Why A Beam Antenna?

Some Basic Antenna Information for the Newcomer

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A NOVICE doesn't have to operate on 15 meters very long before he gets a yen for an antenna that will give more push to his signal. This article treats the design and construction of rotatable antennas, from a simple one to a four-element beam. The latter should appeal to the most seasoned operators.

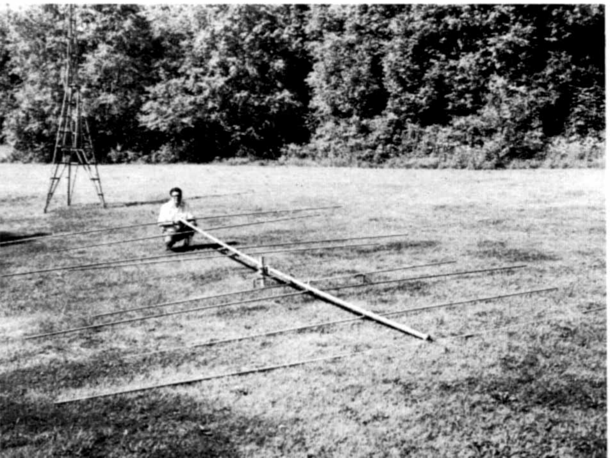
Beam Antennas

Before getting into construction details, let's talk a little about beam antennas so the newcomer will have a better idea of how they work. You won't be in ham radio very long before you hear hams talking about *gain,* or *power gain* from an antenna. Let's make one point clear at the beginning. An antenna is *never* a power amplifier. Some amateurs believe that an antenna can amplify their signal. This is an incorrect assumption. What a beam antenna does is to take our signal and guide it, so that we have more power going in one direction than in another. The more we concentrate our rf energy in one direction, the more gain we have in that direction.

Gain figures are usually expressed in *decibels* (dB). You'll hear a lot about decibels in ham radio, so a short explanation is in order. A decibel is not a unit of power but rather a *ratio* of power levels. One decibel usually refers to a just-noticeable increase in signal strength. If the power were increased by five dB, for example, it means that there have been five just-noticeable increases in signal strength. *Doubling* your power would cause an increase of 3 dB, and *four* times the power would be 6 dB.[1]

* Novice Editor

1 For a power increase of 1.9953 the increase in gain equals 3 dB.



In amateur work, antenna gain is usually rated in dB. Naturally, the next question would be, "Antenna gain over what?" Most amateurs use a half-wavelength dipole as a standard of reference. In theory the dipole has a radiation pattern like a figure 8 with two major lobes of radiation, each with equal signal strength. If we set up a dipole and a test antenna, and then measure the difference in signal strength between the two, we can make relative measurement of the gain or loss of the test antenna against the reference dipole. These gain or loss figures are rated in dB.

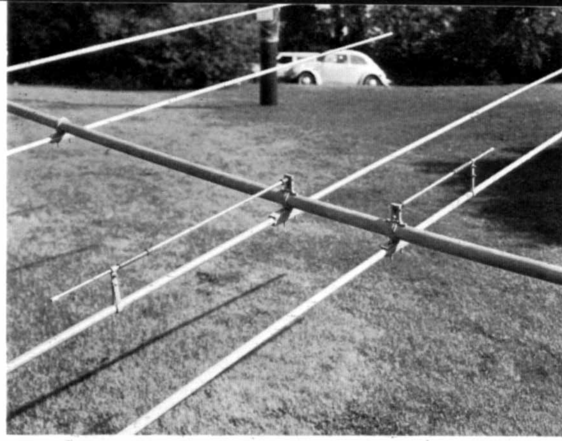
You'll also see gain figures on antennas referenced against an *isotropic source.*[2] It is impossible to make an isotropic "antenna" but such a reference is used in relating antenna gains. The reason this is mentioned here is because a half-wave dipole has a gain of 2.14 dB over the theoretical isotropic radiator. This is why some antenna manufacturers like to show gain figures over an isotropic radiator rather than a dipole. It gives them bigger gain claims in their advertising copy!

Yagi Antennas

The most popular beam antenna used by hams is called a Yagi (after one of its inventors). The Yagi consists of a driven element (a half-wavelength dipole) plus "parasitic" elements. The reason we call them parasitic elements is because power is supplied to only the driven element, directly. These parasitic elements are usually longer (reflectors), or shorter (directors) than the driven element. It is customary to use a single reflector and one or more directors. The common three-element beam consists of a reflector, driven element, and director. Depending on the spacing and lengths of the elements and the tuning of the array, the gain of a three-element beam should be approximately 7 dB over that of a half-wavelength dipole. In other words, if you had a reference dipole aligned so that it radiates best in the same direction as the beam, the beamed signal will be 7 dB stronger in its favored direction.

2 An isotropic antenna would have the ability to send out equal amounts of energy in *all* directions.

Ready for erection, this is the completed dual-band beam.



These are the 15- and 10-meter gamma-matching sections. These matching units, and the boom-to-element U-bolt assemblies are manufactured by Kirk Electronics.

Because the beam concentrates the rf energy, it offers another advantage over a dipole: most of the signal will be going in one direction from the beam – off the front. This means that there will be a signal minimum off the back; thus the beam has a *front-to-back* ratio. Depending on the tuning of the array, the front-to-back ratio of a three-element beam can be as great as 30 dB. This can really help in rejecting undesired received signals. Likewise, a beam antenna can have front-to-side rejection on the order of 40 to 50 dB. One can quickly see the advantage of using a beam antenna.

A Rotatable Dipole

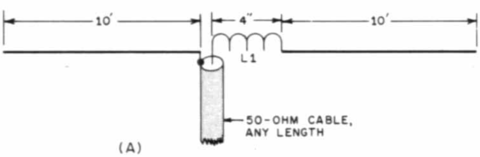
The simplest method of taking advantage of an antenna's directive characteristics is to rotate it. The simplest antenna for this purpose is a rotatable dipole. Shown in Fig. 1 is a 15-meter rotatable antenna that can be made from easily available materials. This antenna will provide a good match to 50-ohm coaxial cable, and without complicated matching networks.

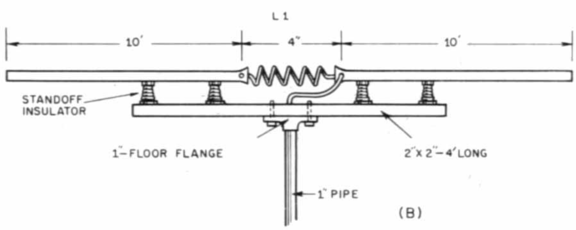
The dipole is made from two 10-foot lengths of electrician's thin-wall steel tubing. Aluminum tubing could be used but practically any electrical supply house has thin-wall tubing in stock, and the two lengths should cost only a few dollars. The correct length for a full-size 21.15-MHz dipole is about 22 feet. Twenty feet of material is slightly short, so the additional length is made up with a small coil mounted at the center of the dipole. The electrical circuit for the antenna is shown at Fig. 1A. The coil is made from 1/8-inch-diameter copper tubing and consists of 5 turns, one inch in diameter with 1/4-inch spacing between turns. The ends of the tubing at the center of the antenna should be flattened with a hammer or in a vise. A coax fitting, chassis type SO-239, is installed as shown in Fig. 1 at C. The coil, L1, is connected between the inner pin of the coax fitting and the other half of the element. Four standoff insulators are mounted on a four-foot length of 2 × 2 wood to support the completed dipole. A one-inch floor-mount pipe flange can be installed on the 2 × 2, and the antenna mast can be a length of one-inch pipe screwed into it. This antenna is light enough to be turned by a TV rotator, or the mast can be mounted near the shack window with TV hardware and rotated via the "Armstrong method."

A 2-, 3-, or 4-Element Beam

The "one-element" beam just described will have no front-to-back ratio because a dipole radiates equally well in two directions. It *will* have useful front-to-side characteristics but if gain is desired, additional elements will be required. Depending on how ambitious the amateur is (and how healthy his pocketbook is), the 4-element beam shown in the photographs may be constructed to provide a high-performance directive array.

With four elements, this antenna will provide approximately 10 dB of gain – which can be likened to increasing your power by 10 times! However, you don't have to employ four elements. A two-element beam with a driven element and a reflector will provide about 5 dB gain and 10 to 15 dB front-to-back ratio. It seems that the majority of hams prefer a three-element array (director, driven element, and reflector). So, depending on space availability and your pocketbook, you can take your choice.





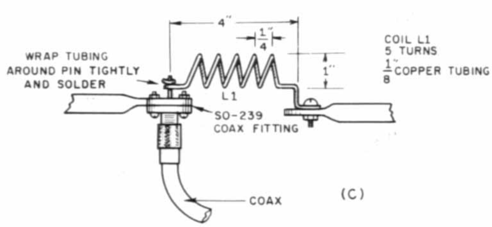
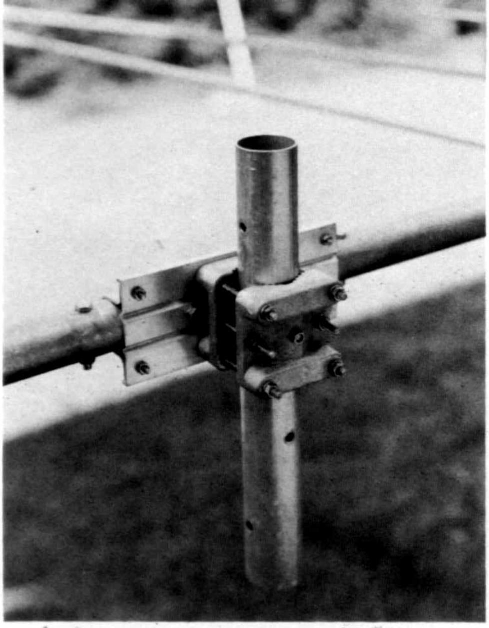


Fig. 1 – At A is the electrical circuit of the one-element rotary antenna, and at B, the construction details. Details for making L1 are shown at C.



This is the boom-to-mast fixture that holds the two 12-foot boom sections together. The unit is made by Hy-Gain Electronics.

Construction Information

Shown in Fig. 1 are the element lengths and spacings. Whatever you decide on – 2, 3, or 4 elements – the same spacing and lengths can be used. For example, a 2-element beam, driven element, and reflector, would have a boom length of 8 feet, and the driven element would be 22 feet, 4 inches long. The reflector would be 23 feet, 6 inches in length. When you get your General Class or higher license you may want to add another band. In the antenna shown here, we actually have made a two-band beam, four elements on 15 and four on 10.

The array is constructed with 6061-T6 aluminum tubing. This material is available from metal dealers; check your Yellow Pages for the nearest supplier. The standard tubing length is 12 feet. This means that telescoping sections have to be used to obtain the required lengths. The 15-meter elements use 1-inch OD sections for the center portions of the elements. The wall thickness is .058 inch. This is an important point to keep in mind if you are to build antennas. If you use .058-inch wall-thickness material, the *next* lower standard size will telescope into it. In this case it would be 7/8-inch OD tubing. For example, the 1-inch stock has an ID of .884 inch, so 7/8-inch tubing (0.875 inch OD) will slide very nicely into the 1-inch OD size. The ends of the larger tubing can be slit with a hacksaw and then compression hose clamps can be used to tighten the connection.

In the antenna shown, the boom has an OD of 2 inches. The boom material also comes in 12-foot lengths so they must be joined together for this antenna. The next smaller size tubing could be used as a joint, but we elected to use a commercial boom-to-mast mounting[3] that serves the dual purpose of joining the sections and as a mast attachment. In addition, with this fixture the beam can be tilted to provide access to the elements after the antenna is installed on the tower.

For 15 meters, each element is made from two lengths of tubing, a 12-foot length of the 1-inch OD (.058 wall), and one 12-foot length of 7/8-inch OD, .035 wall. The 7/8-inch stock is cut into two equal lengths, and these sections are used to telescope into the larger tubing. The ends of the 1-inch OD stock are slit with a hacksaw, about a one-inch cut, and garden hose compression clamps are slid over the slit portion and tightened.

If it is desired to add the 10-meter beam, the elements can be made from 3/4-inch OD, .058-inch wall for the center sections. The telescoping portions are made from 5/8-inch OD stock, .028-inch wall thickness. Only two 12-foot lengths of this material are required for the four-element beam. Each length is cut into four 3-foot pieces and these are used for telescoping sections.

The driven elements of the beams are fed with 50-ohm coaxial cable. A matching network is required on each driven element to match the antenna impedance to that of the coax cable. The matching sections shown in the photograph are called *gamma matches*. These shown are a commercial type, manufactured by Kirk Electronics.[4] Also, the element-to-boom U-bolt assemblies are Kirk products. However, automobile muffler clamps can also be used to support the elements.

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[3] Hy-Gain Electronics Corp., P.O. Box 5407-HK, Lincoln, NE 68505.

[4] Kirk Electronics, 6151 Dayton-Liberty Road, Dayton, OH 45418.

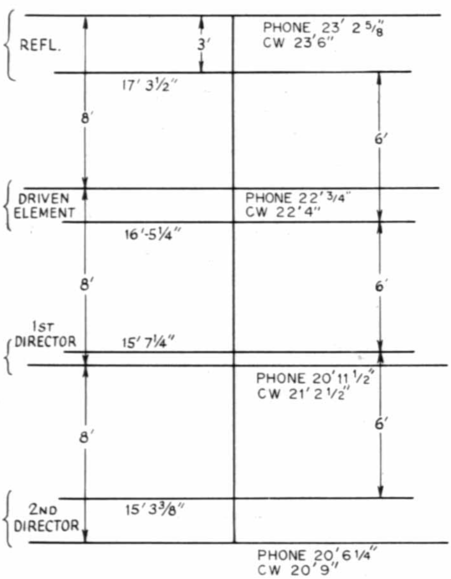

Fig. 2 – Element lengths and spacing information for the 15- and 10-meter beams.

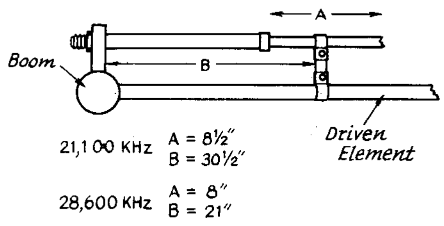

Fig. 3 — Dimensions for the gamma-matching system.

Adustments

The only tuning adjustment for the beam is setting the gamma match. Ideally, the gamma adjustments should be made with the antenna mounted in its permanent location. However, this can be difficult because in many cases it may be impossible to reach the gamma match when the antenna is installed on a tower. Fortunately, there is a simple method of making the adjustments while the antenna is on the ground.

The antenna should first be mounted in a vertical position with the reflector element resting on earth. In other words, the beam would be pointed straight up. The beam can be guyed temporarily with clothesline while making the adjustments. Under this setup, the driven element will only be eight feet above ground and will be easy to reach from a stepladder.

Connect a short length of 50-ohm coax to the feed point on the beam and then insert an SWR bridge between the short length and the transmission line running to the transmitter. Next, set the gamma adjustments to the dimensions shown in Fig. 3. These figures probably won't be the final settings but will provide a starting point. Turn on the transmitter and feed enough power to the beam to obtain a reading on the SWR indicator. Switch the indicator to read reflected power and adjust the gamma section until a reading of zero reflected power is obtained. This indicates a standing wave ratio of 1 – a matched condition for the system. The beam can then be mounted in its permanent location. There may be a slight change in the SWR, and if so, the gamma section can be "tweaked" to get a perfect match. The beam shown was installed on a 60-foot tower after being matched on the ground. The SWR with the beam on the tower was only 1.2:1 so we didn't bother to make any further adjustments.

Some readers may be concerned about the element lengths and tuning of the beam. If you can reach the reflector and directors you'll probably have the urge to tune the antenna for more gain or greater front-to-back ratio. It *may* be worthwhile with very close-spaced arrays where the elements only have one-tenth wavelength separation. However, with wide spacing (such as used in this array) tuning the elements just isn't worth the time and effort. Countless experiments have shown that any difference in gain between an antenna cut to the formula lengths, and one that is tuned, is practically unmeasureable.

Antenna Height

While we don't want to get into a long discussion about angles of radiation from antennas, a word or two about the height above ground for a beam is important. Usually, what the amateur desires from his beam antenna is the lowest possible angle of radiation. The lower the angle, the less the absorption of the signal in the ionosphere. One can get into a lot of arguments about what is the *best* height for a beam so it is difficult to generalize. The vertical angle of radiation from a horizontal antenna is primarily dependent on its height above ground. In general, the ham should try to get his beam at least a wavelength above earth for good performance. On 15 meters this amounts to about 40 feet high. The absolute minimum height for a beam that a ham should try for should be no less than a half-wavelength above ground.

Assuming the Novice operator is running 75-watts input with about 65 percent efficiency, his output power would be on the order of 50 watts. The 4-element array described here has a gain of approximately 10 dB. This means a gain of ten times, so the 50-watt signal is increased by that ratio. It doesn't take much figuring to realize that beam antennas are worthwhile devices. QST

Strays

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. . . Vietnam veterans interested in a net on 3975 kHz. WA1ECY.
. . . hams who keep or are interested in keeping salt-water aquariums. KP4BPH.
. . . French students to converse in French on 15 meters. WA2ORF.
. . . others interested in visions and apparitions. W8HUY.
. . . amateurs associated with Mercedes-Benz sales or service. W1FDA.
. . . anyone interested in a 10-meter teenager net. WN3NUD.
. . . anyone with information about a "talking clock" for use by the blind. ZE1BP.
. . . stockbroker hams to discuss the stock market. W3AXR.
. . . teenagers interested in a 3925 kHz daily net. WB8GBY.
. . . hams interested in the cultivation of orchids. 4S7NG.
. . . former members of the International One Sixty Society. W4WFL.
. . . prospective members for the Eastern Area Slow Net. WA3JSU.
. . . amateurs interested in a school teachers net. WA3PEI.
. . . Wisconsin Novices who would like to start a net. WB9FBG.
. . . amateurs who are stamp dealers. W9CI.
. . . chiropractic amateurs who are alumni of NWCC. WAØOJJ.
. . . Novices in Illinois interested in forming a 15-meter net. WN9FGB.
. . . other hams who are falconers. WA9AXL.
. . . anyone interested in playing chess over the air. WA8CAU.
. . . amateurs interested in telemetry. K9GED.