastic plate to pin down the L-stock. I recommend that you use nuts and bolts near the centerline, but removable fasteners (such as hitch pin clips) near the outer edge. When not in use, you can fold the bottom elements up and the top elements down for easy transport. Be sure to add a bridge wire at the top to connect the two side of the horizontal element. At the bottom, add a coax connector and mounting plate and fasten it to the element support plate.

For either type of quad, you can likely work out the wire and support structure in a way that allows you to store and transport that part of the system as a unit. The more items in the structure that you can fold, bend, and wrap-around for storage, the more quickly you can assemble and disassemble the unit in the field. As well, you create a smaller unit for transport.

These notes do not aim to give you complete construction details of a portable or field quad loop. Instead, they simply provide some ideas and then rely on your own ingenuity for making a complete unit. Over the years, I have built and used several 10-meter quad loops. My personal favorite is the modest rectangle that uses ï¿½" L-stock and side wires. My versions allowed me to loosen the L-stock and fold the element sections next to the half-mast section. Without removing the side wires, I laid the two half-mast sections side by side and then used the side wires to wrap the entire antenna into a loosely secure bundle. The stored antenna was a little over 4' long (not including the mast sections and the guys below the part shown in **Fig. 4**). The only loose part was the bridge wire across the middle of the upper element, and I kept one end attached to one side of that element. In one version, I mounted the coax connector directly to one of the lower pieces of L-stock, with a bridge wire to the other section.

The number of construction variations that are possible is as endless as the materials that we can find at a home center. In fact, the variations on field quad loops are almost as great as the pleasure of operating 10 meters from a hilltop or open field (on a sunny day with warm temperatures, a fine picnic lunch, and someone special with whom to share the fun).

No. 57: A Different Kind of 10-Meter Attic Antenna

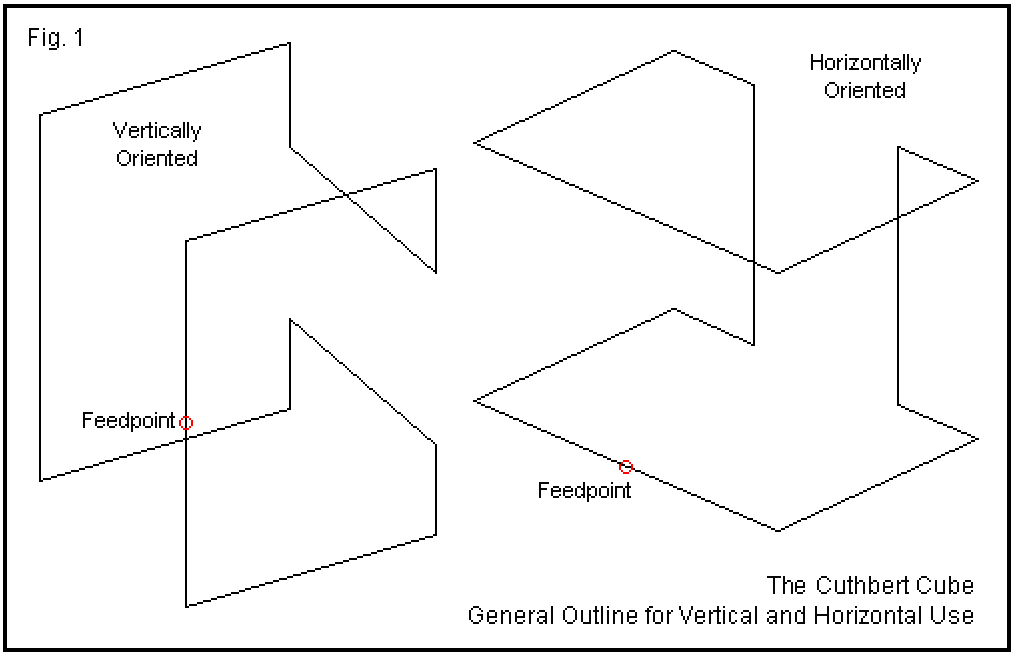
L. B. Cebik, W4RNL

Due to restrictive covenants, many 10-meter operators must use attic antennas or devise other ways to hide the antenna. Older ranch-style homes used to be long and narrow. Hence, many attic antennas are dipoles oriented along the length of the attic. A 10-meter dipole is about 200" long. The operator had to orient the dipole according to the attic space, which might or might not place the wire broadside to the best target communications areas.

The last decade or so has revised home architecture so that the long attic is gone. In its place is a collection of smaller attic spaces, often with more vertical than horizontal room. For these spaces, we need a new kind of attic 10-meter antenna--one that will largely free us from orientation worries and still perform well in the confined space. It must still keep its distance from all metal wiring, ductwork, and foil sheathing. Enter the Cuthbert Cube.

A few years ago, Dave Cuthbert, WX7G, used some basic antenna folding ideas that had appeared in antenneX, an on-line antenna experimentation journal, and developed a 2-meter antenna as a desktop improvement on the usual FM rubber ducky. The design evolved from bending, folding, but not mutilating the 1-wavelength quad loop with a side feedpoint for vertical polarization. However, we can easily tip over the Cuthbert Cube (which is not quite truly cubical) and obtain horizontally polarize patterns, just like a bottom-fed quad loop. **Fig. 1** shows the 2 orientations.

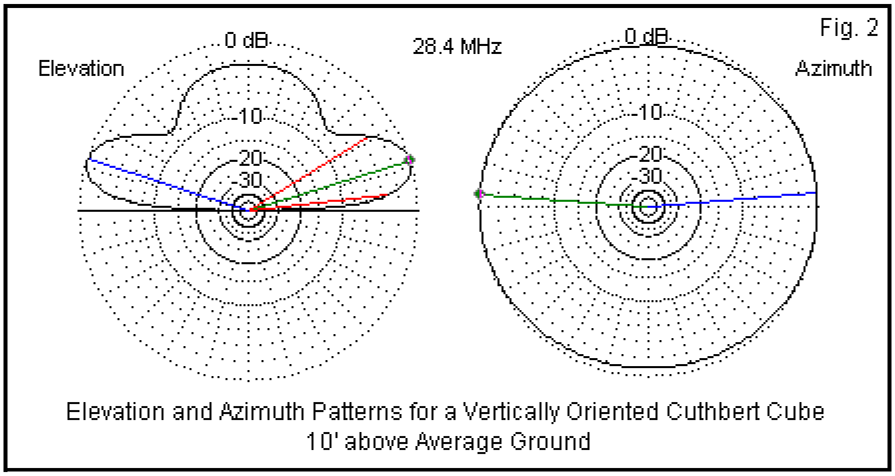
Fig. 1



The Cuthbert Cube
General Outline for Vertical and Horizontal Use

The equivalent of 2-meter desktop height is probably 10' at the antenna bottom for the left part of the sketch, the vertically oriented cube. If we take patterns at that height, we obtain the elevation and azimuth plots on **Fig. 2**. The gain is modest on 10 meters: less than 1 dBi at an elevation angle of 17ï¿½. However, the pattern is nearly circular for the small volume occupied by the antenna.

Fig. 2



Elevation and Azimuth Patterns for a Vertically Oriented Cuthbert Cube
10' above Average Ground

More relevant to 10-meter CW and SSB use is the horizontal orientation. If we assume that the modern attic allows a 20' height above ground for the bottom wires, then we obtain the patterns in **Fig. 3**. The elevation angle is about 21ï¿½, which is lower than for a dipole at the same height. Because we have a loop and the vertical wires carry some current, there is some vertically polarized radiation. So the azimuth pattern is not a traditional dipole figure-8, but instead a broad oval. The maximum gain lies along a line through the feedpoint and the gap between the rear vertical wires and is between 6.7 and 6.8 dBi, less than 1 dB lower than a dipole at the same height. However, the radiation to the sides is only about 5 dB below maximum, enough to hear signals in those directions when the propagation is good.

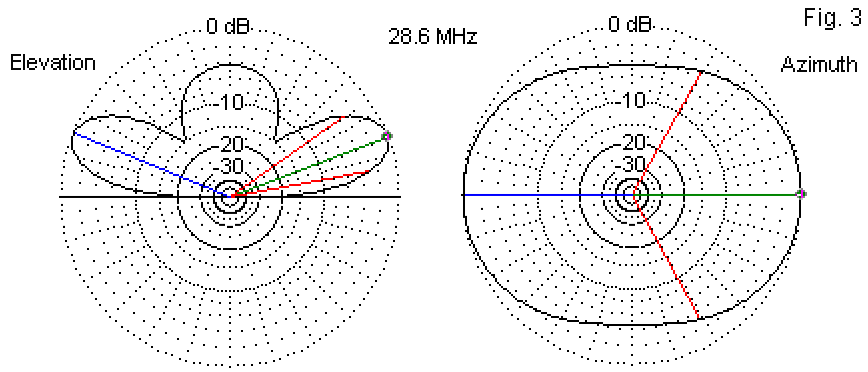


Fig. 3

Elevation and Azimuth Patterns for a Horizontally Oriented Cuthbert Cube
20' Above Average Ground

The 10-meter version of the Cuthbert Cube is about 5'-3" on the feedpoint line. The vertical and the front-back dimensions are identical: 3'-7". Hence, some version of the antenna should not only fit within a small attic, but we should also be able to orient it for maximum gain in desired directions.

The antenna is a closed loop and hence does not change its impedance much as we change height. The resistive part of the impedance is 50 Ohms at the design frequency. However, this antenna has a peculiarity: The inductively reactive part of the impedance increases as we reduce the element size. Hence, for element diameters from about 5/8" downward, we need to add a series capacitor in line with the feedpoint. A 75-pF to 100-pF variable from a hamfest sale will work fine. However, if we use 1" elements, then we no longer need the series capacitor, since the inductive reactance is no longer present at the design frequency. As well, we increase the passband covered with under 2:1 SWR to include all of the first MHz of 10 meters. Wire versions cover about 600 kHz of the band. **Fig. 4** shows the 50-Ohm SWR curve for a Cuthbert Cube with 1" elements.

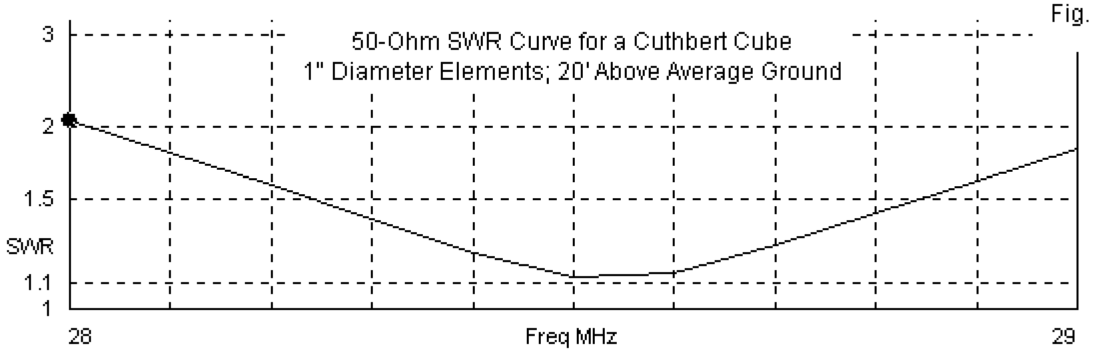


Fig. 4

50-Ohm SWR Curve for a Cuthbert Cube
1" Diameter Elements; 20' Above Average Ground

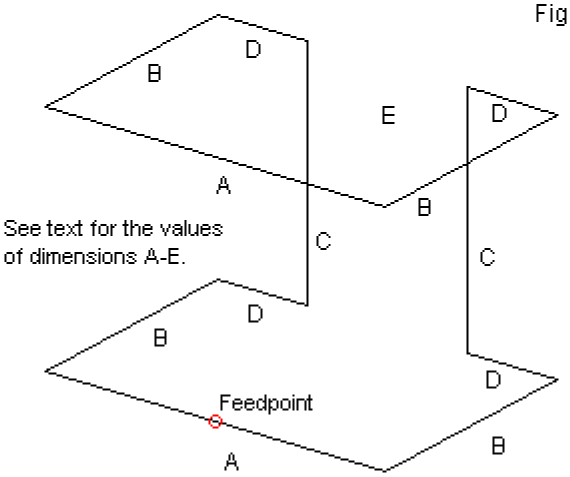
Building the Cuthbert Cube requires a set of dimensions. The following table shows 2 sets: one for 28.4 MHz and intended for wire versions of the antenna. The second set shows dimensions for a design frequency of 28.6 MHz and is intended for the 1" version. **Fig. 5** provides a guide to which dimension goes where. Dimension E is the gap or open space between the vertical wires in the antenna. The dimensions are equally applicable to the antenna when used vertically.

Dimensions for the Cuthbert Cube: All dimensions in inches

28.4-MHz Design Frequency		**28.6-MHz Design Frequency**	
Dimension	**Length**	**Dimension**	**Length**
A	**63**	**A**	**62.5**
B	**43**	**B**	**42.75**

C	**43**	**C**	**42.75**
D	**16.75**	**D**	**16.5**
E	**29.5**	**E**	**29.5**

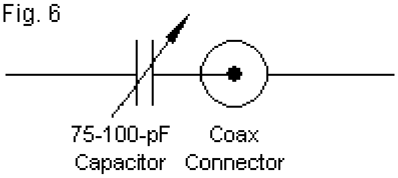
Fig. 5



Dimension Guide to the Cuthbert Cube

A wire version will require some form of support structure. In a dry attic, wood and PVC--or some combination--are good candidates. You will likely need corner supports and a way to prevent the wires from pulling the ends of the supports toward each other. It is also likely that you will need two more supports for the vertical wires. Since these wires have low current, you can run the wires next to the support posts, rods, tubes, or dowels. You will also need a short support for a plate to hold the coax connector and the series capacitor. **Fig. 6** shows a simple schematic representation of the feedpoint with a single variable capacitor. Once you know the required capacitance to produce the lowest SWR at the design frequency, you can replace the variable capacitor by a fixed capacitor of the right value. However, be sure that it can handle the power of your transmitting equipment. 500-volt capacitors are usually adequate for most standard transceivers.

Fig. 6



Feedpoint Arrangement for a Wire Version of the Cuthbert Cube

The 1" element version of the antenna does not require a series capacitor. In fact, it does not even require tubing. You can substitute 1" per side L-stock, which is available at many home centers. The stock usually comes in 1/16" and 1/8" thicknesses. The thickness will make no significant electrical difference, but the weight ratio is 2:1. However, heavier stock is somewhat more rigid. The stock easily let's you create nut-and-bolt corners. As well, you can mount a coax connector directly onto the element at the feedpoint and run a bridge wire from the connector pin to the continuation of the element on the other side of the small (1/4") gap. You can choose whether the connector points horizontally or downward, depending on the likely coax run in your attic and walls. Use any handy plastic strip to join the parts of the element on each side of the gap to sustain a physically rigid element.

One advantage of this form of construction is that you can build everything in the shop and then break the antenna into pieces that you can get into the attic. A screwdriver and a nut-driver may be all the tools you need for in-place final assembly. As with all attic antenna, you want to raise it off the ceiling joists. You can hang it from the rafters or devise a wood or PVC set of elevating supports. The specific construction of your attic and how you want to orient the antenna will make your installation a custom effort.

A stronger alternative construction method is to use copper pipe with a 1" outside diameter. (Piping sizes are "nominal," that is, listed by the minimum inside diameter, not the outside diameter. You will have to check the actual outside diameter of the pipe you select.) You can torch-solder or sweat the corners with 90ï¿½ junctions. Only the feedpoint requires special attention to create a gap for the coax connector while retaining a rigid element. I do not recommend torch flames in the attic. So use this method of construction only for outdoor service or if your attic let's you fit the finished antenna through the entry.

The horizontal Cuthbert Cube may not fit everyone's needs--or even everyone's attic. But for some 10-meter operators, it might make the difference between being on the air or not.

No. 58: AThe Revere Theory of Vacation Antennas

L. B. Cebik, W4RNL

The theory is simple: Horizontal if by land and vertical if by sea, (And I on the opposite shore shall be). Of course, neither Paul Revere nor Henry Wadsworth Longfellow is responsible for the name of the theory. But the name is a catchy way of introducing you to why many contest and vacation operators on beaches or on boats use vertical antennas, while at home, they use horizontal antennas.

For 10 meters, vertical antennas are simpler to use on vacation. A central element and some radial wires (if we are using a ï¿½-wavelength monopole) are usually easier to pack than a pair of support masts to hold up a dipole. The dipole is somewhat directional, so a tubular version on a single support mast resolves the turning question, if only by hand. However, that system can be ungainly on some boats. Actually, the choice of a vertical antenna for contests and vacations near or on the ocean depends less on mechanical simplicity than it does on performance.

To see why verticals have once more become popular on or near salt water, let's perform a little exercise. Since I cannot afford a Caribbean vacation at the moment, we shall have to use modeling software. We shall look at four antennas, all simple ones, as shown in **Fig. 1**. The first is a center-fed vertical dipole with its bottom end 1' above ground. The second is a ground-mounted vertical monopole. The third antenna is simply the monopole raised ï¿½-wavelength above ground with 4 elevated radials. Finally comes the horizontal dipole that is ï¿½-wavelength above ground.

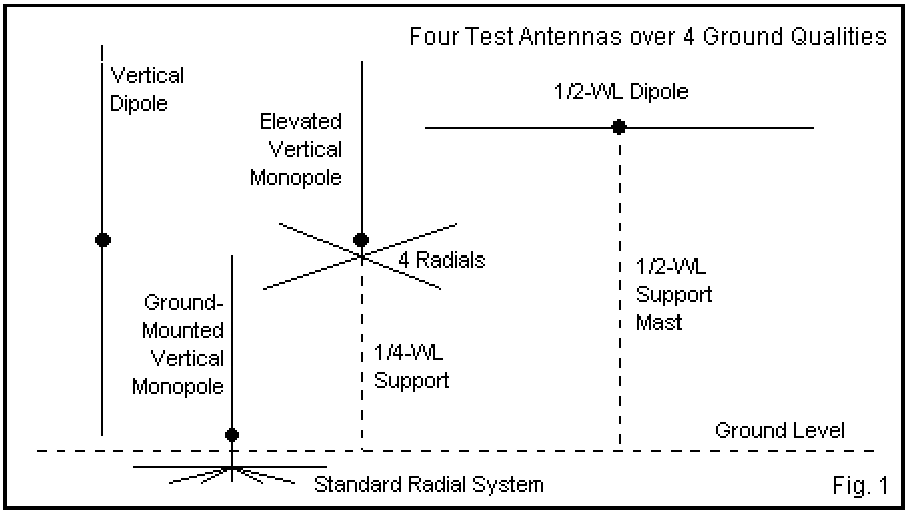


Fig. 1

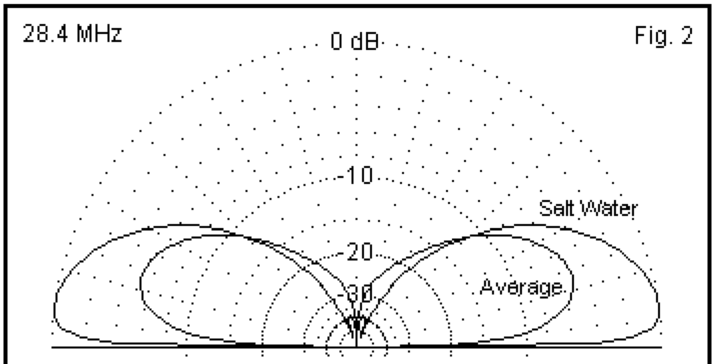
For each antenna, we shall select 4 ground environments. One must be salt water. The other three involve different levels of land-locked ground quality. The standard names are Very Good, Average, and Very Poor Ground. With 4 antennas and 4 ground quality levels, we have 16 tests to run.

1. The Vertical Dipole. Like all good vertical antennas (but not necessarily arrays of verticals), the vertical dipole has an omni-directional azimuth pattern. So we can confine ourselves to the elevation pattern properties. The vertical dipole uses a 1" diameter with its bottom tip only 1' above ground level. We normally bring the feed horizontally from the center point or run coax inside the element to ground level. In either case, we add a common mode current choke at the point where the coax emerges from the antenna. The following table lists the maximum gain and the elevation angle for the four types of ground.

Vertical Dipole 1' above Ground

Ground Quality	**Salt Water**	**Very Good**	**Average**	**Very Poor**
Gain dBi	**5.64**	**0.69**	**0.55**	**0.15**
Elevation Angle	**8ï¿½**	**17ï¿½**	**18ï¿½**	**21ï¿½**

The largest change occurs between salt water and dry land. **Fig. 2** compares elevation patterns for salt water and average soil. I omitted the other soil types, since they are relatively so close together that they would make a single fat line. The advantage of the salt-water ground is very clear in terms of both gain and a low elevation angle for good DX work.



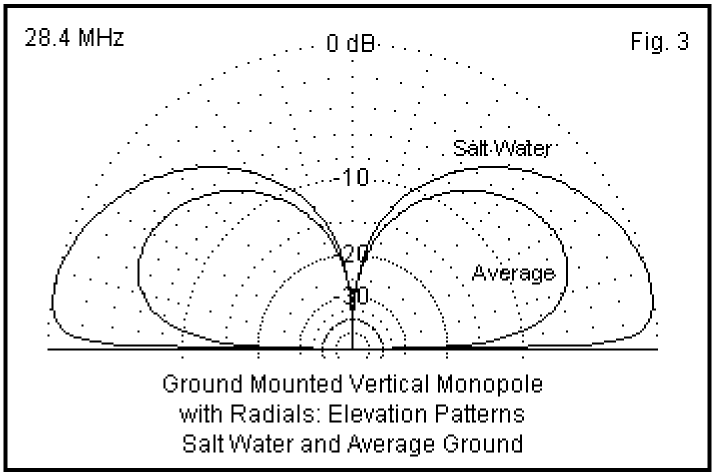
Vertical Dipole Elevation Patterns
Salt Water and Average Ground

2. Ground-Mounted Vertical Monopole with Buried Radials. A vertical monopole at ground level is ï¿½-wavelength long and requires a field of radials. On salt water, the metal cladding of the keel or hull would normally substitute for the radial system, but on land, we need at least 32 buried radials for effectiveness. The table is based on a 32-radial field.

Vertical ï¿½-Wavelength Monopole with a Radial Field at Ground Level

Ground Quality	**Salt Water**	**Very Good**	**Average**	**Very Poor**
Gain dBi	**4.27**	**-0.56**	**-0.31**	**-1.69**
Elevation Angle	**11ï¿½**	**24ï¿½**	**27ï¿½**	**29ï¿½**

The shorter monopole is less effective than the vertical dipole, with higher elevation angles to accompany the lower gain. **Fig. 3** again contrasts just the salt-water pattern with the pattern over average soil. The overall height of the lobes, regardless of soil quality, is immediately apparent. Ground-mounted vertical monopoles find almost no land use on 10 meters, although they are common on ships and buoys.



Ground Mounted Vertical Monopole with Radials: Elevation Patterns Salt Water and Average Ground

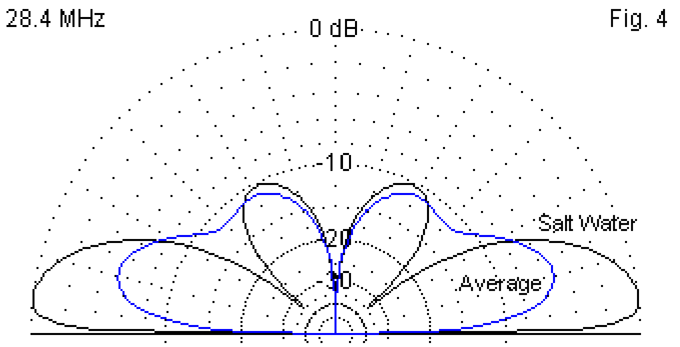
3. Elevated Vertical Monopole with 4 Radials. The vertical monopole works best on 10 meters when we elevated it. The test case uses a height of ï¿½ wavelength between ground and the base of the system. Above about 0.5 wavelength, the higher angle lobes tend to dominate, which is not good for DX communications. Once we place the antenna about 2 wavelength above ground, the lowest lobe again becomes the strongest, but this height is normally not practical for a boat or the beach.

Vertical ï¿½-Wavelength Monopole with a 4-Radial Field ï¿½ Wavelength above Ground Level

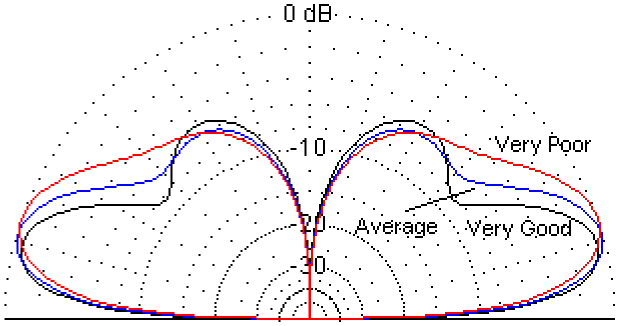
Ground Quality	**Salt Water**	**Very Good**	**Average**	**Very Poor**
Gain dBi	**6.31**	**0.82**	**1.15**	**1.24**
Elevation Angle	**7ï¿½**	**14ï¿½**	**16ï¿½**	**19ï¿½**

The salt-water gain improves by about 2 dB with the 8.7' elevation of the antenna. The top portion of Fig. 4 compares salt water to average ground for consistency with the preceding figures. The gain over dry land also improves, but presents a seeming anomaly. The gain actually decreases as the soil quality improves. However, as the table and the bottom of **Fig. 4** show, the elevation angle becomes (desirably) lower with improving ground quality. The operationally significant matter is the elevation angle rather than the small gain difference across the span of test grounds. Part of the reason for the seeming gain anomaly is the fact that as we improve the soil, the upper or second elevation lobe becomes more pronounced, although it is not problematical at the test height. The higher that we raise the base of this antenna system, the stronger that the second lobe will grow until it becomes the dominant lobe.

Fig. 4



Elevated Vertical Monopole
with 4 Radials: Elevation Patterns
Salt Water and Average Ground



Elevated Vertical Monopole
with 4 Radials: Elevation Patterns
Very Good, Average, and Very Poor Ground

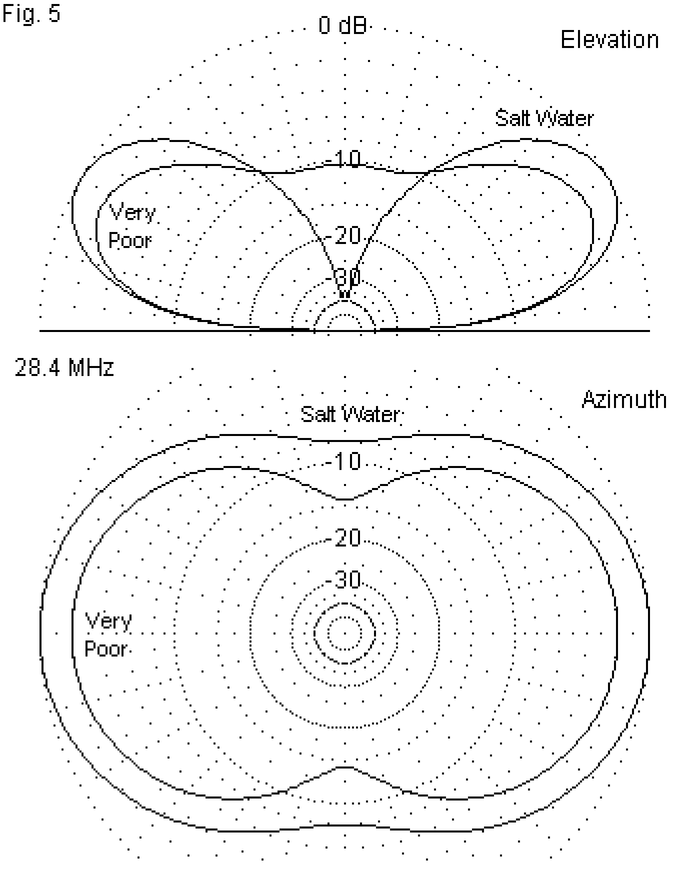
4. Horizontal ï¿½-Wavelength Dipole ï¿½ Wavelength above Ground. For each of our test vertical antennas, the gain over salt water has been about 5 dB stronger than the gain over the best of the dry-land ground qualities. By comparison, the differential among the dry-land grounds has been small. A half-wavelength horizontal dipole that is a half-wavelength above ground has been an old stand-by of vacationers and casual contesters for many decades. The table shows why land operators tend to prefer it to a vertical, while beach and boat operators lean toward vertical antennas.

Horizontal ï¿½-Wavelength Dipole ï¿½-Wavelength above Ground Level

Ground Quality	**Salt Water**	**Very Good**	**Average**	**Very Poor**
Gain dBi	**8.36**	**7.73**	**7.24**	**6.48**
Elevation Angle	**29ï¿½**	**28ï¿½**	**28ï¿½**	**27ï¿½**

We find less than 2-dB gain differential between salt water and very poor soil, compared to the 5-dB differential for the vertical antennas. **Fig. 5** provides both elevation and azimuth patterns for salt water and the worst soil quality. The dry-land elevation pattern shows where part of the missing 2 dB of energy goes: upward. The dry-land elevation beamwidths are wide enough to encompass the lower elevation angles for the vertical dipole and the elevated monopole, and they are about the same as for the ground-mounted vertical. For dry-land, then, the dipole provides considerably more gain than the vertical antenna and becomes the preferred antenna, even if we have to turn it broadside to our targets.

Fig. 5



1/2-WL Horizontal Dipole 1/2 WL above Ground
Elevation and Azimuth Patterns
Salt Water and Very Poor Ground

The dipole, however, offers the beach and boat operator with very little gain advantage. The elevation angle increase tends to detract from DX signal strength more than the small gain increase helps it. Therefore, the best antenna for beach and boat operation--among simple antennas in these tests--is likely one of the verticals.

The modeling tests have used a uniform ground medium in all directions from the antenna. The ground reflection region extends for several wavelengths away from the antenna. On a boat, the ocean is everywhere. However, on a beach, we usually have only 180ï¿½ to 270ï¿½ of salt-water horizon, depending on whether we can find a point of beach-land for our antenna. Selecting a place on an island with ocean between you and the main communications targets is good planning.

However, coastal operations have benefited from verticals near the water's edge. Do not think about propagation as a single thin line between you and your target. RF refracts over a broad region. So a coastal path may actually consist of radio waves that go out over the water and return back to land at shallow angles relative to the straight-line bearing between the 2 points.

The next time you operate from a vacation island or boat, do not discount the simple vertical antenna as a highly effective way to make a lot of contacts (propagation permitting). However, over dry land, a horizontal dipole even as low as ï¿½ wavelength above ground may give you the stronger signal.