Some of us know about antennas. Some of us think we know about antennas. Most of us would like to learn more about antennas.

Let's Talk Antennas—Part I

BY LEW McCOY*, W1ICP

Probably nothing is more important to the successful operation of an amateur radio station than having the correct (and best possible) antenna. You can build or buy the most expensive receiving and transmitting equipment, but such equipment will be severely restricted without a good antenna system. On the other hand, a good-performing antenna system need not be expensive.

What you really need to know is how to tell a good system from a bad system, either before constructing a homebuilt one or buying a commercially built one. There are basic criteria governing all antennas. In this discussion let's start by going over some of these criteria.

Antenna Efficiency

Antenna efficiency is simply explained as getting the most radiation of your signal out of your antenna for what you put into it. I don't mean the power that comes out of your rig, but what actually goes into the antenna itself. This is best illustrated by an example that is shown with a common half-wavelength long dipole (fig. 1[B]). The impedance of a halfwave dipole in free space is approximately 70 ohms. Of this 70 ohms, usually 68 ohms is the radiation resistance, while 2 to 3 ohms are ohmic resistance. Let's assume we have 70 watts reaching the feedpoint of this dipole antenna. Of this 70 watts almost all of the power is radiated. We lose a small amount because of ohmic losses, but this is usually on the order of about 2 to 3 watts (the actual resistance of the wire and nearby objects) The rest of the power is radiated, meaning an antenna efficiency of over 90 percent.

Always keep one point about antennas in mind: The smaller an antenna is for a given frequency, the poorer the efficiency (and the lower the radiation resistance, which also means poorer efficiency). For example, an 80 meter mobile whip is a very inefficient antenna. Using our 70 watt example, only a very few watts will be radiated, and the majority of the power will be dissipated as heat in the ohmic losses, most likely in the frame and metal parts of the automobile. The amateurs who really do a good job on 80, if questioned closely, will admit to doing considerable grounding work on their vehicles.

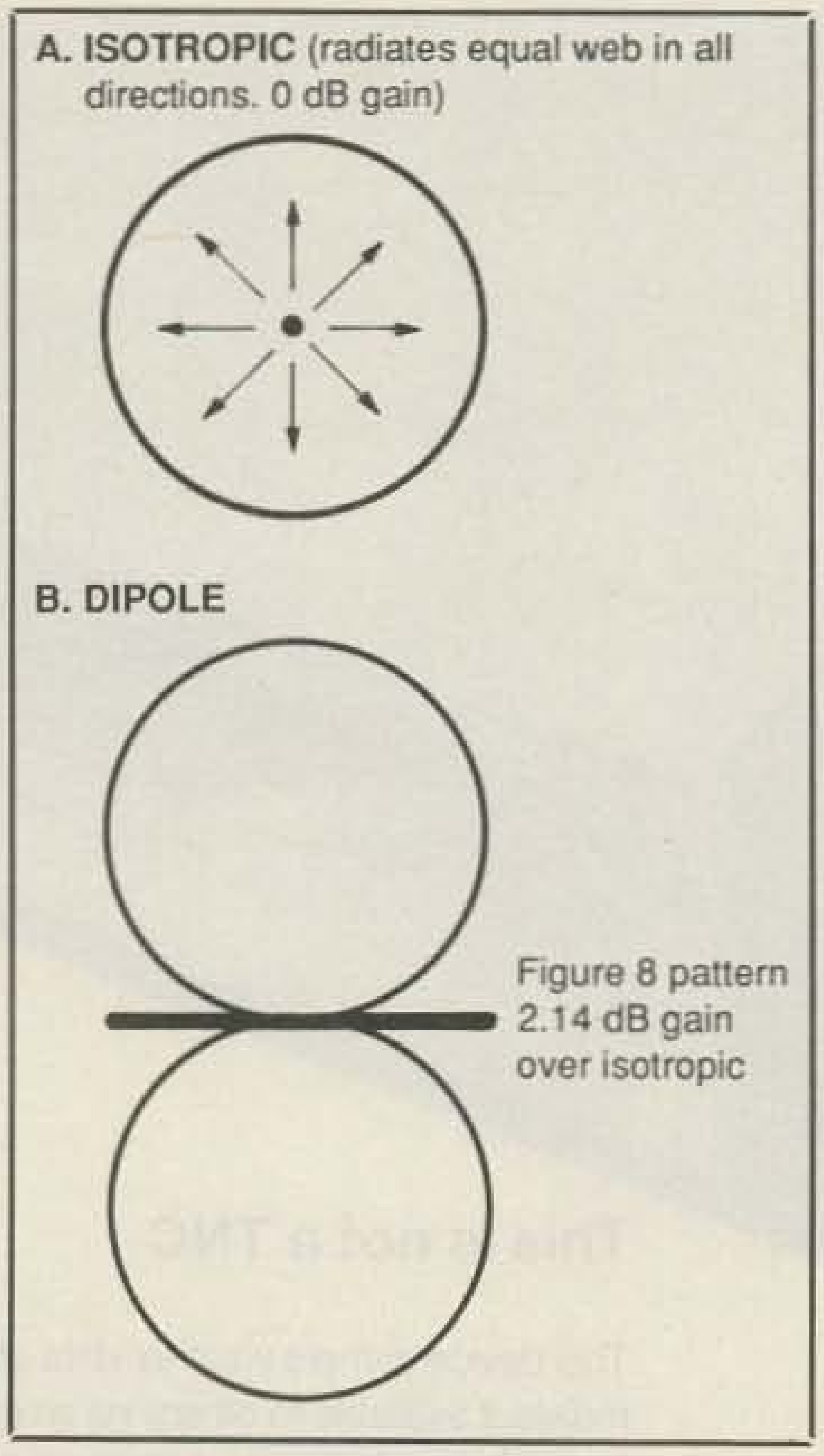

Fig. 1–(A) An isotropic radiator. Visualize it as a ball with radiation emanating equally in all directions. (B) represents a half-wavelength dipole antenna.

Years ago I recall one amateur who reported into our Missouri phone net—and he always had one of the loudest signals. But the kicker is he was usually running mobile. He was always secretive about his methods, but through the use of some good old mountain "moon," a bunch of us got him thoroughly relaxed at an Ozark Mountain hamfest. He told us that he had carefully welded metal straps, grounding all parts of the frame together, connecting to the motor block, etc. He did this to reduce the ratio of ground losses to radiation efficiency. His signal more than proved to me that he knew what he was doing.

Gain

One of the criteria for measuring the worth of an antenna is the amount of gain the antenna will produce. Let me make one point clear. When we speak of antenna gain, we are not saying that the antenna will act as an amplifier. Simply, it is possible to shape the radiated signal so that more power is aimed or directed more in certain directions than in others. The terms that apply to directional antennas are forward gain, front-to-side rejection, and front-to-back rejection.

All antenna gain figures (or losses) are rated by decibels, or dB. Without going into a long discussion about decibels, it is simpler to keep a few facts about them in mind. A power increase of 3 dB means a power increase by a factor of two. In other words, if your signal increases by three decibels, it is twice as powerful. With 10 dB, an easy to remember number, the power factor is 10 times. If you had a beam antenna that had 10 dB gain in a given direction, it would be equivalent to increasing your power 10 times in that direction. The importance of gain figures when considering the building or purchase of an antenna can quickly be seen. Fig. 2 illustrates this beam pattern.

Every antenna will have certain patterns of radiation, putting more signal in some directions rather than others. By using certain types of antennas, it is possible to form these patterns, aiming more radio energy in some directions than in others. In order to measure gain, we need to set down a standard, meaning what is important to you, the reader, in being able to interpret the references used by the manufacturers of antennas.

Normally, there are two reference antennas used. One is an imaginary (that's correct; it isn't a real antenna, but is

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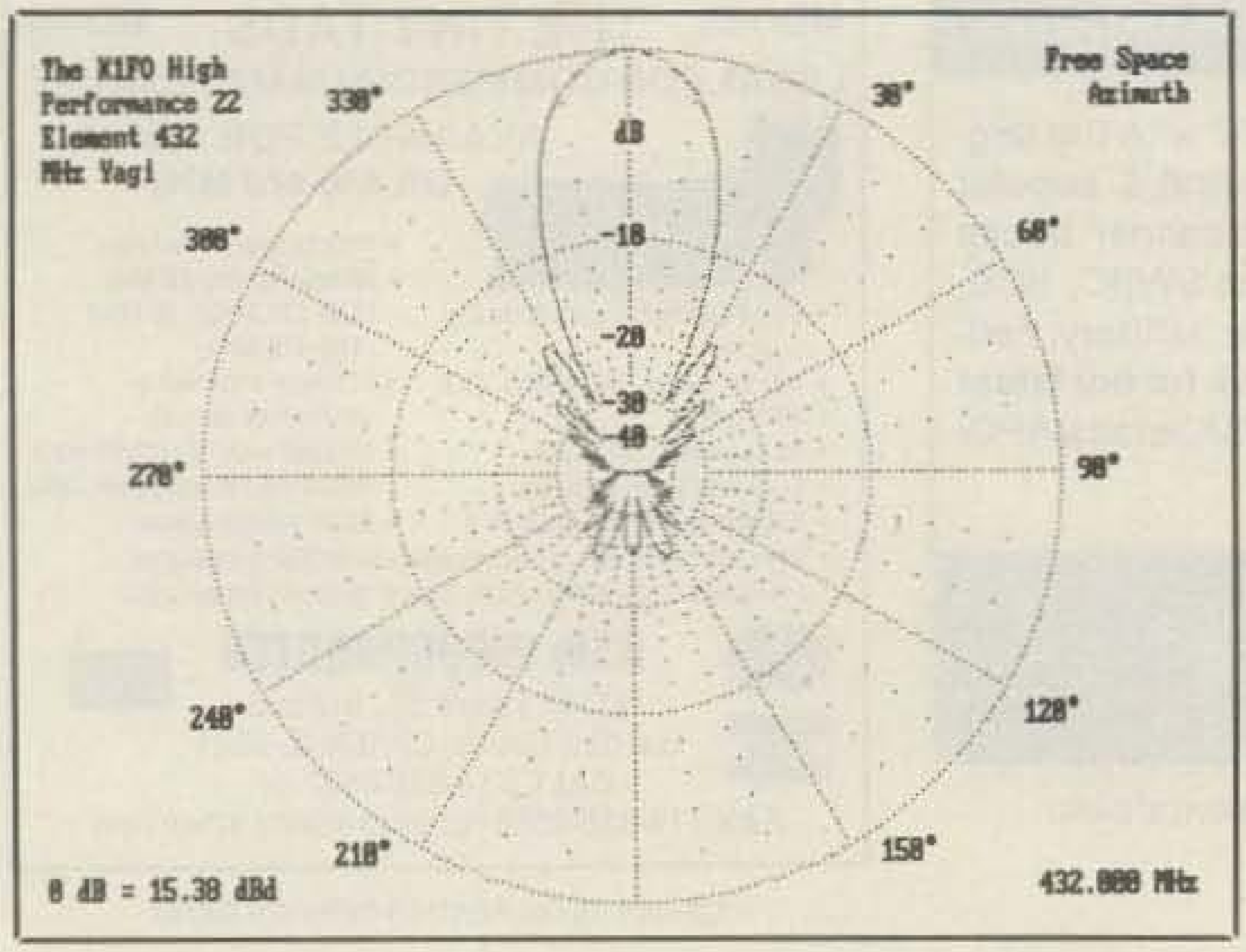

Fig. 2– This is a computer-derived pattern of a very high gain UHF beam. It is the horizontal pattern as viewed from above the antenna. Note how narrow beamwidth is. (Plot courtesy of K6STI [MN]).

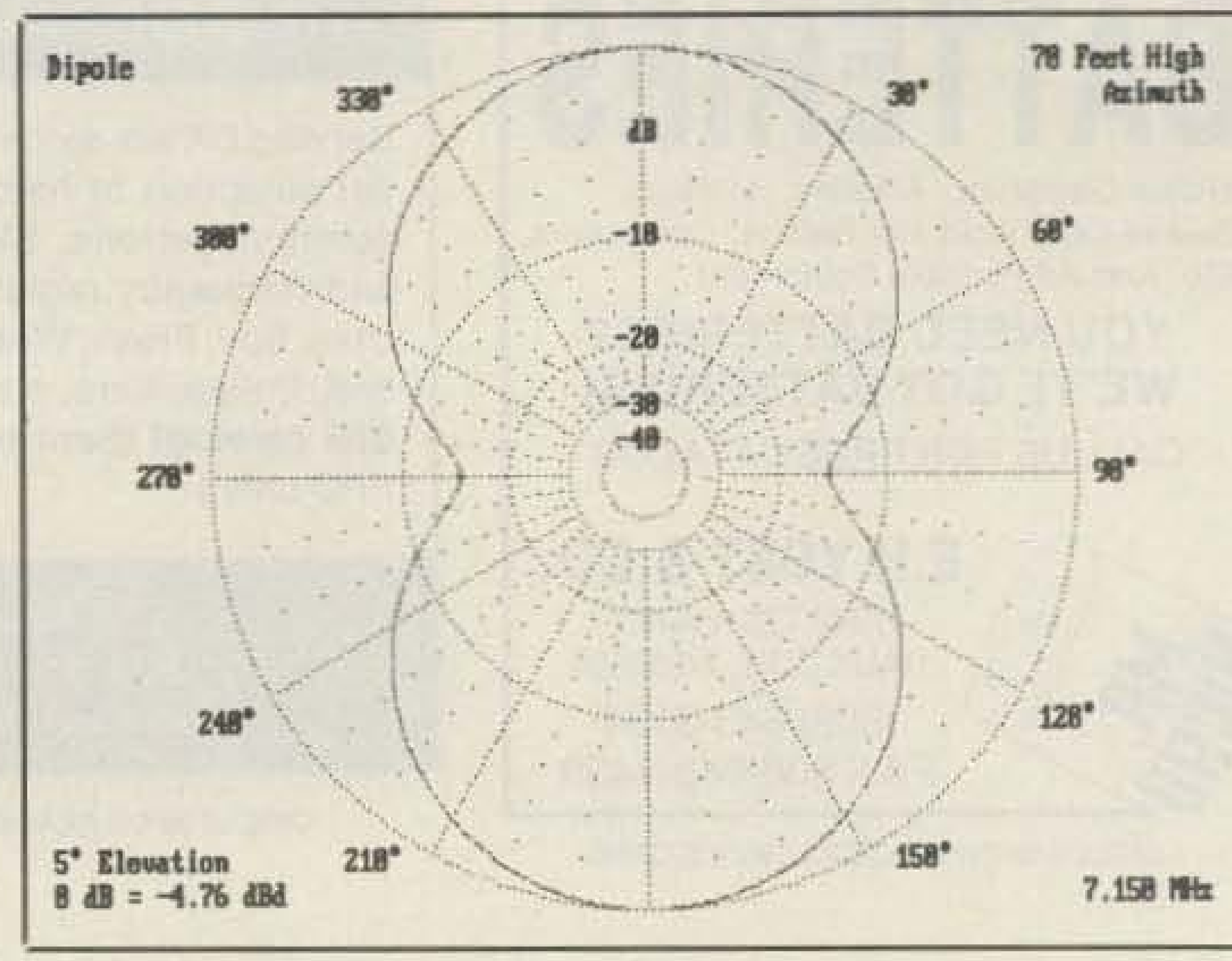

Fig. 3– This is the computer-derived pattern of a half-wavelength dipole as viewed from above the antenna (horizontal radiation). Note the two major lobes in both directions from the plane of the antenna. There is no radiation off the antenna ends.

strictly a theoretical one), and the other is a half-wavelength dipole (more on this in a moment). The theoretical antenna—the one which doesn't actually exist—is called an "isotropic" radiator. In theory it is an antenna that radiates equally well in all directions. Think of a ball of light, such as the sun, radiating equally well in *all* directions (even the sun doesn't actually do that!). (See fig. 1[A].) This type of antenna is called an *isotropic* radiator and has what is known as unity gain. For engineering purposes, the isotropic radiator is excellent for comparing other types of antennas. One other point here: As we have stated, gain is listed in decibels, and an isotropic radiator could be said to have zero decibel gain.

Next, for gain rating, is a half-wavelength dipole, which is an antenna that has two conductors of equal length. This is our other comparison antenna (see fig. 1 [B]). The dipole has a figure-8 pattern, with the two lobes broadside to the plane of the dipole. The dipole has a gain of 2.14 dB over an isotropic radiator. This gain is in two directions (figure-8 pattern) broadside to the antenna. Fig. 3 shows the computer pattern for the two main lobes.

Let's digress for a moment. When we shape the radiation pattern of an antenna, and we can do this in several ways, we can increase the gain of the transmitted or received signal to a certain degree. For example, as you can see, the pattern of the dipole is a figure-8. Actually, what we are showing is a cross-sectional view of the dipole. The isotropic at (A) is a round ball of radiation from its source at the center of the ball. On the other hand, a dipole has two primary circles of radiation—the figure-8 pattern, with the dipole at the center of the figure-8. Visualize two balls, of the same size, side by side. Our dipole would be at the point where the two balls meet. If we viewed these from above, we would have the figure-8. What the drawing shows is a section through these two balls. With the dipole we have actually shaped the pattern of signal, giving us two major lobes of energy, with little or no radiation off the ends of the dipole. One point that is a little difficult to illustrate is the actual dipole pattern for various heights above ground. We maintain a semblance of the figure-8 for all heights, but the actual radiation pattern changes in the sense that there is more radiation in certain vertical planes. This depends, however, on the height above real ground.

When antenna measurements are made or advertised by some antenna manufacturers, the gain is listed two ways—by dBI (dB gain over an isotropic) or dBD (gain over a dipole). The savvy purchaser would rightfully ask, "What is the difference?" Simple. The gain of a dipole over an isotropic is 2.14 dB. In this present world of big numbers, manufacturers compete against each other. Let's show you an example. A normal monoband three-element beam has a real-world gain of about 7 dB compared to a half-wave dipole. However, because there is no hard-and-fast standard, some manufacturers choose to compare their antennas to an isotropic and state that their three-element beam has a gain of 9.2 dB (the normal 7 dB plus the 2.14 of the isotropic). Don't misunderstand. The manufacturers are honest. It is just that you should understand the rating system. When you buy an antenna, you should question the gain figures as to exactly what they mean.

Usually, it is customary to base gain measurements using a half-wavelength dipole as a standard. Among antenna engineers and written discussions about antennas, the usual criteria is to compare gain against a dipole.

Many readers will be operating VHF and UHF. The preceding discussion primarily concerned the lower bands, 160 through 10 meters. You will still find the same general measurement standards at VHF/UHF, but with a slight change, particularly when dealing with vertically polarized antennas (verticals) used to operate through repeaters and so on. For VHF verticals the common standard of comparison among manufacturers here seems to be a one-quarter wavelength vertical. (Although I am not positive about this point.) The gain, or rather the loss, as measured from a half-wavelength dipole is -1.8 dB. The point I want to make here is that when reading gain figures, make sure you understand what those measurements actually mean. It is not unusual to see half-wavelength vertical antennas with gain ratings of 2 dB (of course, they are being compared to a quarter-wavelength antenna). From my above discussion it is obvious that a dipole cannot have a gain *over* a dipole. One other point that needs mentioning: The VHF and UHF gain for vertical antennas is usually meant as *omnidirectional* gain. We normally assume "omni" means in all directions, but actually the gain, while equal *around* the antenna, has a pattern that is *squashed*, or flattened, by the antenna to provide the gain. For example, a ⅝-wavelength long vertical has more low-angle gain than a quarter-wave dipole.

Beamwidth

Beamwidth (not to be confused with bandwidth) is another commonly quoted

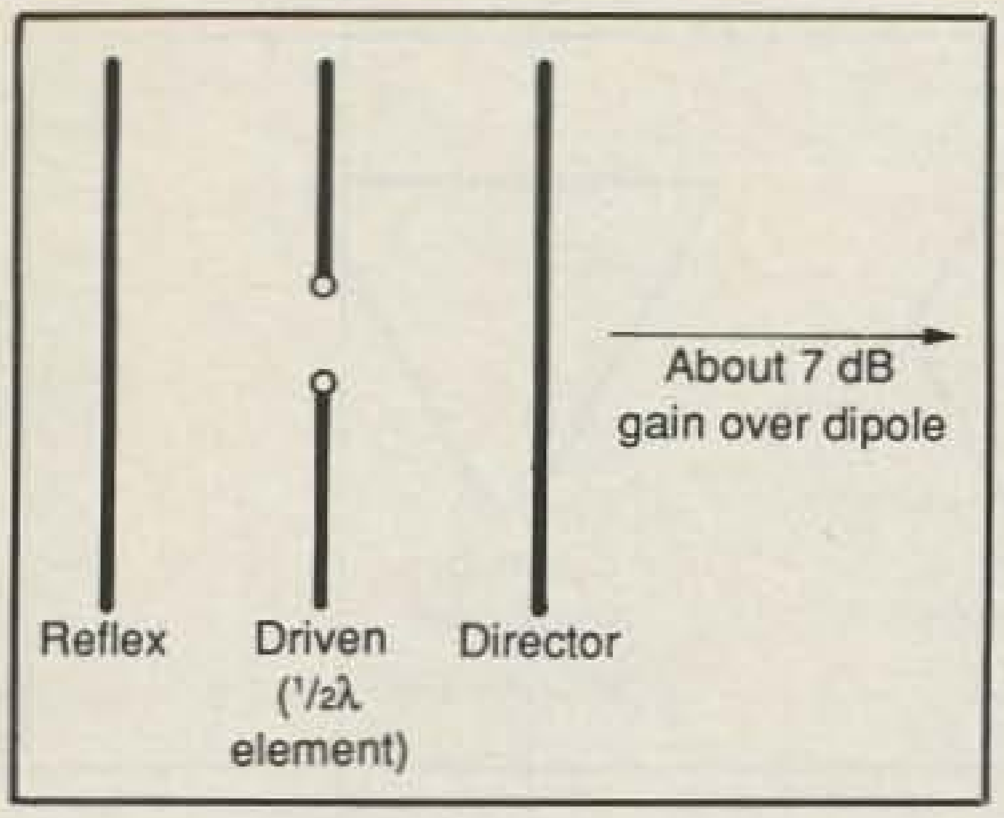

Fig. 4– This is the basic Yagi antenna in which the rear element (reflector) and the front element (director) are parasitically excited. Such an antenna provides on the order of 7 dB gain as compared to a dipole.

statistic when it comes to rating antennas. However, it is a figure a little more difficult to understand. The beamwidth of a directive antenna is the width, given in degrees, of the major radiation lobe between the two directions at which the relative radiated power is equal to one half its value at the peak of the lobe. These are referred to as half-power points. Another way to understand this is to assume we have a beam antenna with a major lobe of power. Let's also assume the maximum power we can measure is 100 milliwatts. As we go out from the center of this lobe, continuing our measurements, we reach a point of 50 milliwatts of power, or a "half power point," and we then do this on the opposite side of center until we reach 50 milliwatts. The angular distance, in degrees, provides us with the beamwidth of the antenna. This is a useful figure in amateur radio where rotatable beam antennas are used.

What all this mumbo jumbo means in simple language is how close we have to aim the beam in order to work or hear a given area. From practical experience, you will find that there is considerable leeway in aiming a normal three-element beam, and it turns out that it just is not too critical. However, with multi-element VHF/UHF arrays, it is a different story. The beamwidth is critical, so be aware (see fig. 3).

Bandwidth and SWR

One of the more important statistics with which we have to deal in understanding antennas is that of bandwidth ("band" not "beam") and SWR (standing-wave ratio). First, let's look at modern-day transmitters and receivers (transceivers) to understand why this is important.

Modern transceivers are designed to work into fixed loads or impedances. Very little leeway is allowed, because excessive mismatch between the load (the combination of the antenna and its feed line is the load) and the transceiver can cause destruction of the final amplifier transistors. Nearly all modern transceivers are designed to work into 50 ohm loads. We normally use 50 ohm impedance coaxial feed lines, but in order for a feed line to present a 50 ohm load to the transceiver, the line *must be matched* into a 50 ohm impedance antenna—and very few antennas work out to be exactly 50 ohms. This in turn means the antenna must be matched to 50 ohms with a matching device. This is another question the purchaser of an antenna must ask: How does the antenna attain a 50 ohm match and what is its bandwidth?

Just about every antenna maker will provide standing-wave ratio curves. However, for bandwidth information you may have to work that out for yourself. The usual method is to look at the SWR curve for a given band and figure at what frequencies the SWR drops below 2 to 1. Let's for example say your beam goes to 2 to 1 SWR at 14.2 MHz and stays below 2 to 1 up to 14.3 MHz. That means the useful bandwidth would be 2 to 1 for 100 kHz. (Most transceivers will handle a 2 to 1 mismatch without shutting down.)

There are certain points that should be mentioned here which we probably have to call "the facts of life." In going through nearly all of the manuals that come with modern transceivers, the instructions point out that if the mismatch exceeds 1.5 to 1, the user is quite likely to be unable to load the transmitter to full power. Most of the manufacturers of such equipment suggest the use of a Transmatch or tuning network to permit proper loading.

One other point that should be made clear to you, the neophyte purchaser, is that all modern transceivers are designed this way. There are no exceptions. It is true that some of these units have optional built-in matching networks called Transmatches or antenna tuners, but these cost extra, so just be aware that the situation exists. And almost without exception, there are no antennas designed today that will exactly match or appear to be 50 ohms on all amateur frequencies.

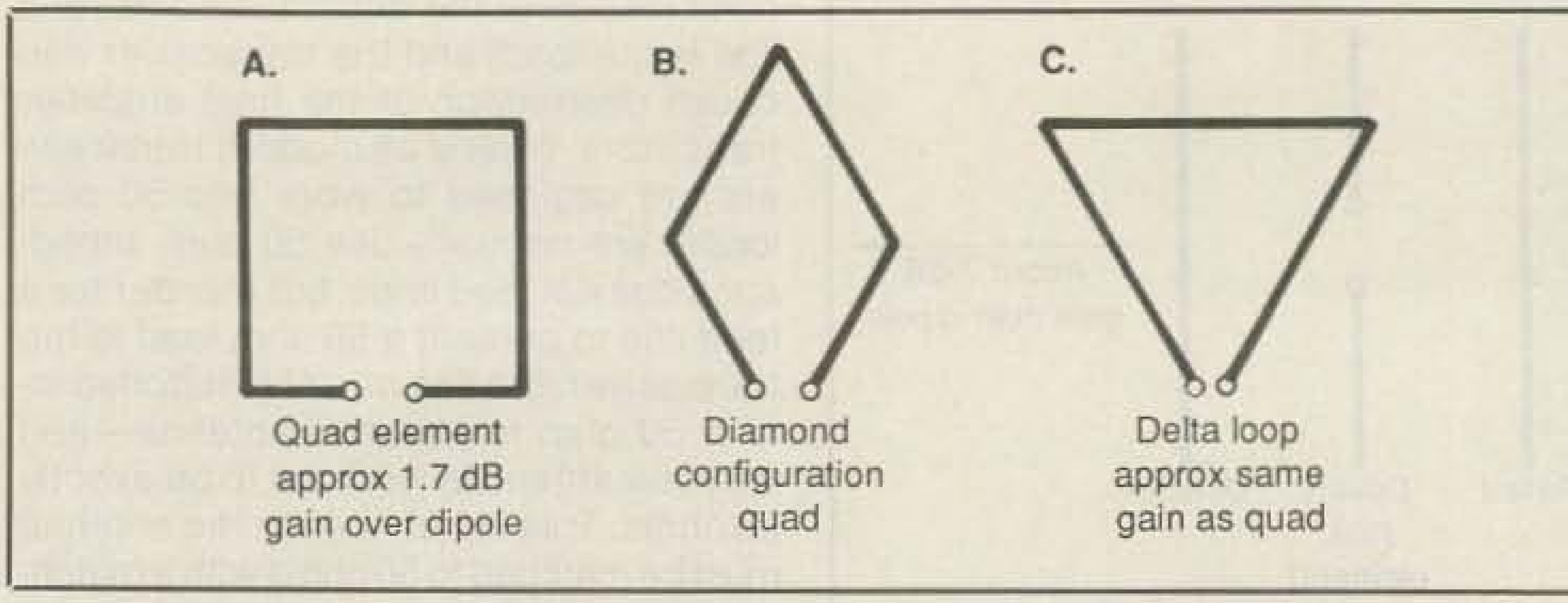

Fig. 5- (A) and (B) are the typical configurations for the Quad antenna invented by Clarence Moore, W9HCF. Keep in mind that these are full-wavelength antennas. Because of this and other factors, they exhibit more gain than a half-wavelength dipole. The Delta Loop antenna at (C) is another very popular antenna.

Standing-Wave Ratio (SWR)

The commonly used feed line these days is 50 ohm coaxial cable. The 50 ohm figure is called the characteristic impedance of the line, and it is determined by the size of the conductors used in the construction of the line, the spacing between these conductors, and the composition of the dielectric material used to insulate the conductors. For any given coaxial line, the impedance is a fixed value, and nothing we can do will change that impedance.

The impedance of an antenna will depend on many, many factors, including the type of antenna, its size, its height above conducting ground, its proximity to nearby objects, and so on. When the feed line is attached to the feed point of the antenna, the two impedances—that of the line and that of the antenna—are joined. When power is fed to the line, a ratio of maximum voltage (or current) to minimum voltage is set up. This is called the standing-wave ratio (SWR). When both the antenna impedance is 50 ohms and the feed line is 50 ohms, the ratio is 1 to 1 (the ideal condition). However, with *any* antenna, the impedance will change as the frequency is changed. This means the SWR will increase. For example, if the impedance of the antenna goes to 100 ohms, the SWR becomes 2 to 1 (100 divided by 50), and so on.

It isn 't easy to put hard-and-fast figures on antennas for the prospective purchaser. As pointed out earlier, modern equipment does not allow much leeway when dealing with mismatches. The circuits built in to protect the final-amplifier transistors from burning out due to operating under less than idea conditions are fairly stringent in limits. In other words, the final-amplifier stage must see a 50 ohm load or matched condition. If, for example, the transceiver sees a 100 ohm load (SWR of 2 to 1), the amplifier will tend to shut itself off.

This leads us, as purchasers, to look for antennas that have reasonable bandwidth. The word "reasonable" is meaningless unless we put a limit on what we can expect. This, in turn, leads us to the discussion of actual antennas. There are many, many different types of antennas available. The prospective purchaser should really decide what his or her goal is going to be and proceed from there. We will attempt to cover the field as much as possible to assist you.

Beam Antennas

Earlier we discussed "shaping" the signal that radiates from an antenna to obtain gain. Many years ago a scientist named Dr. Yagi discovered the concept of applying power to one element, a dipole antenna (see fig. 4), and then adding another element behind or in front of the driven element. This had the effect of shaping the radiated signal, providing gain in one direction and rejecting signals in the opposite direction (this last being called the "front-to-back ratio"). Yagi's design used the concept of "parasitically" exciting all but the driven element, the one with the feed line attached. There are many types of beam antennas available for the buyer. Let's first discuss only monoband beams—antennas designed for single-band use.

Regardless of what you may read in advertising, there are hard-and-fast gain figures that can be applied to monoband beams. These figures have been accumulated over the years, and they are the work of many antenna engineers and laboratories, and what is of importance, they all agree about gain within a fraction of a decibel. Keep in mind that we are only discussing monoband beams. Later we will go into multiband systems.

All of the gain figures given will be based in measurements against a dipole, dBD. The most basic figure is that of a three-element monoband Yagi beam. Maximum gain will be approximately seven decibels dBd (decibels compared to a dipole). The word *approximate* is used because we have seen accurate measurements showing as much as 7.6 dB, but it should be noted that fractional dB figures are difficult to prove, much less measure. As an aside, 7 dB is a power ratio of slightly more than 8, or to look at it another way, if you were running 100 watts from your transmitter to a 7 dB gain beam, it would the equivalent of slightly more than an 800 watt power increase in the desired direction. In practice, this is only a gain of slightly more than one S unit when it comes to receiving, but the amateur should keep in mind that this is a considerable improvement in receiving. In fact, sometimes it is the difference between being heard and not being heard. In a beam antenna, the front-to-side and front-to-back can be a real boon. For example, my present beam (and I might add others I have had) in some instances can reduce a signal on 20 meters from an S9 down to zero off the back. Keep in mind, though, that front-to-back ratios are not for *all* angles. I like to use the term "attack" angle for the back signals. There is, or are, angles of radiation coming into your beam that can be attenuated more than others.

Many amateurs mistakenly assume that if a 3-element beam produces 7 dB gain, then by doubling the size to 6 elements they will get twice the gain, or 14 dB gain. Not so. Generally speaking, if we double the size of the antenna, we will gain 3 dB (that's not bad, though, because 3 dB doubles our power again!) There is no hedging on this rule. Doubling the size of the array or beam increases the gain by 3 dB (or doubles the power).

You must realize that there are limits in obtaining gain in this manner. Antenna sizes can become very unwieldy very quickly. Also, on VHF and UHF, where beams are physically small, some rather high gain figures can be obtained, but at some point, the signal losses in the phasing and harnessing lines become prohibitive.

Yagi antennas are the most common of the beams, but there are others the buyer may wish to consider. Another very popular antenna is the Quad or Delta loop beam. Fig. 5 shows some of the configurations of these antennas.

The Quad or Delta Loop differs in several ways from a Yagi-type beam. In the first place, the driven element of the Quad or Delta is a full wavelength in size as opposed to the Yagi, which is a half wavelength. It is almost axiomatic in antenna theory that the larger an antenna is the better it is. The Quad and Delta Loop have a larger effective aperture (some amateurs call it "capture area") and hence, more gain. A single Quad or Delta element will have about 2 dB gain over a dipole. When a Quad or Delta reflector element is added, the gain of the two elements will be on the order of 7 dB, about the same as a 3-element Yagi. I know I will get arguments from some antenna people but note that I used the word "about."

Additionally, Yagi elements are what are known as high Q elements, and are more critical as to spacing and coupling between each other as opposed to the low Q of Quad or Delta elements. Using lower Q elements provides a greater bandwidth. Also, if you are subjected to rain or snow static, the effect is much less pronounced on the Quad and Delta.

One last point worth mentioning: Many times it is desired to put more power into a lower beam angle from the antenna. This effect can be achieved by stacking two separate Yagis. However, the effect of stacking already exists in a Quad, and even more so in a Delta loop.

The above discussion does not mean that Yagis are better or worse performers than Quads or Deltas. Each have their features and advocates. In Part II, I will discuss multiband beams and wire antennas.

(To Be Continued)

In Part I of this series W1ICP discussed some basics, including antenna patterns and gain. In Part II he starts off with multiband beams and goes on to wire antennas and more.

Let's Talk Antennas—Part II

BY LEW McCOY*, W1ICP

In 1953 an amateur named Buchanan, W3DZZ, produced a single antenna that was fed with a single feed line but would work on many bands and present a *reasonable* load to the transmitter—in other words, a single beam or dipole that would cover more than one band. By inserting electrical traps in the Yagi elements, the antenna could be made to appear to be a 50 ohm antenna, plus be resonant on many bands. However, it should be made very clear to the uninitiated that these multiband beams or trap dipoles are always a compromise and can never approach a monoband beam in performance.

A monoband beam is designed to be optimized for maximum gain or maximum front-to-back, or a combination of both. The spacing of the elements, and their lengths, is critical to obtain maximum performance. With multiband trap or linear loaded beams, it is almost impossible to have optimum spacing of elements simply because what holds true for one band will not hold true for another. Also, there is the problem of trap losses. Any tuned circuit will introduce some losses, and the quality of the traps is very important in order to maintain gain.

One last point about purchasing a beam antenna, either monoband or multiband, and that has to do with quality. A beam is exposed to the weather and must stand rigorous conditions. It may cost more, but in the long run it is well worth the difference in cost to be sure the manufacturer provides all quality parts.

Antenna Supports

For any antenna to perform at its best, it should be mounted as high as possible and in the clear. There are all kinds and types of towers, from roof-mounted to self-supporting unguyed towers. I urge the reader to write to the various tower manufacturers to obtain their literature. This information will tell you what kind of loads the various towers will support, both as to load bearing and wind loading. Antenna manufacturers always provide complete specifications regarding wind loading, surface area, weight, and other critical details.

Frequency	Overall Length
3.7 MHz	324 ft.
7.0 MHz	172 ft.
14.0 MHz	90 ft.
21.0 MHz	60 ft.
28.0 MHz	44 ft.

Table I– Lengths for extended double Zepp antennas.

How high? The question most frequently asked is "How tall a tower should I buy?" That is not an easy question to answer because many variables are involved. It seems every amateur wants to have the loudest signal on the band. Assuming money is no object, it is possible to build a system that will help make you a top performer.

The average height is easy to find out simply by asking a lot of amateurs what they use. This appears to be a tower of 50 to 60 feet high. The big guns—those with the very strong signals—usually have towers in the 80 to 120 foot range. There is a good reason for this. The angles of radiation for 20 meters from the average beam don't tend to become low enough to be useful for long-haul DX until you reach something over 80 feet. If you are not concerned with becoming a "top gun," then 50 to 60 feet is a good compromise for multiband beams. I would be remiss if I didn't mention the fact that a Delta Loop beam rises from the boom with the apex of the triangle at the boom height. A major part of the radiating portion of this antenna is at the very top of the antenna. In the case of 20 meters, and utilizing a 60 foot high tower, some of the antenna will actually be working (radiating) above 80 feet.

If you live in an area subjected to high winds, then you must consider a guyed tower. Again, we suggest you write to tower manufacturers and get literature on their products. This will assist you in determining exactly what you need for your location and situation.

Roof-mounted towers are excellent for lightweight beams, even some small or lightweight tribanders. Again, manufacturers' specifications are the thing to look for here. Anchoring a tower to a roof must be done according to good engineering techniques, and steps must be taken to dampen antenna elements and wires to prevent vibration, which will be transmitted to the tower and then through the roof to the dwelling. (Your family will quickly take a dim view of such noise. I know, as it happened to me.)

Vertical Antennas

Many amateurs who have space limitations will want to choose vertical antennas simply because they don't require much in the way of real estate. Again, there are many excellent trap-type multiband verticals and one non-trap that I know of. However, bandwidths can be rather limited on 80 and 40 meters simply because on these bands the antennas are shortened physically. A quarter-wavelength-long vertical on 80 meters is on the order of 65 feet high. The normal feedpoint impedance of this antenna is on the order of 30 ohms or so, and as such, without a matching device, 50 ohm cable will be mismatched and the bandwidth narrowed. When the 80 meter antenna is shortened physically, its impedance drops considerably and the bandwidth is narrowed even more. Trap verti-

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cals are usually adjusted to fit the user's desired operating frequency on 80 meters. On 40 and higher, this is not as much a problem.

Ground-mounted verticals will operate with a single ground rod installed near the base of the antenna. However, performance is improved immeasurably when radial wires are installed.

Radials

Installing a radial ground plane beneath a vertical is not really a difficult project. In the case of a multiband vertical, including 80 meters, the ideal ground plane would be at least 30 wires, at a minimum length of 0.2 wavelengths long. The 0.2 wavelengths would mean about 50 feet long to cover 80 meters and the higher bands. This may sound as if it is an impossible project, but it is not difficult at all. Ideally, the wires would all be connected together to a ground plate at the base of the antenna and the wires would radiate out in a perfect circle. However, this would be impractical on a small city lot. The wires do not have to run straight. Also, they can be separated by only inches. Suppose the vertical is mounted alongside a house. The wires can run along the house and fan out to the fence line and then along the fence to the desired length. Naturally, you would want to bury them—but only do so just below the surface. Of course, if 40 meters is the lowest band, then 25 foot wires would be adequate. Also, any kind of wire can be used, insulated or uninsulated.

I like to give credit where it is due, and Jerry Sevick, W2FMI, made many extensive tests to determine the required number of radials. His primary reasoning was that a vertical has a theoretical impedance of about 30 ohms. He kept adding radials until he established this impedance. My statement above of 30 radials is not quite the required number (50 being needed), but I am sure that Jerry will forgive me for making the job a little easier with only a slight addition in ground losses. Sevick's work was recounted in a series of articles some years ago in *QST*.

Many amateurs choose to mount verticals above ground. In this case, you should use as many radials as possible, but at least four should be used in order to establish some semblance of a ground plane beneath the vertical.

Wire Antennas

The discussion on antennas up to this point has been about multiband beams and verticals. However, many amateurs start out with simple dipoles, either single band or multiband. First, though, it should be pointed out that there are trap dipoles available that cover 80 through 10 meters. These are all coax fed, using 50 ohm line. None of these, however, are truly broadband on 80 or 160 meters, and some type of tuning device must be used with such antennas in order for the transceiver to operate.

You will find ads in this magazine for dealers who primarily sell wire and feed lines. In order to make a good-performing antenna, very little knowledge is required. As I stated earlier, a half-wavelength dipole is the most efficient antenna there is. This dipole consists of two equal lengths of wire or tubing separated at the center by an insulator and supported at the ends with insulators. The antenna can be fed with 50 ohm coaxial line and it will provide a match that will be close enough for all practical purposes. The formula for calculating a half-wave dipole is very simple. Divide 468 by the desired frequency in megaHertz and the answer will be in feet. Let's suppose we want to make a dipole antenna for 3800 kHz (3.8 MHz). We divide 468 by 3.8 and come up with 123 feet. The antenna can be used in an inverted-V configuration or simply as a horizontal dipole. It will work well either way. How will it work if we feed it with coax directly, no balancing device used? Believe it or not, it will work the same either way. You can install a balun if you want, but more than likely it will not improve the performance.

What many amateurs do not realize when they make a dipole such as this is that they have actually created a multiband antenna, one that will work on all bands and all frequencies. There are a couple of things we have to do, but they are not complicated. First, we do not feed the dipole with coax. We use either open-wire line or the more popular transmitting-type twin lead. Why open wire line? The answer is simple. Coax cannot tolerate high standing-wave ratios without increasing losses. On the other hand, the transmitting twin lead can have an extremely high SWR without the losses. So our choice is clear cut.

As you can gather from reading all of the preceding parts of this article, we must provide a 50 ohm load for our very fussy transceiver. And, our multiband antenna with its feed line is going to present some pretty crazy loads. I know some of our readers will realize I have said a lot of this in previous articles, but it always bears repeating. We can install a Transmatch, sometimes called antenna tuner, directly at the transceiver and then proceed to adjust the Transmatch so that the transceiver always sees a 50 ohm load. In this case we take the unknown load presented at the end of the feed line and transform that load to 50 ohms by way of the Transmatch. This is a very simple procedure and makes any dipole, regardless of its overall length, into a multiband antenna.

Of course, you could take an end-fed wire, connect the far end as high as possible, connect the other end to the Transmatch, and make the same adjustments. In this case you never have to worry about feed lines. However, the idea of using a balanced line is more appealing.

The amateur will come across a whole family of antennas that are supposed to work as a 50 ohm load on all bands and frequencies, but none will really do so without a Transmatch. These include the G5RV, multiple half-wavelength dipoles with a common feed point, off-center-fed antennas, and coaxial dipoles (most of these are usually referred to as broadband dipoles).

Maybe you might even want to use a "McCoy" antenna. It is extremely simple to make and will work like a bomb—on all bands, and always present an SWR of 1 to 1 to your rig. All you need do is to measure the distance between your two support points. Suppose the distance is 100 feet. Take a wire that long—any kind of wire (#18 or larger enamel-covered wire is preferred but not necessary)—and cut the wire into two equal lengths. Put an insulator on each end and one in the center. Oh, yes. You can use short lengths of PVC tubing with holes drilled in them to make the insulators or buy some insulators at Radio Shack.

The feed line is going to be open-wire line, either the commercial TV twinlead or preferably the 450 ohm type available from advertisers in this magazine (Nemal Electronics or Certified Communications, for example). You make the feed line long enough to reach from the antenna center insulator to the Transmatch in your shack. The insulated twin-lead or open-wire type can be brought directly under a window or through the wall to the shack. It is perfectly safe and a simple way to bring in the line. You then simply adjust the Transmatch for a match and go to work on the bands. For some reason (which I don't understand) many amateurs are reluctant to bring open-wire-type line into the shack. The insulated type line is perfectly safe. However, if it improves your peace of mind, you can run two adjacent lengths of coax from the tuner to the outside wall and then connect the two inner conductors to the open-wire line conductors. I would emphasize that a good-quality coax be used; the RG-8/U types would be preferred. Also, ground the shields at the Transmatch and at the other, or wall, end. Don't be concerned with the differences in line impedance. Two adjacent 50 ohm coax lines would be 100 ohms attached to a 450 ohm line. Keep in mind that you are always matching a "system" load. In other words, the unknown impedance with reactance at the Transmatch.

How long or short can the McCoy antenna be? As long as you can make it. How short can it be? That is a little tougher, but I have used this antenna as short as 40 feet (center fed) for 80 meters and higher and it produced creditable results. I might add that you can make it 102 feet and then you'll have a bonafide G5RV antenna. Or, if you have the room, an extended double Zepp is an excellent antenna for all bands. It is a dipole that is 0.64 wavelength long on each side of center. An antenna this long produces major lobes that have at least 3 dB gain. When this antenna, 1.28 wavelength long overall, is used on the higher bands, the number of lobes increases and the antenna has even more gain. It should be noted that the overall length for a 20 meter extended double Zepp is 45 feet long, and such an antenna with open-wire line and a Transmatch will work on 80 and 40, even though the antenna is short. Table I provides the EDZ lengths for all the bands.

Even if you don't have the space for the EDZ, the McCoy antenna is still the one which should be made long enough to fit between your farthest supports. It is foolish, for example, to make an 80 meter dipole a half-wavelength long if you can make it longer, as long as a tuned system (open-wire feeders and Transmatch) is used. Remember what I said earlier: Bigger is better, and in this case I mean longer. I have mentioned this before, but it bears repeating. By Goodman, W1DX, the famous antenna man, once told me, "An amateur should always make his antenna as big as possible and put it as high as possible. If it stays up, it isn't big enough or high enough!"

In Part III, I'll discuss other pertinent information about antennas. CQ

Now that this series is just about talked out, it's time to make a trip to the hardware store and put some of this talk into practice.

Let's Talk Antennas—Part III

BY LEW McCOY*, W1ICP

In the first two parts of this series I discussed what to look for in gain, and so on. However, all of us are very conscious of the cost of things. Being a notable cheapskate, I would be remiss if I didn't describe some way to beat the high cost of hamming when it comes to antennas.

In Parts I and II of this series I described some low-cost wire antennas. However, inexpensive (meaning really cheap) rotary antennas are hard to find. We shouldn't blame the manufacturers of antennas, as aluminum tubing has gone out of sight as far as costs are concerned. But there are methods to come up with rotary antennas that are relatively cheap by anyone's standards, including mine.

Rotatable Dipoles

I know every amateur gets excited about beam antennas, but you should keep in mind that a rotatable dipole is really a beam antenna. Granted it has no front-to-back ratio, but it does have directional gain versus the very high rejection of side lobes. Also, remember from my earlier discussion that the beams are usually measured compared to a dipole. And this is important—the beam's gain figure usually is represented by no more than 1 to 1½ S-units. With skip signals on the 20 through 10 meters, an S-unit doesn't amount to that much. Also keep in mind that the angle of radiation from a beam *as well as a simple dipole* is primarily dependent upon the height of the antenna above ground.

Normally, you would use the formula 468 divided by the frequency to determine a half-wave dipole length. However, sometimes as a means to an end, it helps to juggle the antenna lengths. Some years ago, because electrician's thin-wall tubing came in 10 foot lengths and was very cheap, I made a rotatable dipole for the 21 MHz band that was slightly less than the normal dipole length. The actual dipole length (20 feet) was slightly short of that of a half wavelength by about 2 feet (which would be about 22 feet normally for 21,250 MHz). This shorter length resulted in a feed impedance of about 50 ohms (instead of 72 ohms) plus introduced some capacitive reactance which I eliminated by the use of a small coil. This antenna was (and is) very popular, and many amateurs have worked well over 100 countries on low power using the antenna.

I later used the same technique for the other bands with great success. One would naturally ask, "Why deliberately shorten an antenna when you could make it a half wavelength long?" The answer is relatively simple when you think about it. Because the criteria for our transceivers

Frequency	Length
14.2 MHz	30 feet
18.1 MHz	24 feet
21.3 MHz	20 feet
24.9 MHz	17 feet

Table I– Rotatable dipole lengths using reactance coil.

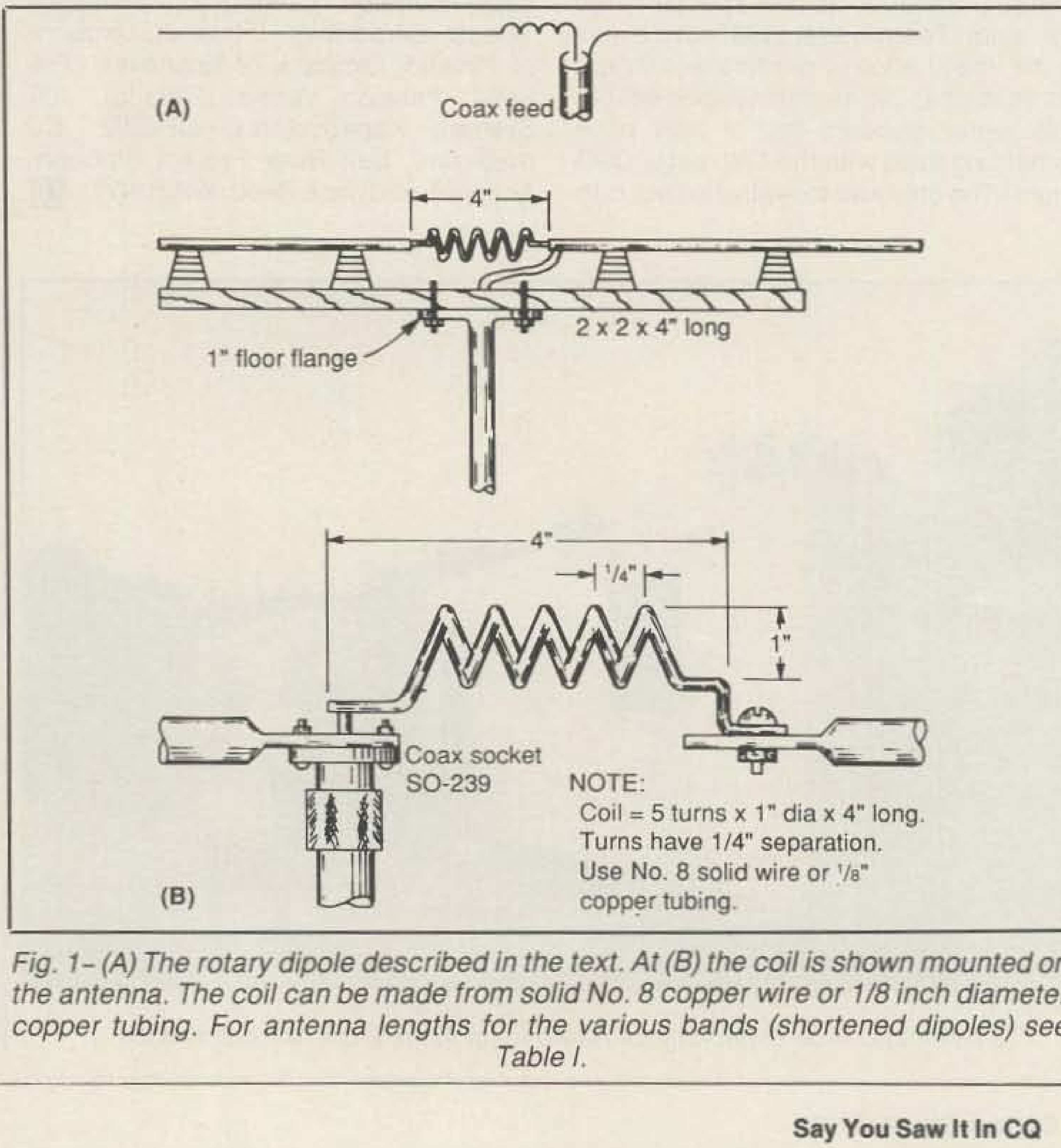

Fig. 1– (A) The rotary dipole described in the text. At (B) the coil is shown mounted on the antenna. The coil can be made from solid No. 8 copper wire or 1/8 inch diameter copper tubing. For antenna lengths for the various bands (shortened dipoles) see Table I.

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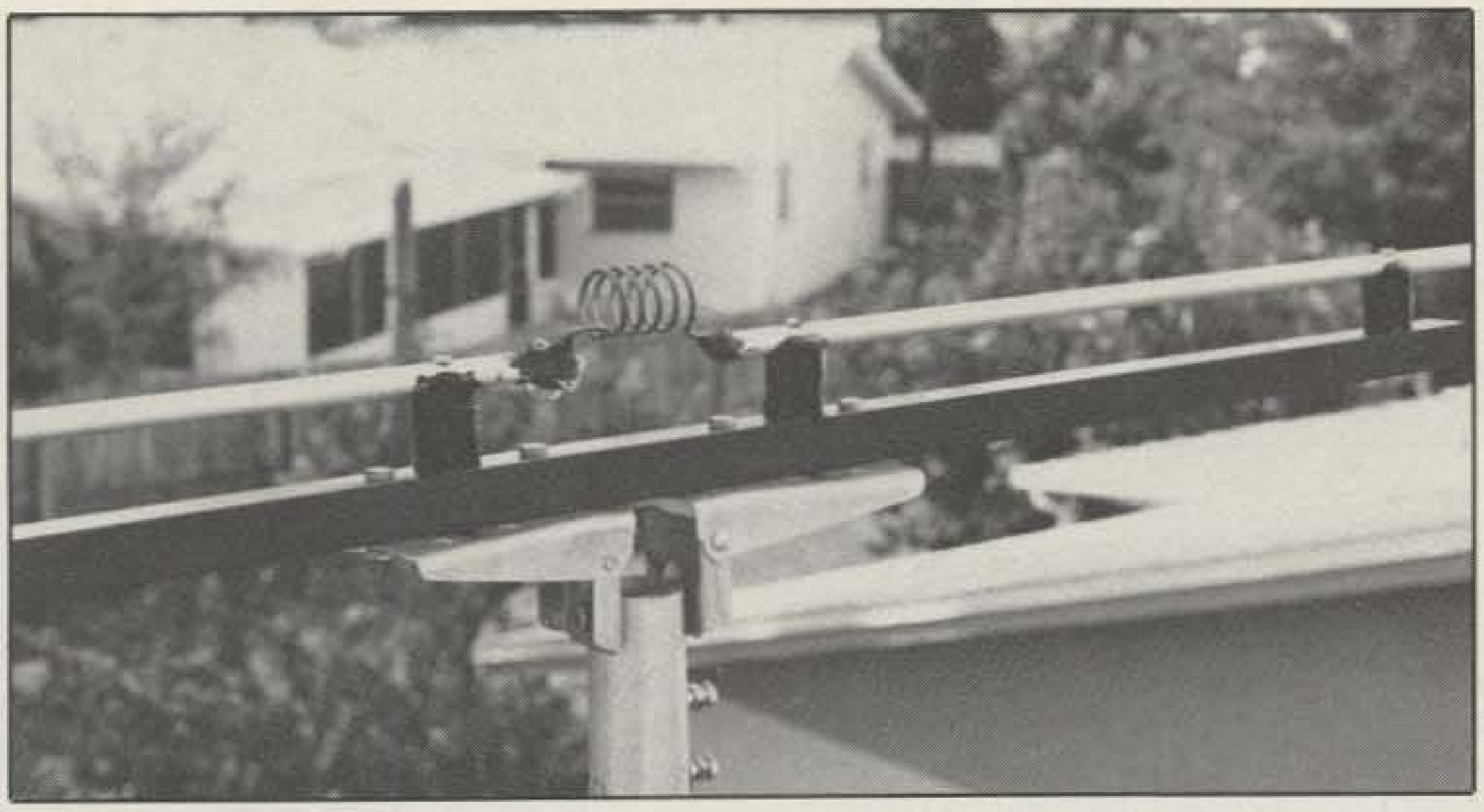


This is a photo of the 12 meter rotatable dipole antenna made by K4TTO. He made his coil from No. 8 solid copper wire. The support is a Radio Shack roof mount. It is supporting a 1 inch square aluminum support which in turn has four nylon standoffs to hold the antenna proper. As pointed out in the text, a wood 2 by 2 could be used for the element support.

is a 50 ohm load, the concept of using a slightly shortened dipole to get a perfect match is a good one. Using my computer program, I went through the various bands (including the WARC bands) from 20 through 10 to get the correct antenna length for a good match with a specific coil (reactive) size. In other words, one coil fits all the antenna lengths specified for a 50 ohm match.

Let me digress for a moment here. I know that I discussed matching and bandwidth, but a few points should be emphasized. If you can obtain a perfect 1 to 1 match, it means the antenna will exhibit a better bandwidth, as far as working with modern rigs. With the exception of 10 meters, these shortened matched dipoles will exhibit very low SWR across the bands.

As to actual rotatable dipole construction, the antennas need to be made from tubing that is strong enough to support itself. I have had excellent results with electrician's thin-wall tubing, which is very inexpensive and, as I said, comes in 10 foot lengths (and it really isn't too heavy). If you are planning to make a 20 meter rotatable antenna, you'll need on the order of 30 feet. In this case you might have to use slightly larger tubing and telescope smaller sections into the ends. (I wouldn't recommend this material for 40 meters, as the dipole would be too big and heavy (60 or so feet long).

In making these dipoles you have to use your amateur ingenuity and examine what the electrical supply houses have in stock in order to find suitable telescoping sizes. However, aside from 20 meters, one diameter in 10 foot lengths can be used for all bands, including 18.1 MHz and higher. The length for 18.1 MHz works out to be 24 feet. Two 10 foot lengths of tubing plus two pieces of stiff wire each about 2 feet long should do the job. The wires are mounted on the ends of the dipole (tubing) to electrically lengthen the antenna.

The dipoles can be mounted on a 2" × 2" or 2" × 4" using homemade standoffs (PVC pieces, etc.). See the drawings I have included. The feed point is made by flattening the end of the thin wall for a distance of about 2 inches (see photo). Use a hammer and a flat piece of metal (vise). Next mount an SO-239 coax fitting on this flattened area. Likewise, flatten the opposite side of the dipole end and drill a hole to take a nut and bolt. The coil will fit between the SO-239 center tip (solder) and the nut and bolt on the other section. In this way the shield or outer conductor will feed one side of the antenna, and the inner conductor will go via the inner section of the fitting, through the coil, to the other side of the antenna. The coil can be made from 1/8 inch diameter tubing or No. 8 copper wire.

The 2" × 2" can then be mounted on a floor flange (inverted) and a pipe mast used. Keep in mind the dipole only has to be rotated 180 degrees. (A cheap TV rotor will handle the job.) As I stated above, one of the more popular antennas I designed was a one-element rotary for 15 meters. I used the two 10 foot lengths of thin wall. I inserted a small coil in the center of the antenna to get rid of the reactance resulting in an impedance of 50 ohms. Fig. 1(C) is an electrical drawing of this antenna.

The impedance of a half-wave dipole is on the order of 70 ohms, so using a direct feed with 50 ohm coax would give us a mismatch that could cause problems. The shortening of the antenna slightly, plus the coil, puts the impedance at 50 ohms, an excellent match. (You could use a coax stub to get an exact 50 ohm match.) In any case, don't overlook the rotatable dipole. It is a superior antenna and will do darn near as well as a beam.

Incidentally, while I haven't tried it, there is no reason why you couldn't stack dipoles above each other, possibly mounted at right angles to each other and fed with the same feed line. It would be worth a try.

Some amateurs have added reflectors to make a true beam out of the rotary dipole. I don't have the dimensions, but it could be done experimentally, as a reflector would be 23 feet 2 inches long (approximately) for 21,250 MHz. A length of wire at each end of the dipole and some at the center could be added to make up this length. The idea is to make the reflector 5 percent longer (electrically) than the driven element. Properly adjusted, the two-element beam should provide 15 to 29 dB front to back ratio. Adding a reflector will change the impedance slightly, but you still could have a good match, assuming an element spacing of 0.150 to 0.2 wavelength.

For 10 meter amateurs a three-element beam would be a natural using the thin wall. A director, driven element, and reflector, using a gamma match (see any antenna handbook), would give you a 7 dB gain antenna, not to mention having good front to back, etc. All this could be done for probably less than $30 or $40. In this case (10 meters) you don't need to lengthen the thin wall tubing, but rather cut it to size for each of the three elements. I would recommend Bill Orr, W6SAI's *Beam Antenna Handbook*, as this has all the details for making beams and matching them. It is available from CQ's Bookstore ($11.95 plus $4.00 shipping). What I am really saying here is that there are many ways of beating the high cost of beams. You have to think in terms of cheap tubing and low-cost supports (two by fours, etc). Again, to emphasize, these beams will perform as well as some more expensive ones.

At the Dayton Hamvention this past year Metal and Cable Corp. was selling aluminum tubing and other extruded aluminum types. I hadn't seen or heard of anyone else marketing tubing, so I felt it worthwhile to pass this information along. This company lists, for example, 6061-T6, ½ inch diameter tubing, .058 wall, for $16.95 per 12 foot length. Unfortunately, their minimum order is $50, so if you plan on a rotary antenna, you might just as well go for two or three elements. They have a two-sheet list of their products available, but I would suggest a business-size SASE: Metal and Cable Corp. Inc., 2170 E. Aurora Road, P.O. Box 117, Twinsburg, OH 44087 (216-425-8455).

My final point is that you can save some dollars by building your own beam.

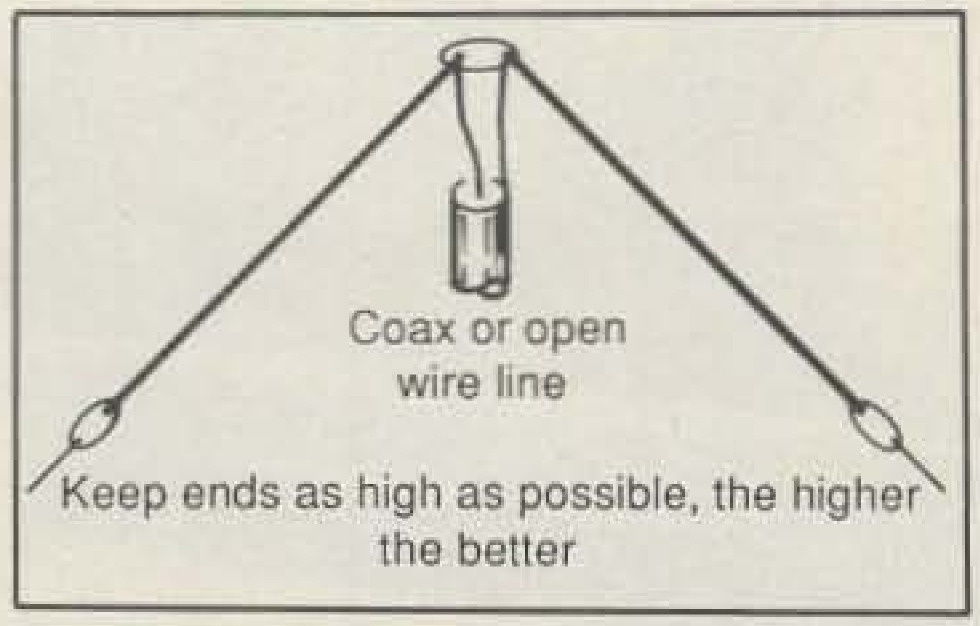


Fig. 2- The inverted-Vee is a very popular antenna. It can be a half wavelength overall. However, the McCoy dipole (make 'em as long as possible) could be used if the antenna is fed with an open-wire type line and a Transmatch. The object is to make the antenna center as high as possible and also keep the ends as high as can be.

Inverted-Vee Antennas

Many amateurs are not fortunate enough to have two supports to put up a horizontal dipole. All the wire antennas I have discussed thus far can be put up in an inverted-Vee configuration and will do a very creditable job. Many years ago, clear back at the inception of amateur radio, amateurs found that obtaining two supports or towers wasn't practical. Hence, the inverted-Vee was born. In this case (fig. 2) a dipole was suspended from the center and the ends made as high as possible.

There are a few facts to keep in mind about an inverted-Vee. First, it is never as efficient a radiator as a horizontal dipole. However, usually the amount of difference is not worth considering unless you are talking about truly "high above the earth" dipoles. Also, an inverted-Vee, depending on the band, frequency, etc., can produce some low-angle vertical radiation which a similar horizontal dipole will not do.

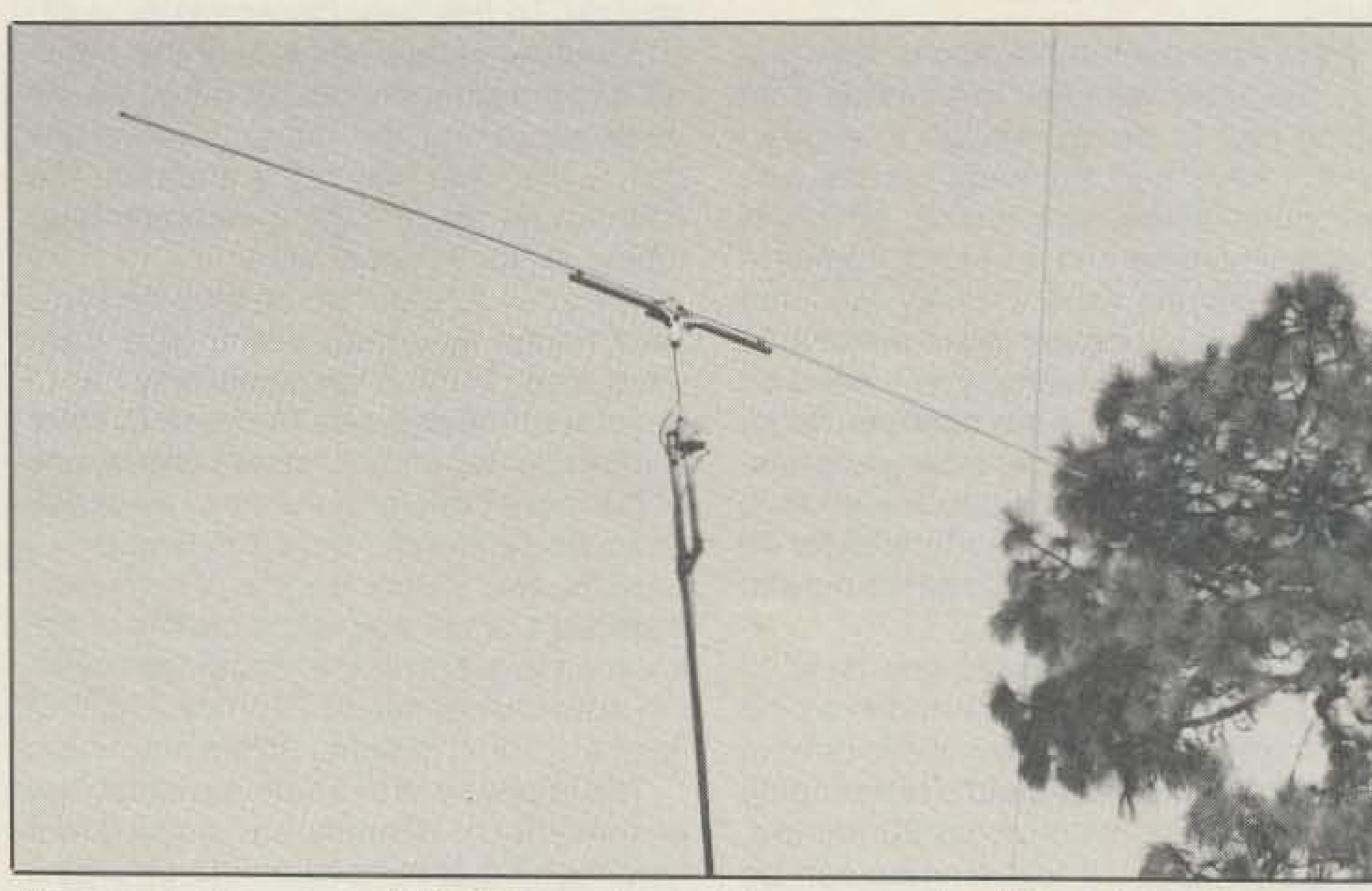
Still another method of obtaining broadbanding (bandwidth) when using coax feeders is to make dipoles that have a 50 ohm non-inductive resistor at the center. These antennas will provide broadbanding, but you must also be aware that as much as 50 percent of your power will be lost. In other words, a good deal of the transmitted power will be dissipated as heat; usually at least half your power is lost this way. But if you want to accept the power loss, such antennas will present an approximate 50 ohm load to your transceiver.

Random Or "Long" Wire, Antennas

A popular type of antenna is simply a random-length wire that is brought directly into the Transmatch and used on all bands. Many amateurs mistakenly call such antennas "long wires." However, a long-wire antenna by definition is one that is several wavelengths long at the lowest used frequency. The primary criteria here is to put the far end of the wire as high as possible and insulate the wire where it enters the house. Keep in mind that even running relatively low power, you can get some rather high RF voltages present on the wire. You should use a ground on the Transmatch, although it isn't absolutely necessary. And that brings up another point—grounds.

Grounds

Many amateurs mistakenly believe that if they use a beam, they should have a good ground at the base of the tower because they feel this will influence their signal. I have known amateurs who run out hun-



Here is another view of K4TTO's antenna. He employed a U100 lightweight rotor to turn the antenna. He also used Penetrox on all connections.

dreds of radials just to get such a ground. The only thing that such a ground might do is to help establish the impedance of the beam, because height above ground has a lot to do with determining the antenna impedance. However, as to actual signal radiation, such a ground at the base of a tower will have little effect on a horizontally polarized antenna.

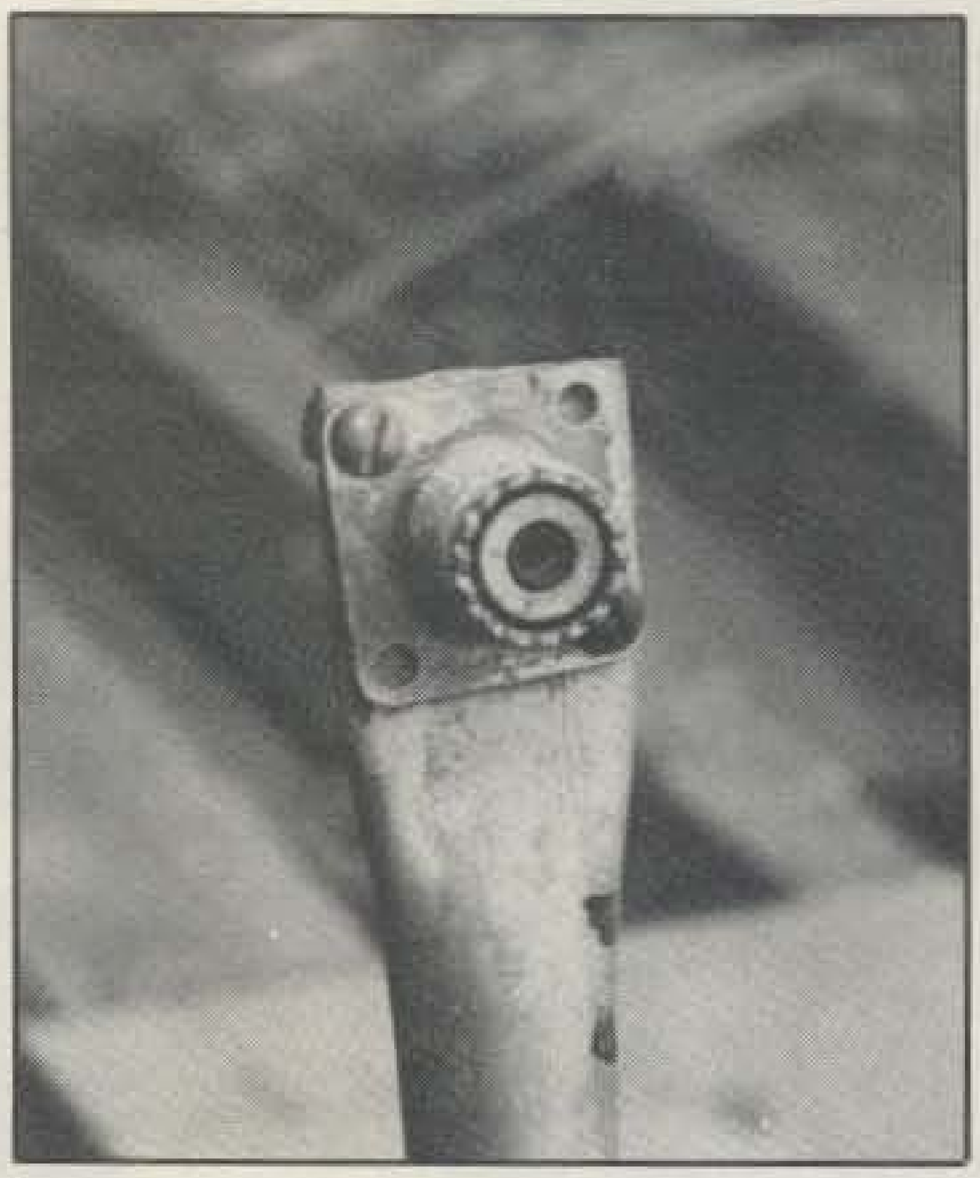
For example, let's assume the major vertical lobe from your beam is 20 degrees. There are actually two of these "major" lobes coming from the beam—one above the plane of the beam and one below. The upper beam goes on up into the ionosphere without any ground effect on it to speak of. Let's assume your beam is 60 feet above ground. The lower 20-degree angle travels out a considerable distance from the tower before it strikes the earth. Where it strikes the earth, and the condition of that earth, is what is important, because the signal is reflected back up from the earth to join the upper-angle signal.

There are many other factors involved here, including the ground loss, phase of the two signals, etc. However, what is important is that we really have no control over the earth conditions, because they are so distant from the antenna. This is why I consider extensive grounds immediately below the antenna of little concern.

Grounding Equipment And Lightning

It is always recommended that we have a good earth ground for our equipment. There are a couple of points you should be aware of here.

We run our equipment off the electric mains. Where the power company installs the electricity entrance they usually install a ground. Keep in mind that good old Mother Earth is always our reference for electricity. Let's for a moment, and forgive me for trying to oversimplify this, assume that we have a house that is 60 feet long—not an unusual situation. Let's also assume that our electric entrance is at the opposite end of the house from our station. Suppose we put a ground rod



I dug this out of my old scrap pile and photographed it to show how the SO-239 fitting is mounted on the end of the element. (But don't be sloppy like me; use four nuts and bolts on the fitting.)

down just outside the station and ground all our equipment. This ground establishes the value of the AC voltage entering the house. The ground from our AC entrance is carried to the outlet by the radio equipment. To ground the equipment, many of us install a ground rod at the station. There may be a difference in the earth's resistance between the entrance ground and the station ground, meaning a voltage difference, enough so that we may get "bites" off our equipment.

I am always being asked how to protect equipment from lightning strikes. There are devices available which will help in protecting against minor nearby strikes. Even though a storm may be miles away, your antenna can pick up enough energy to damage solid-state equipment. That's why things such as coaxial in-line arresters are a good idea. However, there is no real protection for direct strikes. I would recommend a large master switch that would disconnect all antennas and feeders from the equipment and lines connected to earth ground. Also, it is smart to disconnect the equipment from the AC mains if you plan on being away for any length of time. Of course, if you are selling your spouse or parents on letting you put up a tower, you might point out that a well-grounded tower will offer a zone of protection for your home—hi!

Conclusions: Transmatches

Should you always use a Transmatch? Well, the answer should be apparent. If your rig doesn't like the load, you need a Transmatch. Do I use one? Always! Even though I use a beam that has a low SWR, I still feed it through a Transmatch. In fact, nothing comes out of my transmitter that doesn't go through the Transmatch. My reasoning is quite simple. The transmitter (and receiver) of my transceiver was designed for 50 ohm input on all bands, all frequencies. The simplest method of meeting this *required* condition is to always use a Transmatch. Therefore, I do.

In addition, the Transmatch offers a certain degree of selectivity in that it can improve reception simply by the fact that it puts another tuned circuit in series with the receiver (transceiver). Many amateurs who live near an AM broadcast station are bothered by interference from the BC station, particularly on 160 and 80 meters. A Transmatch will go far in eliminating this problem.

It is obvious from this series that a 1 to 1 load is a very desired condition. The only real way to ensure this condition on all bands and all frequencies is to use a Transmatch.

More Conclusions

This material is designed to make you a more astute antenna, or antenna system, user. It is well nigh impossible to tell someone what to use or what to buy. My advice here is to seek help from other more experienced amateurs. For one thing, you must set goals for yourself. Do you want to be a DXer? Maybe you would prefer aiming at contest work, or possibly handling traffic. Or like many amateurs, perhaps you would prefer to just work them as they come.

Join a radio club and ask questions. Amateurs are great people for volunteering information whether it is correct or not! And most important, I would suggest obtaining the *CQ Antenna Buyer's Guide.* There is a wealth of information available in the book. Be sure to write to the suppliers listed in this book, as much valuable information can be obtained from their literature.

Please don't write to me asking me to design your antenna system. At 75-plus, I am getting far too old for the time involved. Now isn't that a heckuva way to end an article? CQ