

# Antenna Supports

A prime consideration in the selection of a support for an antenna is that of structural safety. Building regulations in many localities require that a permit be obtained in advance of the erection of certain structures, often including antenna poles or towers. In general, localities having such requirements also have building safety codes that must be observed. Such regulations may govern the method and materials used in construction of, for example, a self-supporting tower. Checking with your local government building department before putting up a tower may save a good deal of difficulty later, because a tower would have to be taken down or modified if not approved by the building inspector on safety grounds.

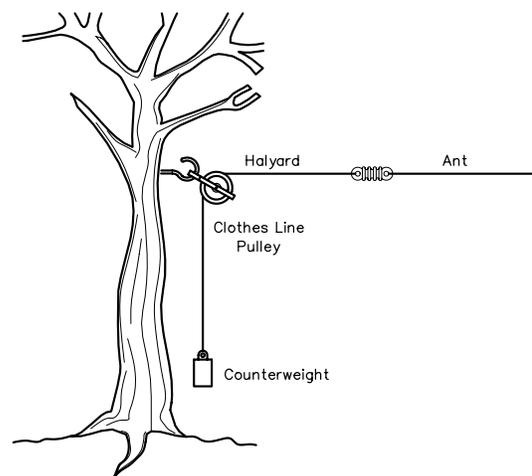
Municipalities have the right and duty to enforce any reasonable regulations having to do with the safety of life or property. The courts generally have recognized, however, that municipal authority does not extend to aesthetic questions. The fact that someone may object to the mere presence of a pole, tower or other antenna structure because in his opinion it detracts from the beauty of the neighborhood, is not grounds for refusing to issue a permit for a safe structure to be erected. Since the introduction of PRB-1 (federal preemption of unnecessarily restrictive antenna ordinances), this principle has been borne out in many courts. Permission for erecting amateur towers is more easily obtained than in the recent past because of this legislation.

Even where local regulations do not exist or are not enforced, the amateur should be careful to select a location and a type of support that contribute as much safety as possible to the installation. If collapse occurs, the chances of personal injury or property damage should be minimized by careful choice of design and erection methods. A single injury can be far more costly than the price of a more rugged support, in terms of both monetary loss and damage to the respect with which Amateur Radio is viewed by the public.

### TREES AS ANTENNA SUPPORTS

From the beginning of Amateur Radio, trees have been used widely for supporting wire antennas. Trees cost nothing to use, and often provide a means of supporting a wire antenna at considerable height. As antenna supports, trees are unstable in the presence of wind, except in the case of very large trees used to support antennas well down from the top branches. As a result, tree supported antennas must be constructed much more sturdily than is necessary with stable supports. Even with rugged construction, it is unlikely that an antenna suspended from a tree, or between trees, will stand up indefinitely. Occasional repair or replacement usually must be expected.

There are two general methods of securing a pulley to a tree. If the tree can be climbed safely to the desired level, a pulley can be attached to the trunk of the tree, as shown in **Fig 1**. To clear the branches of the tree, the antenna end of the halyard can be tied temporarily to the tree at the pulley level. Then



**Fig 1**—A method of counterweighting to minimize antenna movement and avoid its breaking from tree movement in the wind. The antenna may be lowered without climbing the tree by removing the counterweight and tying additional rope at the bottom end of the halyard. Excess rope may be left at the counterweight for this purpose, as the knot at the lower end of the halyard will not pass through the pulley.

the remainder of the halyard is coiled up, and the coil thrown out horizontally from this level, in the direction in which the antenna runs. It may help to have the antenna end of the halyard weighted.

After attaching the antenna to the halyard, the other end is untied from the tree, passed through the pulley, and brought to ground along the tree trunk in as straight a line as possible. The halyard need only be long enough to reach the ground after the antenna has been hauled up. (Additional rope can be tied to the halyard when it becomes necessary to lower the antenna.)

The other method consists of passing a line over the tree from ground level, and using this line to haul a pulley up into the tree and hold it there. Several ingenious methods have been used to accomplish this. The simplest method employs a weighted pilot line, such as fishing line or mason's chalk line. By grasping the line about two feet from the weight, the weight is swung back and forth, pendulum style, and then heaved with an underhand motion in the direction of the tree top.

Several trials may be necessary to determine the optimum size of the weight for the line selected, the distance between the weight and the hand before throwing, and the point in the arc of the swing where the line released. The weight, however, must be sufficiently large to carry the pilot line back to ground after passing over the tree. Flipping the end of the line up and down so as to put a traveling wave on the line often helps to induce the weight to drop down if the weight is marginal. The higher the tree, the lighter the weight and the pilot line must be. A glove should be worn on the throwing hand, because a line running swiftly through the bare hand can cause a severe burn.

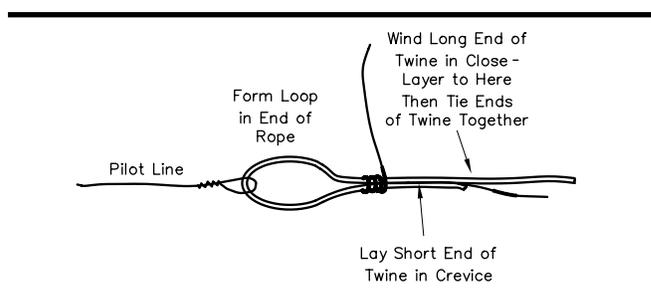
If there is a clear line of sight between ground and a particularly desirable crotch in the tree, it may eventually be possible to hit the crotch after a sufficient number of tries. Otherwise, it is best to try to heave the pilot line completely over the tree, as close to the center line of the tree as possible. If it is necessary to retrieve the line and start over again, the line should be drawn back very slowly; otherwise the swinging weight may wrap the line around a small limb, making retrieval impossible.

Stretching the line out straight on the ground before throwing may help to keep the line from snarling, but it places extra drag on the line, and the line may snag on obstructions overhanging the line when it is thrown. Another method is to make a stationary reel by driving eight nails, arranged in a circle, through a 1-inch board. After winding the line around the circle formed by the nails, the line should reel off readily when the weighted end of the line is thrown. The board should be tilted at approximately right angles to the path of the throw.

Other devices that have been used successfully to pass a pilot line over a tree are the bow and arrow with heavy thread tied to the arrow, and the short casting rod and spinning reel used by fishermen. The Wrist Rocket slingshot made from surgical rubber tubing and a metal frame has proved highly effective as an antenna launching device. Still another method that has been used where sufficient space is available is flying a kite to sufficient altitude, walking around the tree until the kite string lines up with the center of the tree, and paying out string until the kite falls to the earth. This method can be used to pass a line over a patch of woods between two higher supports, which may be impossible using any other method.

The pilot line can be used to pull successively heavier lines over the tree until one of adequate size to take the strain of the antenna has been reached. This line is then used to haul a pulley up into the tree after the antenna halyard has been threaded through the pulley. The line that holds the pulley must be capable of withstanding considerable chafing where it passes through the crotch, and at points where lower branches may rub against the standing part. For this reason, it may be advisable to use galvanized sash cord or stranded guy wire for raising the pulley.

Larger lines or cables require special attention when they must be spliced to smaller lines. A splice that minimizes the chances of coming undone when coaxed through the tree crotch must be used. One type of splice is shown in **Fig 2**.



**Fig 2—In connecting the halyard to the pilot line, a large knot that might snag in the crotch of a tree should be avoided, as shown.**

The crotch in which the line first comes to rest may not be sufficiently strong to stand up under the tension of the antenna. If, however, the line has been passed over (or close to) the center line of the tree, it will usually break through the lighter crotches and come to rest in a stronger one lower in the tree.

Needless to say, any of the suggested methods should be used with due respect to persons or property in the immediate vicinity. A child's sponge-rubber ball (baseball size) makes a safe weight for heaving a heavy thread line or fishing line.

If the antenna wire snags in the lower branches of the tree when the wire is pulled up, or if other trees interfere with raising the antenna, a weighted line thrown over the antenna and slid to the appropriate point is often helpful in pulling the antenna wire to one side to clear the interference as the antenna is being raised. This is shown in **Fig 3**.

### Wind Compensation

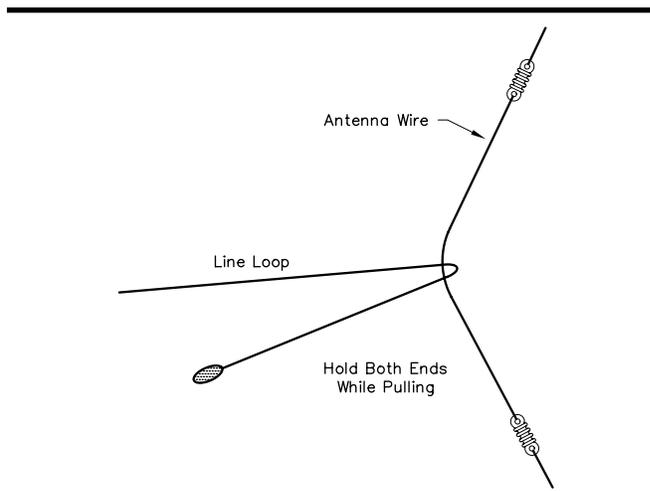
The movement of an antenna suspended between supports that are not stable in the wind can be reduced by the use of heavy springs, such as screen-door springs under tension, or by a counterweight at the end of one halyard. This is shown in **Fig 1**. The weight, which may be made up of junk-yard metal, window sash weights, or a galvanized pail filled with sand or stone, should be adjusted experimentally for best results under existing conditions. **Fig 4** shows a convenient way of fastening the counterweight to the halyard. It eliminates the necessity for untying a knot in the halyard which may have hardened under tension and exposure to the weather.

### TREES AS SUPPORTS FOR VERTICAL WIRE ANTENNAS

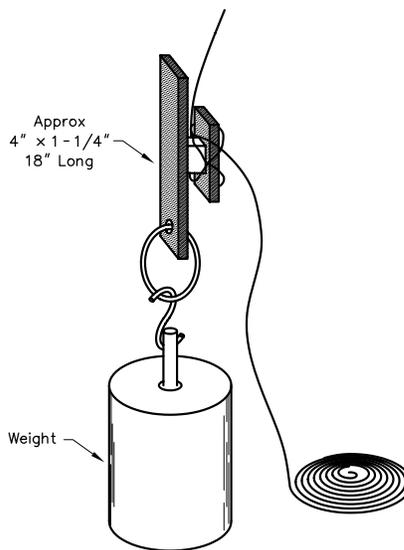
Trees can often be used to support vertical as well as horizontal antennas. If the tree is tall and has overhanging branches, the scheme of **Fig 5** may be used. The top end of the antenna is secured to a halyard passed over the limb, brought back to ground level, and fastened to the trunk of the tree.

### MAST MATERIALS

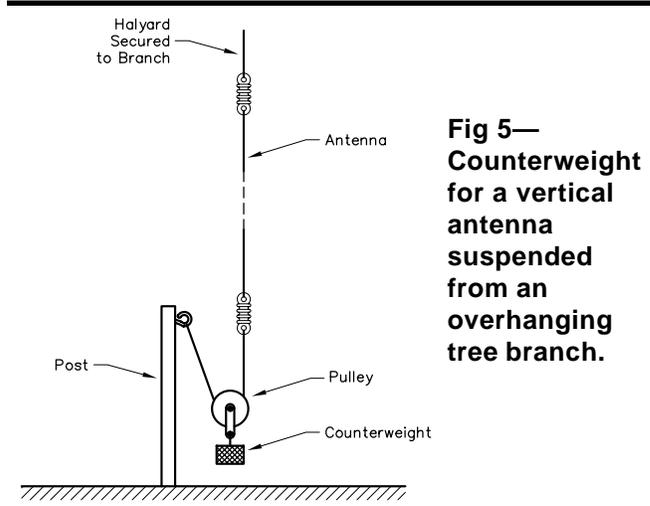
Where suitable trees are not available, or a more stable support is desired, masts are suitable for wire antennas of reasonable span length. At one time, most amateur masts were constructed



**Fig 3**—A weighted line thrown over the antenna can be used to pull the antenna to one side of over-hanging obstructions, such as tree branches, as the antenna is pulled up. When the obstruction has been cleared, the line can be removed by releasing one end.



**Fig 4**—The cleat eliminates the need to untie a knot that may be weather hardened.



**Fig 5**—Counterweight for a vertical antenna suspended from an overhanging tree branch.

of lumber, but the TV industry has brought out metal masts that are inexpensive and much more durable than wood. However, there are some applications where wood is necessary or desirable.

### A Ladder Mast

A temporary antenna support is sometimes needed for an antenna system for antenna testing, site selection, emergency exercises or Field Day. Ordinary aluminum extension ladders are ideal candidates for this service. They are strong, light, extendable, weatherproof and easily transported. Additionally, they are readily available and can be returned to normal use once the project is concluded. A ladder tower will support a lightweight triband beam and rotator.

With patience and ingenuity one person can erect this assembly. One of the biggest problems is holding the base down while “walking” the ladder to a vertical position. The ladder can be guyed with  $\frac{1}{4}$ -inch polypropylene rope. Rope guys are arranged in the standard fashion with three at each level. If help is available, the ladder can be walked up in its retracted position and extended after the antenna and rotator are attached. The lightweight pulley system on most extension ladders is not strong enough to lift the ladder extension. This mechanism must be replaced (or augmented) with a heavy-duty pulley and rope. Make sure when attaching the guy ropes that they do not foul the operation of the sliding upper section of the ladder.

There is one hazard in this system that must be avoided: Do not climb or stand on the ladder when it is being extended—even as much as one rung. *Never* stand on the ladder and attempt to raise or lower the upper section. Do all the extending and retracting with the heavy-duty rope and pulley.

If the ladder is to be raised by one person, use the following guidelines. First, make sure the rung-latching mechanism operates properly before beginning. The base must be hinged so that it does not slip along the ground during erection. The guy ropes should be tied and positioned in such a way that they serve as safety constraints in the event that control of the assembly is lost. Have available a device (such as another ladder) for supporting the ladder during rest periods. (See **Fig 6**.)

After the ladder is erect and the lower section guys tied and tightened, raise the upper portion one rung at a time. *Do not raise the upper section higher than it is designed to go*; safety is far more important than a few extra feet of height.

For a temporary installation, finding suitable guy anchors can be an exercise in creativity. Fence posts, trees, and heavy pipes are all possibilities. If nothing of sufficient strength is available, anchor posts or pipes can be driven into the soil. Sandy soil is the most difficult to work with because it does a very poor job of holding anchors. A discarded car axle can be driven into the ground as an anchor, if its mass and strength are substantial. A chain and car-bumper jack can be used to remove the axle when the operation is done.

Above all else, keep the tower and antenna away from power lines. Make sure that nothing can touch the lines if the assembly falls. Disassemble by reversing the process. Ladder towers are handy for “quickie” antenna supports, but as with any improvisation of support materials, care must be taken to ensure safe construction.

### The A-Frame Mast

A light and relatively inexpensive mast is shown in **Fig 7**. In lengths up to 40 feet it is very easy to erect and will stand the pull of ordinary wire antenna systems. The lumber used is  $2 \times 2$ -inch straight-grained pine (which many lumber yards know as hemlock) or even fir stock. The up-rights can be as long as 22 feet each (for a mast slightly over 40 feet high) and the cross pieces are cut to fit. Four pieces of  $2 \times 2$  lumber, each 22 feet



**Fig 6**—Walking the ladder up to its vertical position. Keith, VE2AQU, supports the mast with a second ladder while Chris, VE2FRJ, checks the ropes. (Photo by Keith Baker, VE2XL)

long, provides more than enough. The only other materials required are five 1/4-inch carriage bolts 5 1/2 inches long, a few spikes, about 300 feet of stranded or solid galvanized wire for guying, enough glazed porcelain compression (“egg”) insulators to break up the guys into sections, and the usual pulley and halyard rope. If the strain insulators are put in every 20 feet, approximately 15 of them will be enough.

After selecting and purchasing the lumber—which should be straight-grained and knot-free—sawhorses or boxes should be set up and the mast assembled as shown in Fig 8. At this stage it is wise to give the mast a coat of primer and a coat of outside white latex paint.

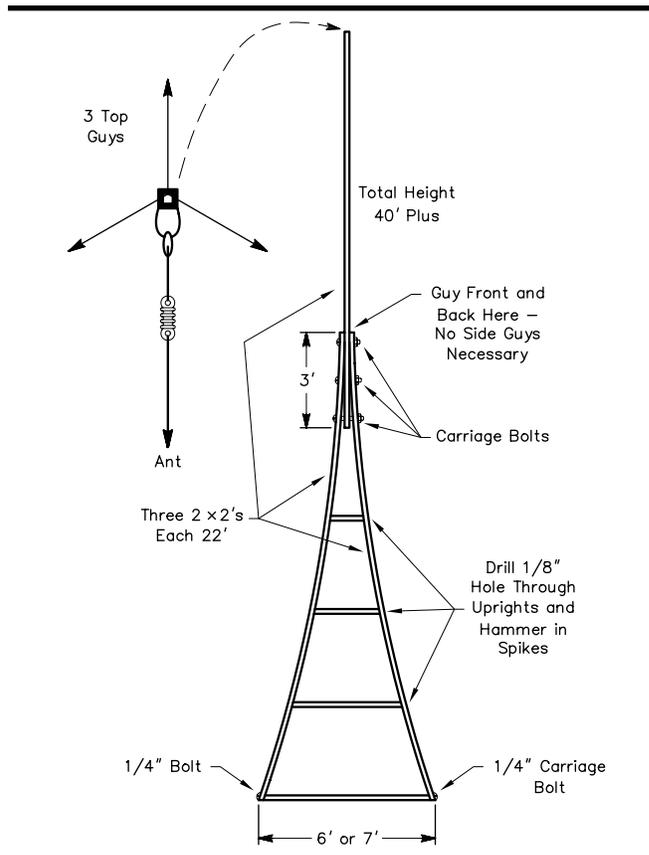
After the coat of paint is dry, attach the guys and rig the pulley for the antenna halyard. The pulley anchor should be at the point where the top stays are attached so the back stay will assume the greater part of the load tension. It is better to use wire wrapped around the mast with a small through-bolt to prevent sliding down than to use eye bolts.

If the mast is to stand on the ground, a couple of stakes should be driven to keep the bottom from slipping. At this point the mast may be “walked up” by a helper. If it is to go on a roof, first stand it up against the side of the building and then hoist it, from the roof, keeping it vertical. The whole assembly is light enough for two men to perform the complete operation—lifting the mast, carrying it to its permanent berth, and fastening the guys with the mast vertical all the while. It is therefore entirely practicable to put up this kind of mast on a small flat area of roof that would prohibit the erection of one that had to be raised to the vertical in its final location.

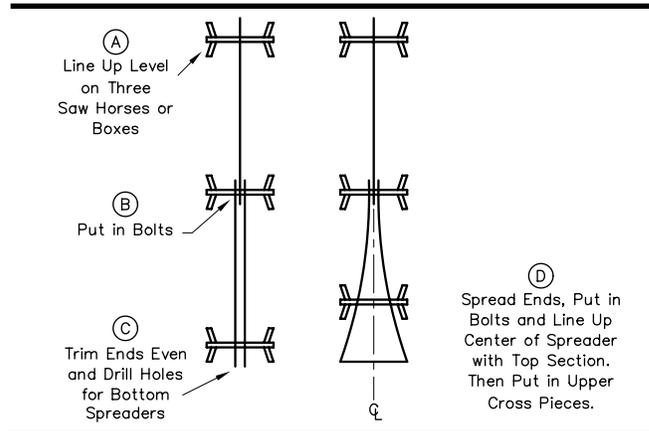
### TV Mast Material

TV mast is available in 5 and 10-foot lengths, 1 1/4 inches diameter, in both steel and aluminum. These sections are crimped at one end to permit sections to be joined together. A form that is usually more convenient is the telescoping mast available from many electronic supply houses. The masts may be obtained with three, four or five 10-foot sections, and come complete with guying rings and a means of locking the sections in place after they have been extended. These masts are stronger than the nontelelescoping type because the diameters of the sections increase toward the bottom of the mast. For instance, the top section of a 50-foot mast is 1 1/4 inches diameter, and the bottom section is 2 1/2 inches diameter.

Guy rings are provided at 10-foot intervals, but guys may not be required at every point. Guying is essential at the top and at least one other place near the center of the mast. If the mast has any tendency to whip in the wind, or to bow under the stress of the antenna, additional guys should be added at the appropriate points.



**Fig 7—The A-frame mast is lightweight and easily constructed and erected.**



**Fig 8—Method of assembling the A-frame mast on sawhorses.**

## MAST GUYING

Three guy wires in each set are usually adequate for a mast. These should be spaced equally around the mast. The required number of sets of guys depends on the height of the mast, its natural sturdiness, and the required antenna tension. A 30-foot mast usually requires two sets of guys, and a 50-foot mast needs at least three sets. One guy of the top set should be anchored to a point directly opposite the direction in which the antenna runs. The other two guys of the same set should be spaced  $120^\circ$  with respect to the first, as shown in Fig 7.

Generally, the top guys should be anchored at distances from the base of the mast of at least 60% of the mast height. At the 60% distance, the stress on the guy wire opposite the antenna is approximately twice the tension on the antenna. As the distance between the guy anchor and the base of the mast is decreased, the tension on the rear guy in proportion to the tension on the antenna rises rapidly. The extra tension results in additional compression on the mast, increasing the tendency for the mast to buckle.

Additional sets of guys serve to correct for any tendency that the mast may have to buckle under the compression imposed by the top guys. To eliminate possible mechanical resonance in the mast that might cause the mast to vibrate, the sets of guys should not be spaced equally on the mast. A second set of guys should be placed at approximately 60% of the distance between the ground and the top of the mast. A third set should be placed at about 60% of the distance between the ground and the second set of guys.

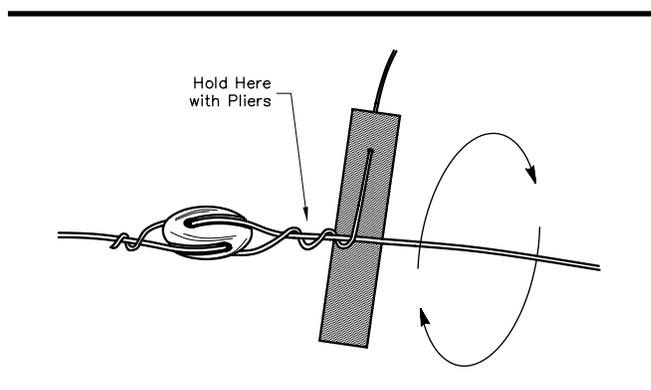
The additional set of guys should be anchored at distances from the base of the mast equal to at least 60% of the distance between the ground and the points of attachment on the mast. In practice, the same anchors are usually used for all sets of guys, automatically meeting this requirement if the top set has been anchored at the correct distance.

Electrical resonances that might cause distortion of the radiation pattern of the antenna can be eliminated by breaking each guy into nonresonant lengths by the insertion of strain insulators (see Figs 9 and 10). This subject is covered in detail later in this chapter.

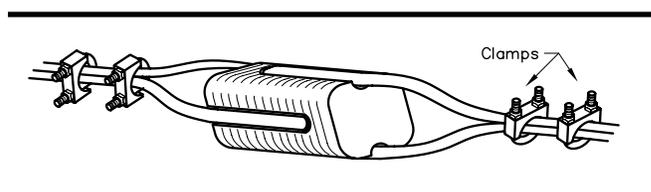
### Guy Material

Within their stress ratings, any of the hal-yard materials listed in Chapter 20 may be used for the construction of guys. Nonmetallic materials have the advantage that there is no need to break them up into sections to avoid resonances. All of these materials are subject to stretching, however, which causes mechanical problems in permanent installations. At rated working load tension, dry manila rope stretches about 5%, while nylon rope stretches about 20%.

Antenna wire is also suitable for guys, particularly the copper-clad steel types. Solid galvanized steel wire is also widely used for guying. This wire has approximately twice the tension ratings of similar sizes of copper-clad wire, but it is more susceptible to corrosion. Stranded galvanized wire sold for guying TV masts is also suitable for light-duty applications, but is also susceptible to corrosion.



**Fig 9—Simple lever for twisting solid guy wires when attaching strain insulators.**



**Fig 10—Stranded guy wire should be attached to strain insulators by means of standard cable clamps made to fit the size of wire used.**

## Guy Anchors

**Figs 11 and 12** show two different kinds of guy anchors. In Fig 11, one or more pipes are driven into the ground at right angles to the guy wire. If a single pipe proves to be inadequate, another pipe can be added in tandem, as shown. Steel fence posts may be used in the same manner. Fig 12 shows a “dead-man” type of anchor. The buried anchor may consist of one or more pipes 5 or 6 feet long, or scrap automobile parts, such as bumpers or wheels. The anchors should be buried 3 or 4 feet in the ground. Some tower manufacturers make heavy auger-type anchors that screw into the earth. These anchors are usually heavier than required for guying a mast, although they may be more convenient to install. Trees and buildings may also be used as guy anchors if they are located appropriately. Care should be exercised, however, to make sure that the tree is of adequate size, and that the fastening to a building can be made sufficiently secure.

### Guy Tension

Most troubles encountered in mast guying are a result of pulling the guy wires too tight. Guy-wire tension should never be more than necessary to correct for obvious bowing or movement under wind pressure. In most cases, the tension needed does not require the use of turnbuckles, with the possible exception of the guy opposite the antenna. If any great difficulty is experienced in eliminating bowing from the mast, the guy tension should be reduced.

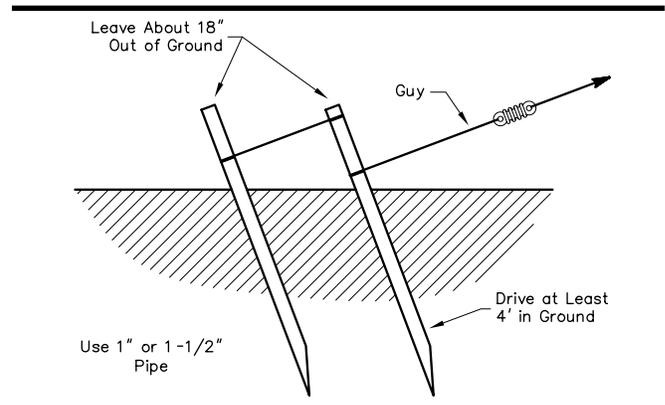
### ERECTING A MAST OR OTHER SUPPORT

Masts less than 30 feet high usually can be simply “walked” up after blocking the bottom end securely. Blocking must be done so that the base can neither slip along the ground or upend when the mast is raised. An assistant should be stationed at each guy wire, and may help by pulling the proper guy wire as the mast nears the vertical position. Halyards can be used in the same manner.

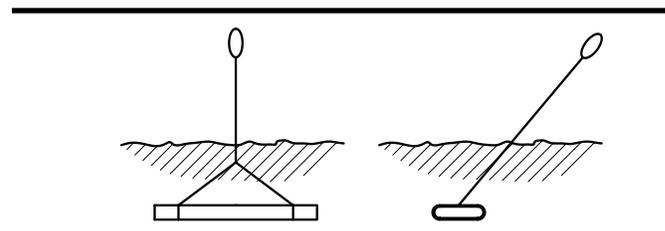
As the mast is raised, it may be helpful to follow the underside of the mast with a scissors rest (Fig 13), should a pause in the hoisting become necessary. The rest may also be used to assist in the raising, if each leg is manned by an assistant.

As the mast nears the vertical position, those holding the guy wires should be ready to temporarily fasten the guys to prevent the mast from falling. The guys can then be adjusted until the mast is perfectly straight.

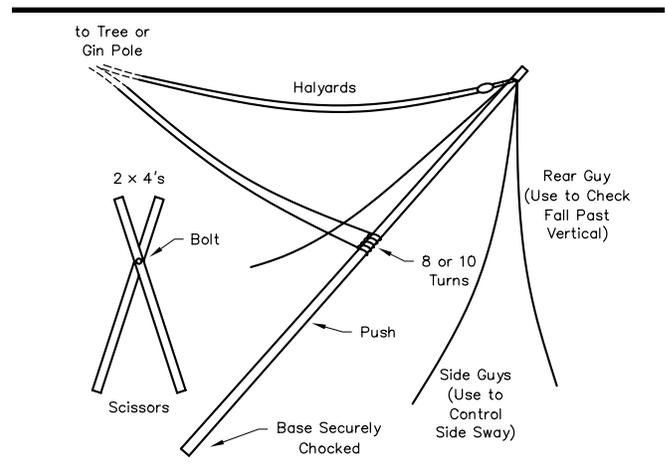
For masts over 30 feet long, a “gin” of some form may be required, as shown in Fig 13. Several turns of rope are wound around a point on the mast above center. The ends of the rope are then brought together and passed over a tree limb. The rope should



**Fig 11—Driven guy anchors. One pipe is usually sufficient for a small mast. For added strength, a second pipe may be added, as shown.**



**Fig 12—Buried “dead-man” guy anchor (see text).**



**Fig 13—Pulling on a gin line fastened slightly above the center point of the mast and on the halyards can assist in erecting a tall mast. The tensions should be just enough to keep the mast in as straight a line as possible. The “scissors” may be used to push on the under side and to serve as a rest if a pause in raising becomes necessary.**

be pulled as the mast is walked up to keep the mast from bending at the center. If a tree is not available, a post, such as a 2 × 4, temporarily erected and guyed, can be used. After the mast has been erected, the assisting rope can be removed by walking one end around the mast (inside the guy wires).

Telephone poles and towers are much sturdier supports. Such supports may require no guying, but they are not often used solely for the support of wire antennas because of their relatively high cost. For antenna heights in excess of 50 feet, however, they are usually the most practical form of support.

## Tower Selection and Installation

The selection of a tower, its height, and the type of antenna and rotator to be used may seem like a complicated matter, particularly for the newcomer. These aspects of an antenna system are interrelated, and one should consider the overall system before making any decisions as to a specific component. Perhaps the most important consideration for many amateurs is the effect of the antenna system on the surrounding environment. If plenty of space is available for a tower installation and there is little chance of the antenna causing aesthetic distress on the part of other family members or the neighbors, the amateur is indeed fortunate. The limitations in this case are mostly financial. For most, however, the size of the property, the effect of the system on others, local ordinances, and the proximity of power lines and poles influence the selection of antenna components considerably.

The amateur must consider the practical limitations for installation. Some points for consideration are given below:

- 1) A tower should not be installed in a position where it could fall onto a neighbor's property.
- 2) The antenna must be located in such a position that *it cannot possibly tangle with power lines, either during normal operation or if the structure fell.*
- 3) Sufficient yard space must be available to position a guyed tower properly. The guy anchors should be between 60% and 80% of the tower height in distance from the base of the tower.
- 4) Provisions must be made to keep children from climbing the support. (Poultry netting around the tower base will serve this need.)
- 5) Local ordinances should be checked to determine if any legal restrictions affect the proposed installation.

Other important considerations are (1) the total dollar amount to be invested, (2) the size and weight of the antenna desired, (3) the climate, and (4) the ability of the owner to climb a fixed tower.

The selection of a tower support usually is dictated more by circumstances than by desire. The most economical system, in terms of feet per dollar investment, is a guyed tower.

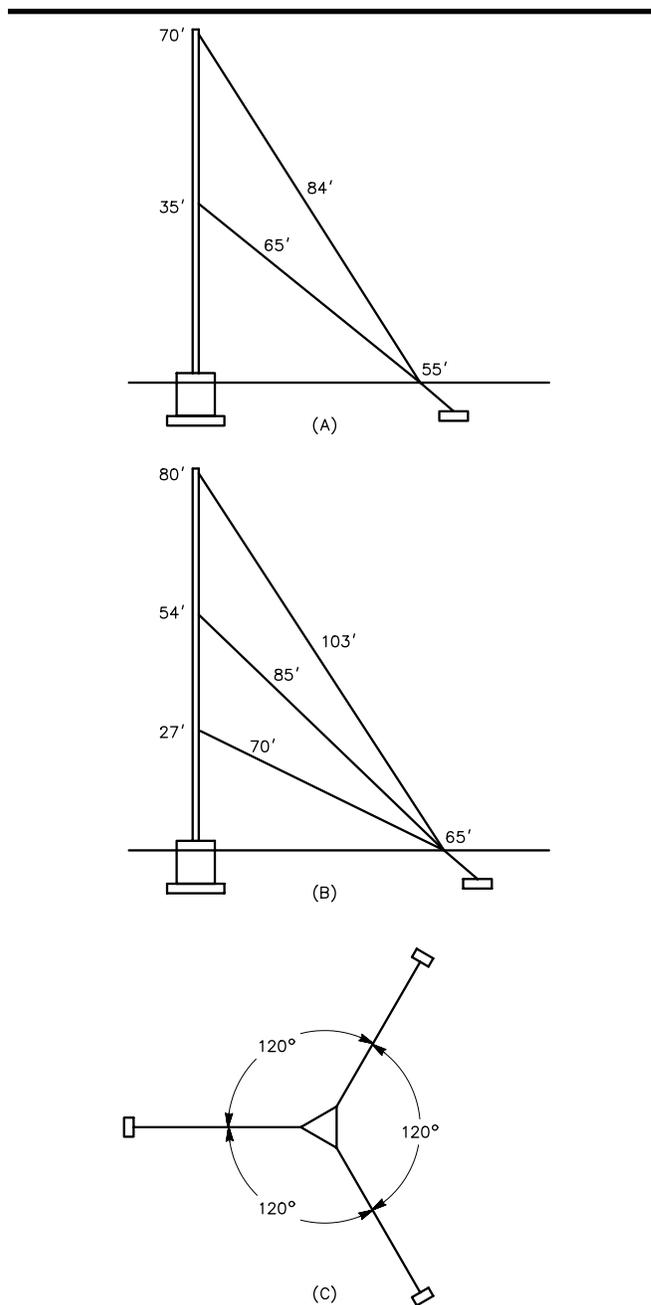


Fig 14—The proper method of installation of a guyed tower.

Once a decision has been tentatively made, the next step is to write to the manufacturer (several are listed in [Chapter 21](#)) and request specifications for the equipment that may be needed. Locate and mark guy anchor points to ensure that they fit on the available property. The specification sheet for the tower should give a wind-load capability; antennas can then be chosen based on the ratings of the structure.

It is often very helpful to the novice tower installer to visit other local amateurs who have installed towers. Look over their hardware and ask questions. If possible, have a few local experienced amateurs look over your plans—before you commit yourself. They may be able to offer a great deal of help. If someone in your area is planning to install a tower and antenna system, be sure to offer your assistance. There is no substitute for experience when it comes to tower work, and your experience there may prove invaluable to you later.

## THE TOWER

The most common variety of tower is the guyed tower made of stacked identical sections. The information in [Fig 14](#) is based on data taken from the Unarco-Rohn catalog. Rohn calls for a maximum vertical separation of 35 feet between sets of guy wires. At A, the tower is 70 feet high, and there are two sets of evenly spaced guy wires. At B, the tower is 80 feet high, and there are three sets of evenly spaced guy wires. Exceeding the vertical spacing requirements (under-guying) could result in the tower buckling.

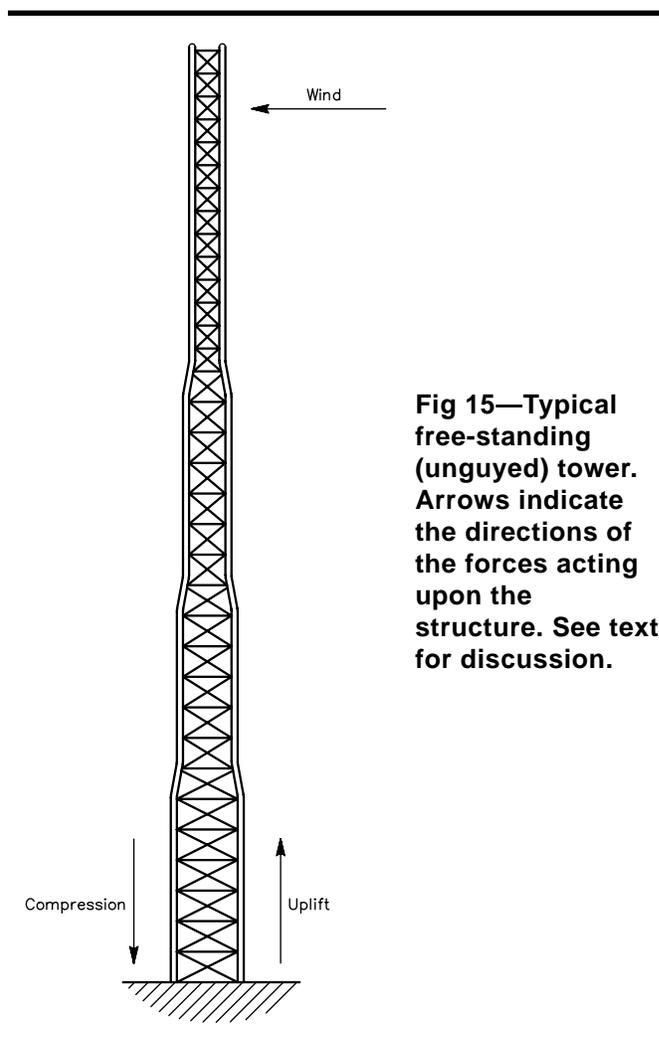
This may not seem to be a likely occurrence unless the function of guy wires is well understood. Guy wires restrain the tower against the force of the wind. They translate the lateral force of the wind into a downward compression that forces the tower down onto the base. Manufacturers usually specify the initial tension in the guy wires. This is another force that is translated into the downward compression on the tower. If there are not enough guys and if they are not properly spaced, a heavy gust of wind may over-stress the structure, causing the tower to buckle at a weak point.

An overhead view of a guyed tower is given in [Fig 14C](#). Manufacturers usually call for equal angular spacing between guy wires. If it is necessary to deviate from this spacing, the engineering staff of the tower manufacturer or a civil engineer should be contacted for advice.

### Unguyed Towers

Some towers are not normally guyed—these are usually referred to as free-standing or self-supporting towers. The principles involved are the same regardless of the term the manufacturers use to describe them. The wind blowing against the side of the tower creates an overturning movement that would topple the tower if it were not for the anchoring at the base. [Fig 15](#) details the action and reaction involved. The tower is restrained by the base. As the wind blows against one side of the tower, the opposite side is compressed downward much as in the guyed installation.

Because there are no guys to restrain the top, the side on which the wind is blowing is simultaneously pulled up (uplift). The force of the wind creates a moment that tends to pivot about a point at the base of the tower. The base of the guyed



**Fig 15—Typical free-standing (unguyed) tower. Arrows indicate the directions of the forces acting upon the structure. See text for discussion.**

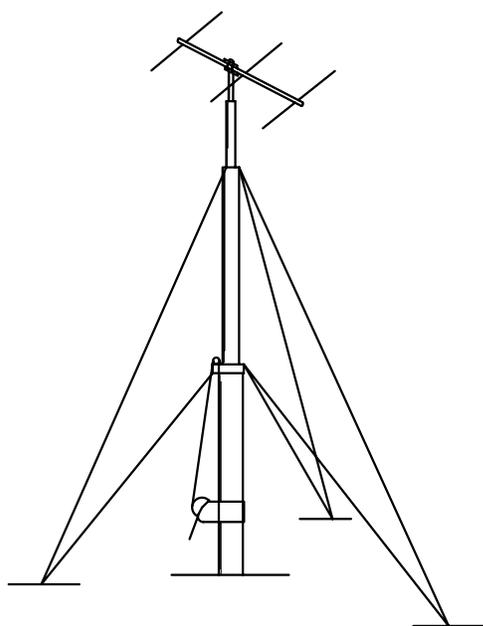
tower simply must hold the tower up, but the base of the free-standing tower must simultaneously hold one side of the tower up and the other side *down*! For this reason, manufacturers often call for a great deal more concrete in the base of free-standing towers than they do in the base of guyed towers.

**Fig 16** shows two variations of another popular type of tower, the crank-up. In regular guyed or free-standing towers, each section is bolted atop the next lower section. The height of the tower is the sum of the heights of the sections (minus any overlap). Crank-up towers use a different system. The outer diameter of each section is smaller than the inner diameter of the next lower section. Instead of

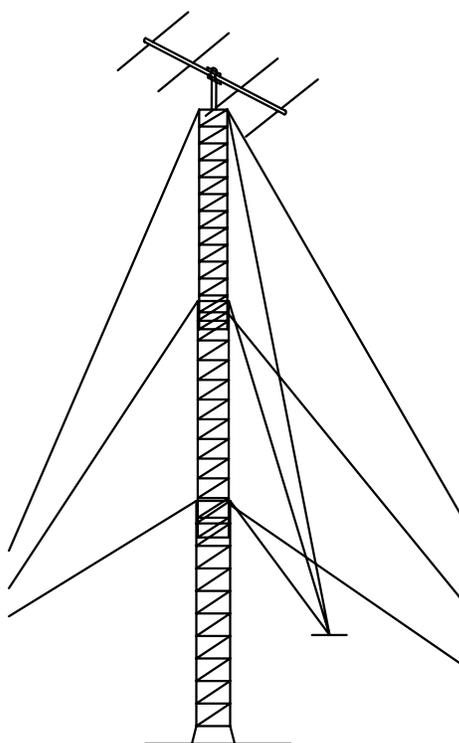
bolting together, the sections are attached with a set of cables and pulleys. The overall height of the tower is adjusted by using the pulleys and cables to “telescope” the sections together or apart.

Depending on the design, the manufacturer may or may not require guy wires. The primary advantage of the crank-up tower is that antenna work can be done near the ground. A second advantage is that the tower can be kept retracted except during use, which reduces the guying needs. (Presumably, the tower would not be extended during periods of high wind.) The disadvantages include mechanical complexity and (usually) cost. *NEVER* climb on an extended crank-up tower, even if it is extended only a small amount. Serious injury could result if the hoisting system fails.

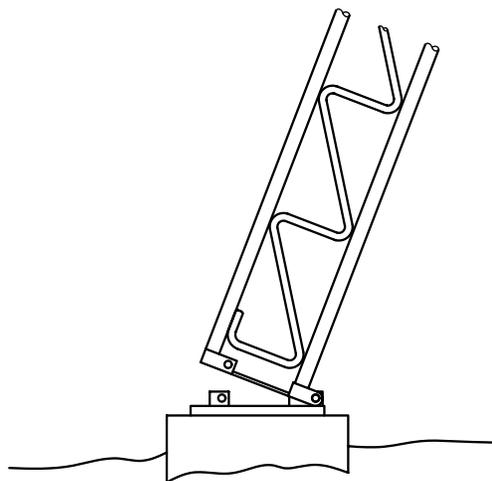
Some towers have another convenience feature—a hinged section that permits the owner to fold over all or a portion of the tower. The primary benefit is in allowing antenna work to be done close to ground level, without the necessity of removing the antenna and lowering it for service. **Fig 17** shows a hinged base; of course, the hinged section can be designed for portions of the tower other than the base. Also, a hinge feature can be added to some crank-up towers.



(A)



(B)



**Fig 17**—Fold-over or tilting base. There are several different kinds of hinged sections permitting different types of installation. Great care should be exercised when raising or lowering a tilting tower.

**Fig 16**—Two examples of “crank-up” towers.

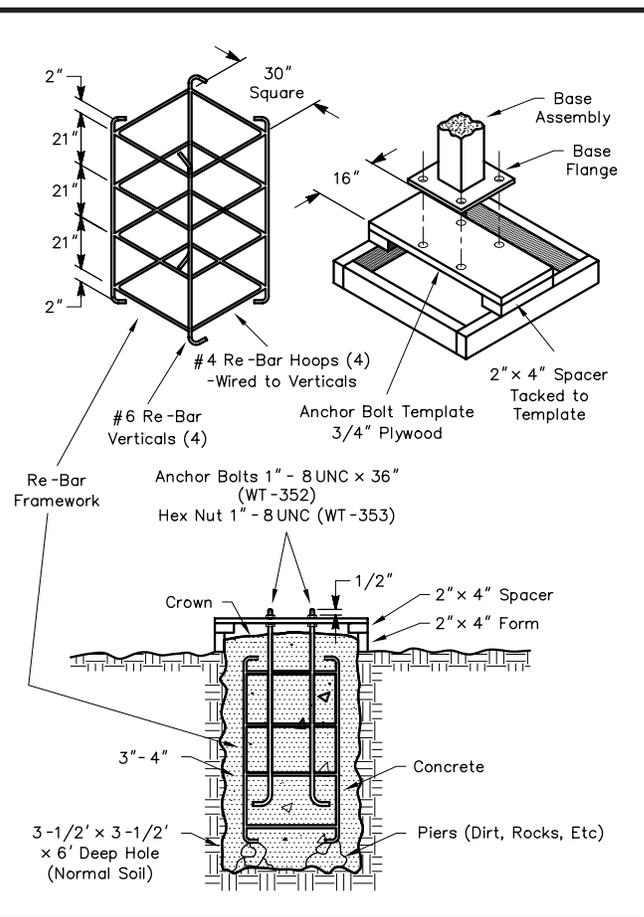
Misuse of hinged sections during tower erection is a dangerously common practice among radio amateurs. Unfortunately, these episodes often end in accidents. If you do not have a good grasp of the fundamentals of physics, it might be wise to avoid hinged towers or to consult an expert if there are any questions about safely installing and using such a tower. It is often far easier (and safer) to erect a regular guyed tower or self-supporting tower with gin pole and climbing belt than it is to try to “walk up” an unwieldy hinged tower.

### TOWER BASES

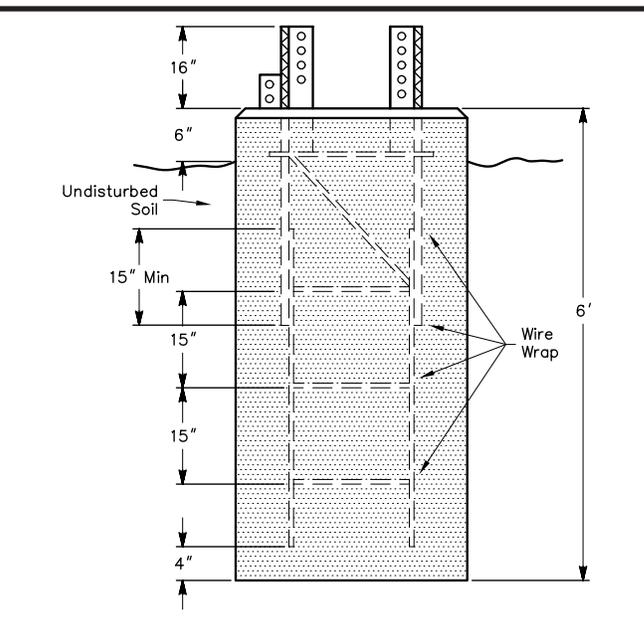
Tower manufacturers can provide customers with detailed plans for properly constructing tower bases. **Fig 18** is an example of one such plan. This plan calls for a hole that is  $3\frac{1}{2} \times 3\frac{1}{2} \times 6$  feet. Steel reinforcement bars are lashed together and placed in the hole. The bars are positioned so that they will be completely embedded in the concrete, yet will not contact any metallic object in the base itself. This is done to minimize the possibility of a direct discharge path for lightning through the base. Should such a discharge occur, the concrete base would likely explode and bring about the collapse of the tower.

A strong wooden form is constructed around the top of the hole. The hole and the wooden form are filled with concrete so that the resultant block will be 4 inches above grade. The anchor bolts are embedded in the concrete before it hardens. Usually it is easier to ensure that the base is level and properly aligned by attaching the mounting base and the first section of the tower to the concrete anchor bolts. Manufacturers can provide specific, detailed instructions for the proper mounting procedure. **Fig 19** shows a slightly different design for a tower base.

The one assumption so far is that “normal” soil is predominant in the area in which the tower is to be installed. “Normal soil” is a mixture of clay, loam, sand and small rocks. More conservative design parameters for the tower base should be adopted (usually, more concrete) if the soil is sandy, swampy or extremely rocky. If there are any doubts about the soil, the local agricultural extension office can usually provide specific technical information about the soil in a given area. When this information is in hand, contact the engineering department of the tower manufacturer or a civil engineer for specific recommendations with regard to compensating for any special soil characteristics.



**Fig 18—Plans for installing concrete base for Wilson ST-77B tower. Although the instructions and dimensions vary from tower to tower, this is representative of the type of concrete base specified by most manufacturers.**



**Fig 19—Another example of a concrete base (Tri-Ex LM-470).**

## TOWER INSTALLATION

The installation of a tower is not difficult when the proper techniques are used. A guyed tower, in particular, is not hard to erect, because each of the individual sections are relatively lightweight and can be handled with only a few helpers and some good quality rope. A gin pole is a handy device for working with tower sections. The gin pole shown in **Fig 20** is designed to fit around the leg of a Rohn 25 tower and clamp in place. The tubing, which is about 12 feet long, has a pulley on one end. A rope is routed through the tubing and over the pulley. When the gin pole is attached to the tower and the tubing is extended into place and locked, the rope can be used to haul tower sections and the antenna into place.

One of the most important aspects of any tower installation project is the safety of all persons involved. **Chapter 1** details several safety points to be observed. Basically, the use of hard hats is highly recommended for all assistants helping from the ground. Helpers should always stand clear of the tower base to prevent being hit by a dropped tool or hardware. A good climber's safety belt should be used by each person working on the tower. When climbing the tower, if more than one person is involved, one should climb into position before the other begins climbing. The same procedure is required for climbing down a tower after the job is completed. The purpose is to have the nonclimbing person stand relatively still so as not to drop any tools or objects on the climbing person, or unintentionally obstruct his movements. When two persons are working on top of a tower, only one should change position (unbelt and move) at a time.

For most installations, a good-quality 1/2-inch diameter manila hemp rope can adequately handle the work load for the hoisting tasks. The rope must be periodically inspected to assure that no tearing or chafing has developed, and if the rope should get wet from rain, it should be hung out to dry at the first opportunity. Safety knots should be used to assure that the rope stays tied during the hoisting of a tower section or antenna.

## ATTACHING GUY WIRES

In typical Amateur Radio installations, guy wires may experience loads in excess of 1000 pounds. Under such circumstances, the wires cannot merely be twisted together and expected to hold. **Figs 21, 22** and **23** depict the traditional method for fixing the end of a guy wire. A thimble is used to prevent the



**Fig 20—A gin pole is helpful in positioning antennas and tower sections. The weight of the assembly is held by the ground crew via a heavy rope, making tower work safer and less tiring. (Photo by Dave Pietraszewski, K1WA)**



**Fig 21—Proper tension can be placed on the guy wires with the aid of a block-and-tackle system. (Photo by K1WA)**



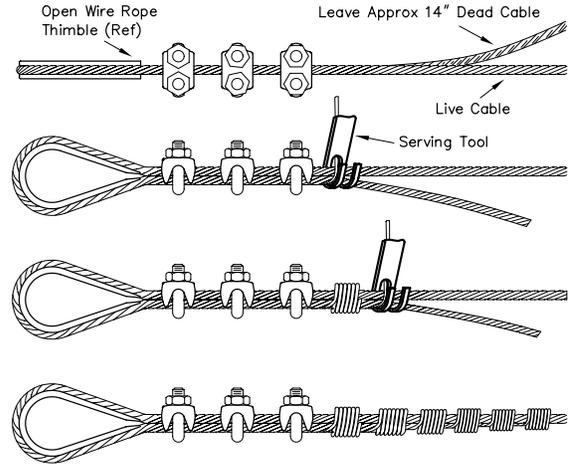
**Fig 22—**A length of guy cable is used to assure that the turnbuckles remain in place after they are tightened. This procedure is an absolute requirement in guyed tower systems. (Photo by K1WA)

wire from breaking because of a sharp bend at the point of intersection. Three cable clamps follow to hold the wire securely. As a final backup measure, the individual strands of the free end are unraveled and wrapped around the guy wire. It is a lot of work, but it is necessary to ensure a safe and permanent connection.

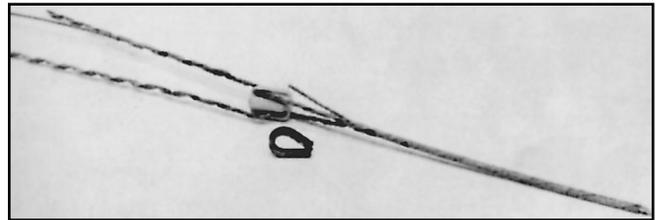
**Fig 24** shows the use of a device that replaces the clamps and twisted strands of wire. These devices are known as *dead ends*. They are far more convenient to use than are clamps. The guy wires must be cut to the proper length. The dead end of each wire is installed into the object to which the guy wire is being attached (use a thimble, if needed). One side of the dead end is then wrapped around the guy wire. The other side of the dead end follows. The savings in time and trouble more than make up for the slightly higher cost.

As indicated in Chapter 20, guy wire comes in different sizes, strengths and types. Typically,  $\frac{3}{16}$ -inch EHS guy wire is adequate for moderate tower installations at most amateur stations. Some amateurs prefer to use  $\frac{5}{32}$ -inch “aircraft” cable. Although this cable is somewhat more flexible than  $\frac{3}{16}$ -inch EHS, it is only about 70% as strong. Standard guy wire at least  $\frac{3}{16}$ -inch EHS is the safest bet in tower guying.

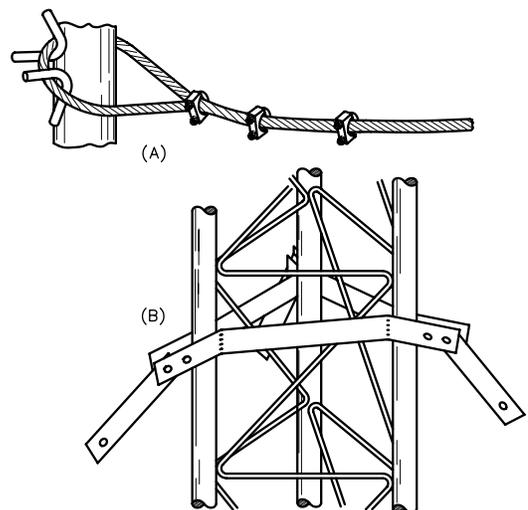
**Fig 25** shows two different methods for attaching guy wires to towers. At A, the guy wire is simply looped around the tower leg and terminated



**Fig 23—**Traditional method for securing the end of a guy wire. Note that the base of the clip bears against the live end of the wire rope.



**Fig 24—**Alternative method for attaching guy wires using dead ends. The dead end on the right is completely assembled (the end of the guy wire extends beyond the grip for illustrative purposes). On the left, one side of the dead end is partially attached to the guy wire. In front, a thimble is used where a sharp bend might cause the guy wire or dead end to break.



**Fig 25—**Two methods of attaching guy wires to tower. See text for discussion.

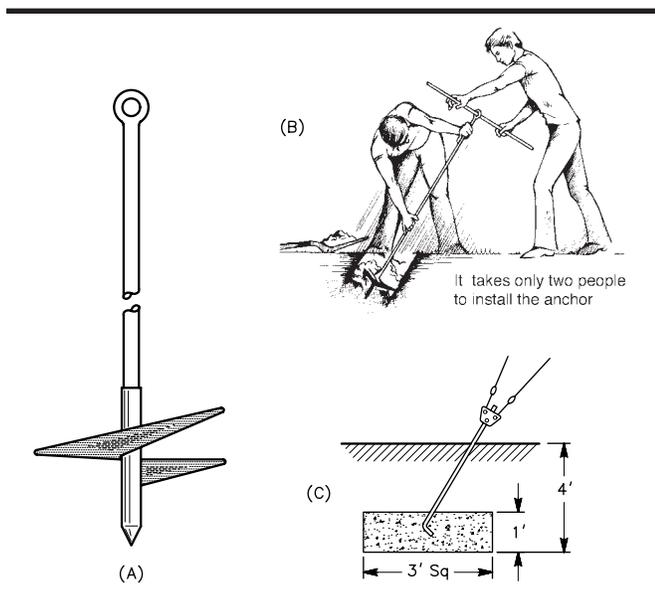
in the usual manner. At B, a “torque bracket” has been added. There is not much difference in performance for wind forces that tend to “push the tower over.” If more loading area (antennas, feed lines, etc.) is present on one side of the tower than the other, the force of the wind causes the tower to “twist” into the ground. The torque bracket is far more effective in resisting this twisting motion than the simpler installation. The trade-off is in terms of initial cost.

There are two types of commonly used guy anchors. **Fig 26A** depicts an earth screw. These are usually 4 to 6 feet long. The screw blade at the bottom typically measures 6 to 8 inches diameter. Fig 26B illustrates two people installing the anchor. The shaft is tilted so that it will be in line with the guy wires. Earth screws are suitable for use in “normal” soil where permitted by local building codes.

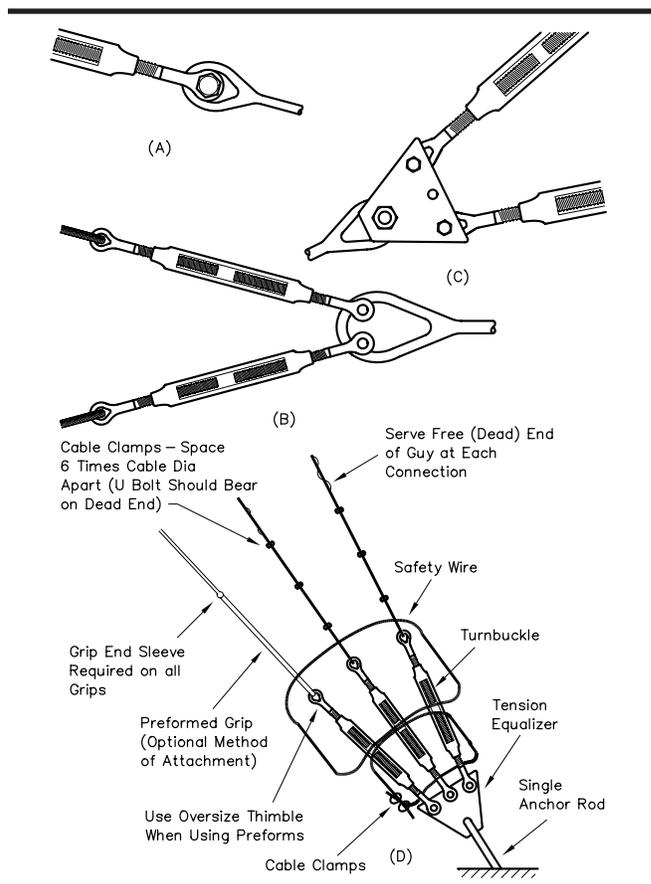
The alternative to earth screws is the concrete block anchor. Fig 26C shows the installation of this type of anchor; it is suitable for any soil condition, with the possible exception of a bed of lava rock or coral. Consult the instructions from the manufacturer for the precise method of installation.

Turnbuckles and associated hardware are used to attach guy wires to anchors and to provide a convenient method of adjusting tension on the guy wires. **Fig 27A** shows a turnbuckle of a single guy wire attached to the eye of the anchor. Turnbuckles are usually fitted with either two eyes, or one eye and one jaw. The eyes are the oval ends, while the jaws are U-shaped with a bolt through each tip. Fig 27B depicts two turnbuckles attached to the eye of an anchor. The procedure for installation is to remove the bolt from the jaw, pass the jaw over the eye of the anchor and reinstall the bolt through the jaw, through the eye of the anchor, and through the other side of the jaw.

If two or more guy wires are attached to one anchor, equalizer plates should be installed (Fig 27C). In addition to providing a convenient point to attach the turnbuckles, the plates pivot slightly and equalize the tension on the guy wires. Once the installation is complete, a safety wire should be passed through the turnbuckles in a “figure-eight” fashion to prevent the turnbuckles from turning under load.



**Fig 26—Two standard types of guy anchors. The earth screw shown at A is easy to install and widely available, but may not be suitable for use in certain soils. The concrete anchor is more difficult to install properly, but it is suitable for use with a wide variety of soil conditions and will satisfy most building code requirements.**



**Fig 27—Variety of means available for attaching guy wires and turnbuckles to anchors.**

## Resonance in Guy Wires

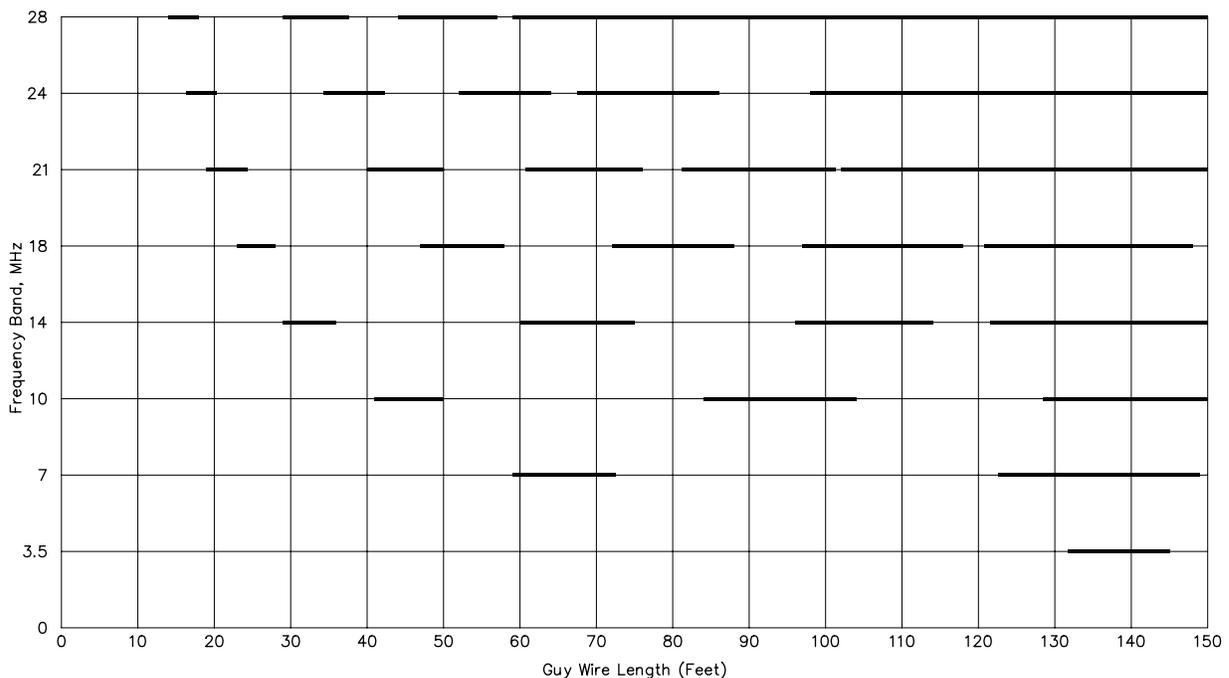
If guy wires are resonant at or near the operating frequency, they can receive and reradiate RF energy. By behaving as parasitic elements, the guy wires may alter and thereby distort the radiation pattern of a nearby antenna. For low frequencies where a dipole or other simple antenna is used, this is generally of little or no consequence. But at the higher frequencies where a unidirectional antenna is installed, it is desirable to avoid pattern distortion if at all possible. The symptoms of reradiating guy wires are usually a lower front to back ratio and a lower front to side ratio than the antenna is capable of producing. The gain of the antenna and the feed-point impedance will usually not be significantly affected, although sometimes changes in SWR can be noted as the antenna is rotated. (Of course other conductors in the vicinity of the antenna can also produce these same symptoms.)

The amount of reradiation from a guy wire depends on two factors—its resonant frequency, and the degree of coupling to the antenna. Resonant guy wires near the antenna will have a greater effect on performance than those which are farther away. Therefore, the upper portion of the top level of guy wires should warrant the most attention with horizontally polarized arrays. The lower guy wires are usually closer to horizontal than the top level, but by virtue of their increased distance from the antenna, are not coupled as tightly to the antenna.

To avoid resonance, the guys should be broken up by means of egg or strain insulators. **Fig 28** shows wire lengths that fall within 10% of  $1/2\text{-}\lambda$  resonance (or a multiple of  $1/2\text{-}\lambda$ ) for all the HF amateur bands. Unfortunately, no single length greater than about 14 feet avoids resonance in all bands. If you operate just a few bands, you can locate greater lengths from Fig 28 that will avoid resonance. For example, if you operate only the 14, 21 and 24-MHz bands, guy wire lengths of 27 feet or 51 feet would be suitable, along with any length less than 16 feet.

## ANTENNA INSTALLATION

All antenna installations are different in some respects. Therefore, thorough planning is the most important first step in installing any antenna. Before anyone climbs the tower, the whole process should



**Fig 28—The black bars indicate ungrounded guy wire lengths to avoid for the eight HF amateur bands. This chart is based on resonance within 10% of any frequency in the band. Grounded wires will exhibit resonance at odd multiples of a quarter wavelength. (By Jerry Hall, K1TD)**

be discussed to be sure each crew member understands what is to be done. Consider what tools and parts must be assembled and what items must be taken up the tower, and plan alternative actions for possible trouble spots. Extra trips up and down the tower can be avoided by careful planning.

Raising a beam antenna requires planning. If done properly, the actual work of getting the antenna into position can be executed quite easily with only one person at the top of the tower. The ground crew should do all the heavy work and leave the person on the tower free to guide the antenna into position. Because the ground crew does all the lifting, a large pulley, preferably on a gin pole placed at the top of the tower, is essential. Local radio clubs often have gin poles available for use by their members. Stores that sell tower materials frequently rent gin poles as well.

A gin pole should be placed along the side of the tower so the pulley is no more than 2 feet above the top of the tower (or the point at which the antenna is to be placed). Normally this height is sufficient to allow the antenna to be positioned easily. An important reason that the pulley is placed at this level, however, is that there can be considerable strain on the pole when the antenna is maneuvered past the guy wires.

The rope (halyard) through the pulley must be somewhat longer than twice the tower height so the ground crew can raise the antenna from ground level. The rope should be  $\frac{1}{2}$  or  $\frac{5}{8}$  inch diameter for both strength and ease of handling. Smaller diameter rope is less easily manipulated; it has a tendency to jump out of the pulley track and foul pulley operation.

The first person to climb the tower should carry an end of the halyard so that the gin pole can be lifted and secured to the tower. Those climbing the tower *must* have safety belts. Belts provide safety and convenience; it is simply impossible to work effectively while hanging onto the tower with one hand.

Once positioned, the gin pole and pulley allow parts and tools to be sent quickly up the tower. A useful trick for sending up small items like bolts and pliers is for a ground crew member to slide them through the rope strands where they are held by the rope for the trip to the top of the tower. Items that might be dislodged by contact with the tower should either be taped or tied to the halyard.

*Remember, once someone is on the tower, no one should be allowed to stand near the base of the tower!* Ever present is the hazard of falling tools or hardware. It is foolish to stand near a tower when someone is working above. Hard-hats should be worn by ground-crew members as extra insurance.

### **Raising the Antenna**

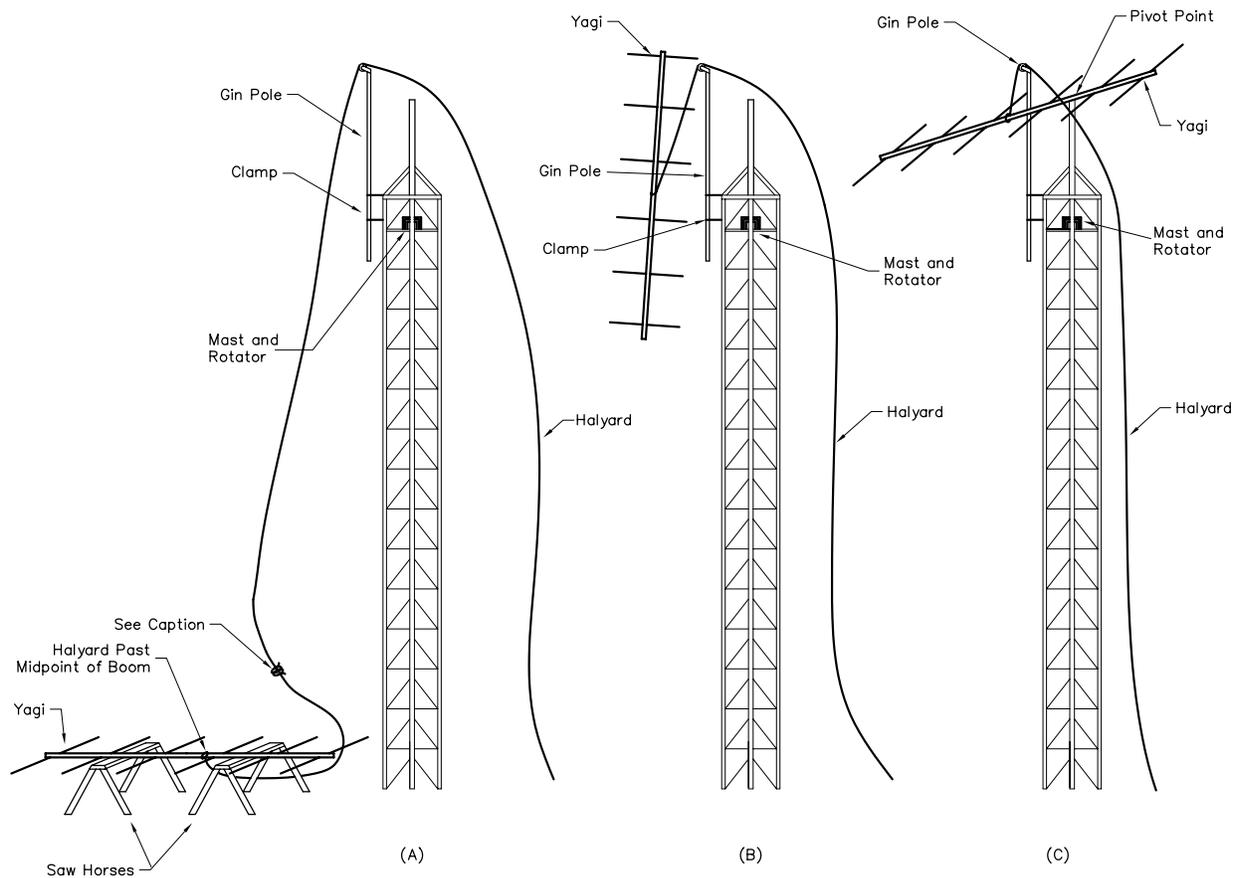
A technique that can save much effort in raising the antenna is outlined here. First, the halyard is passed through the gin-pole pulley, and the leading end of the rope is returned to the ground crew where it is tied to the antenna. The assembled antenna should be placed in a clear area of the yard (or the roof) so the boom points toward the tower. The halyard is then passed under the front elements of the beam to a position past the midpoint of the antenna, where it is securely tied to the boom (**Fig 29A**).

Note that once the antenna is installed, the tower worker must be able to reach and untie the halyard from the boom; the rope must be tied less than an arm's length along the boom from the mounting point. If necessary, a large loop may be placed around the first element located beyond the midpoint of the boom, with the knot tied near the center of the antenna. The rope may then be untied easily after completion of the installation. The halyard should be tied to the boom at the front of the antenna by means of a short piece of light rope or twine.

While the antenna is being raised, the ground crew does all the pulling. As soon as the front of the antenna reaches the top of the mast, the person atop the tower unties the light rope and prevents the front of the antenna from falling, as the ground crew continues to lift the antenna (**Fig 29B**). When the center of the antenna is even with the top of the tower, the tower worker puts one bolt through the mast and the antenna mounting bracket on the boom. The single bolt acts as a pivot point and the ground crew continues to lift the back of the antenna with the halyard (**Fig 29C**). After the antenna is horizontal, the tower worker secures the rest of the mounting bolts and unties the halyard. By using this technique, the tower worker performs no heavy lifting.

### **Avoiding Guy Wires**

Although the same basic methods of installing a Yagi apply to any tower, guyed towers pose a special problem. Steps must be taken to avoid snagging the antenna on the guy wires. With proper precautions,



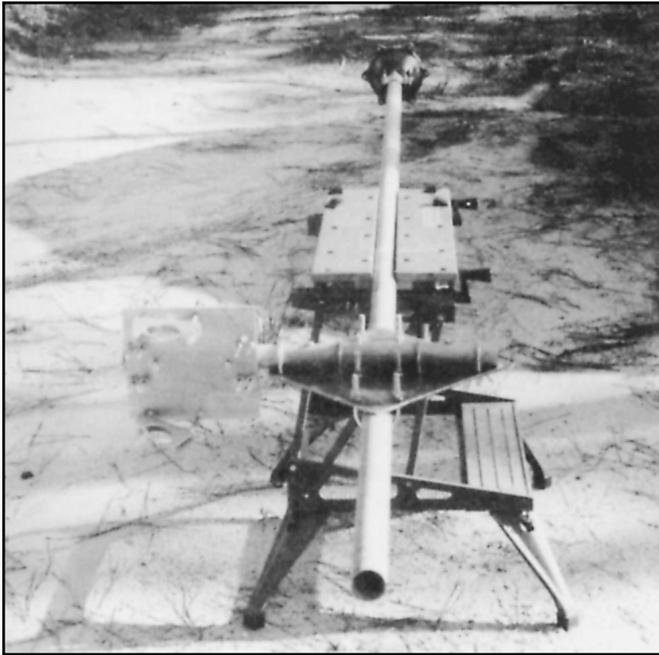
**Fig 29—Raising a Yagi antenna to the top of a tower. At A the Yagi is placed in a clear area, with the boom pointing toward the tower. The halyard is passed under the elements, then secured to the boom beyond the midpoint. B shows the antenna approaching the top of the mast. The person on the tower guides it after the lifting rope has been untied from the front of the antenna. At C the antenna is pulled into a horizontal position by the ground crew. The tower worker inserts the pivot bolt and secures it. Note: A short piece of rope is tied around the halyard and the boom at the front of the antenna. It is removed by the tower worker when the antenna reaches the top.**

however, even large antennas can be pulled to the top of a tower, even if the mast is guyed at several levels.

Sometimes one of the top guys can provide a track to support the antenna as it is pulled upward. Insulators in the guys, however, may obstruct the movement of the antenna. A better track made with rope is an alternative. One end of the rope is secured outside the guy anchors. The other end is passed over the top of the tower and back down to an anchor near the first anchor. So arranged, the rope forms a narrow V track strung outside the guy wires. Once the V track is secured, the antenna may simply be pulled up the track.

Another method is to tie a rope to the back of the antenna (but within reach of the center). The ground crews then pull the antenna out away from the guys as the antenna is raised. With this method, some crew members are pulling up the antenna to raise it while others are pulling down and out to keep the beam clear of the guys. Obviously, the opposing crews must act in coordination to avoid damaging the antenna. The beam is especially vulnerable when it begins to tip into the horizontal position. If the crew continues to pull out and down against the antenna, the boom can be broken. Another problem with this approach is that the antenna may rotate on the axis of the boom as it is raised. To prevent such rotation, long lengths of twine may be tied to outer elements, one piece on each side of the boom. Ground personnel may then use these “tag lines” to stabilize the antenna. Where this is done, provisions must be made for untying the twine once the antenna is in place.

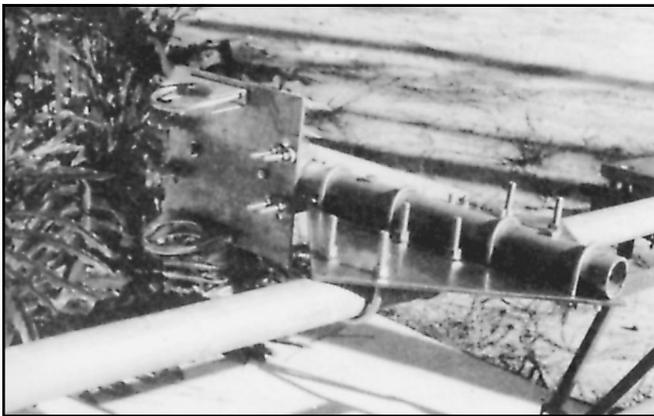
A third method is to tie the halyard to the center of the antenna. A crew member, wearing a safety belt, walks the antenna up the tower as the crew on the ground raises it. Because the halyard is tied at



**Fig 30—The PVRC mount, boom plate, mast and rotator ready to go. The mast and rotator are installed on the tower first.**



**Fig 32—Working at the 70-foot level. A gin pole makes pulling up and mounting the boom to the boom plate a safe and easy procedure.**



**Fig 31—Close-up of the PVRC mount. The long pipe (horizontal in this photo) is the rotating mast. The U bolts in the vertical plate at the left are ready to accept the antenna boom. The heads of two locking pins (bolts) are visible at the midline of the boom plate. The other two pins help secure the horizontal pipe to the large steel mast plate. (The head of the bolt nearest the camera blends in with the right hand leg of the U bolt behind it.)**

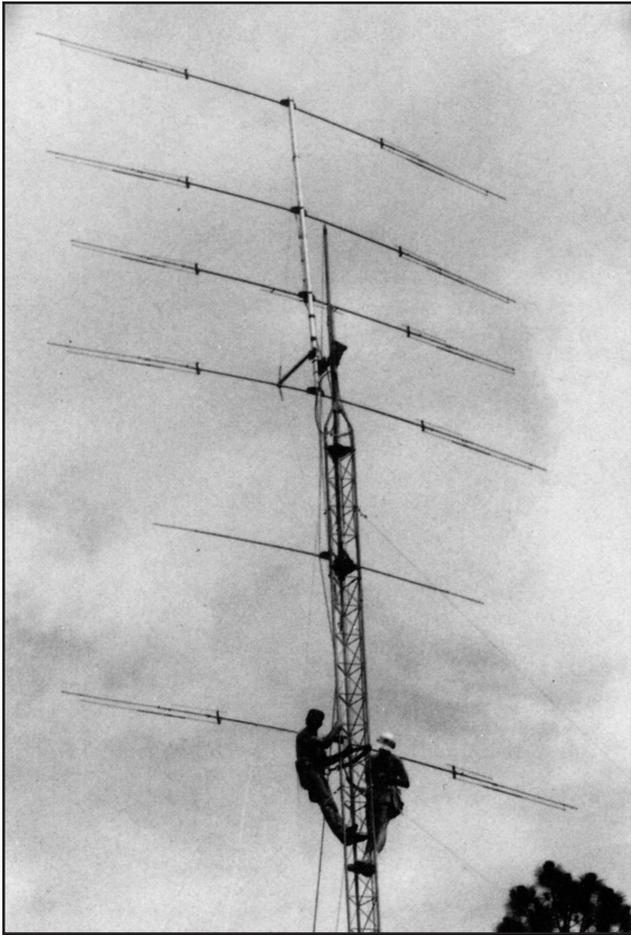
the balance point, the tower worker can rotate the elements around the guys. A tag line can be tied to the bottom end of the boom so that a ground worker can help move the antenna around the guys. The tag line must be removed while the antenna is still vertical.

### THE PVRC MOUNT

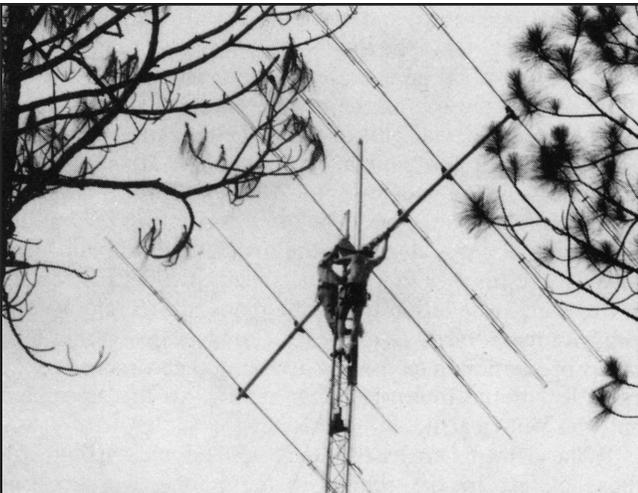
The methods described earlier in this chapter for hoisting antennas are sometimes not satisfactory for large arrays. The best way to handle large Yagis is to assemble them on top of the tower. One way to do this easily is by using the “PVRC mount.” Many members of the Potomac Valley Radio Club have successfully used this method to install large antennas. Simple and ingenious, the idea involves offsetting the boom from the mast to permit the boom to tilt 360° and rotate *axially* 360°. This permits the entire length of the boom to be brought alongside the tower, allowing the elements to be attached one by one. (It also allows *any part* of the antenna to be brought

alongside the tower for antenna maintenance.)

See **Figs 30 through 34**. The mount itself consists of a short length of pipe of the same diameter as the rotating mast (or greater), a steel plate, eight U bolts and four pinning bolts. The steel plate is the larger, horizontal one shown in Fig 31. Four U bolts attach the plate to the rotating mast, and four attach the horizontal pipe to the plate. The horizontal pipe provides the offset between the antenna boom and the tower. The antenna boom-to-mast plate is mounted at the outer end of the short pipe. Four bolts are used to ensure that the antenna ends up parallel to the ground, two pinning each plate to the short pipe. When the mast pinning bolts are removed and the four U bolts loosened, the short pipe and boom plate can be rotated



**Fig 33—Mounting the last element prior to positioning the boom in a horizontal plane.**



**Fig 34—The U bolts securing the short pipe to the mast plate are loosened and the boom is turned to a horizontal position. This puts the elements in a vertical plane. Then the pipe U bolts are tightened and pinning bolts secured. The boom U bolts are then loosened and the boom turned axially 90°.**

through 360°, allowing either half of the boom to come alongside the tower.

First assemble the antenna on the ground. Carefully mark all critical dimensions, and then remove the antenna elements from the boom. Once the rotator and mast have been installed on the tower, a gin pole is used to bring the mast plate and short pipe to the top of the tower. There, the “top crew” unpins the horizontal pipe and tilts the antenna boom plate to place it in the vertical plane. The boom is attached to the boom plate at the balance point of the assembled antenna. It is important that the boom be rotated axially so the bottom side of the boom is closest to the tower. This will allow the boom to be tilted without the elements striking the tower.

During installation it may be necessary to remove one guy wire temporarily to allow for tilting of the boom. As a safety precaution, a temporary guy should be attached to the same leg of the tower just low enough so the assembled antenna will clear it.

The elements are assembled on the boom, starting with those closest to the center of the boom, working out alternately to the farthest director and reflector. This procedure *must* be followed. If all the elements are put first on one half of the boom, it will be dangerous (if not impossible) to put on the remaining elements. By starting at the middle and working outward, the balance point of the partly assembled antenna will never be so far removed from the tower that tilting of the boom becomes impossible.

When the last element is attached, the boom is brought parallel to the ground, the horizontal pipe is pinned to the mast plate, and the mast plate U bolts tightened. At this point, all the antenna elements will be positioned vertically. Next, loosen the U bolts that hold the boom and rotate the boom axially 90°, bringing the elements parallel to the ground. Tighten the boom bolts and double check all the hardware.

Many long boom Yagis employ a truss to prevent boom sag. With the PVRC mount, the truss must be attached to a pipe that is independent of the rotating mast. A short length of pipe is attached to the boom as close as possible to the balance point. The truss then moves with the boom whenever the boom is tilted or twisted.

## THE TOWER ALTERNATIVE

A cost saving alternative to the ground-mounted tower is the roof-mounted tripod. Units suitable for small HF or VHF antennas are commercially available. Perhaps the biggest problem

with a tripod is determining how to fasten it securely to the roof.

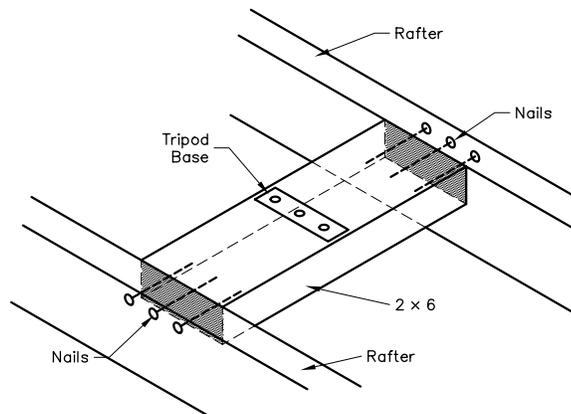
One method of mounting a tripod on a roof is to nail  $2 \times 6$  boards to the undersides of the rafters. Bolts can be extended from the leg mounts through the roof and the  $2 \times 6$ s. To avoid exerting too much pressure on the area of the roof between rafters, place another set of  $2 \times 6$ s on top of the roof (a mirror image of the ones in the attic). Installation details are shown in **Figs 35** through **38**.

The  $2 \times 6$ s are cut 4 inches longer than the outside distance between two rafters. Bolts are cut from a length of  $\frac{1}{4}$ -inch threaded rod. Nails are used to hold the boards in place during installation, and roofing tar is used to seal the area to prevent leaks.

Find a location on the roof that will allow the antenna to turn without obstruction from such things as trees, TV antennas and chimneys. Determine the rafter locations. (Chimneys and vent pipes make good reference points.) Now the tower is set in place atop three  $2 \times 6$ s. A plumb line run from the top center of the tower can be used to center it on the



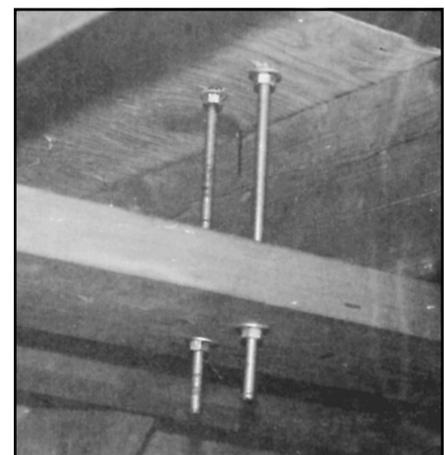
**Fig 35**—This tripod tower supports a rotary beam antenna. In addition to saving yard space, a roof-mounted tower can be more economical than a ground-mounted tower. A ground lead fastened to the lower part of the frame is for lightning protection. The rotator control cable and the coaxial line are dressed along two of the legs. (Photo courtesy of Jane Wolfert)



**Fig 36**—This cutaway view illustrates how the tripod tower is secured to the roof rafters. The leg to be secured to the cross piece is placed on the outside of the roof. Another cross member is fastened to the underside of the rafters. Bolts, inserted through the roof and the two cross pieces, hold the inner cross member in place because of pressure applied. The inner cross piece can be nailed to the rafter for added strength.



**Fig 37**—Three lengths of  $2 \times 6$  wood mounted on the outside of the roof and reinforced under the roof by three identical lengths provide a durable method for anchoring the tripod. A thick coat of roofing tar protects against weathering and leaks.



**Fig 38**—The strengthened anchoring for the tripod. Bolts are placed through two  $2 \times 6$ s on the underside of the roof and through the  $2 \times 6$  on the top of the roof as shown in Fig 37.

peak of the roof. Holes for the mounting bolts can now be drilled through the roof.

Before proceeding, the bottom of the 2 × 6s and the area of the roof under them should be given a coat of roofing tar. Leave about 1/8 inch of clear area around the holes to ensure easy passage of the bolts. Put the tower back in place and insert the bolts and tighten them. Apply tar to the bottom of the legs and the wooden supports, including the bolts. For added security the tripod can be guyed. Guys should be anchored to the frame of the house.

If a rotator is to be mounted above the tripod, pressure will be applied to the bearings. Wind load on the antenna will be translated into a “pinching” of one side of the bearings. Make sure that the rotator is capable of handling this additional stress.

## **ROTATOR SYSTEMS**

There are not many choices when it comes to antenna rotators for the amateur antenna system. However, making the correct decision as to how much capacity the rotator must have is very important if trouble free operation is desired. There are basically four grades of rotators available to the amateur. The lightest duty rotator is the type typically used to turn TV antennas. Without much difficulty, these rotators will handle a small three-element tribander array (14, 21 and 28 MHz) or a single 21 or 28-MHz monoband three-element antenna. The important consideration with a TV rotator is that it lacks braking or holding capability. High winds turn the rotator motor via the gear train in a reverse fashion. Broken gears sometimes result.

The next grade up from the TV class of rotator usually includes a braking arrangement whereby the antenna is held in place when power is not applied to the rotator. Generally speaking, the brake prevents gear damage on windy days. If adequate precautions are taken, this group of rotators is capable of holding and turning stacked monoband arrays, or up to a five-element 14-MHz system. The next step up in rotator strength is more expensive. This class of rotator will turn just about anything the most demanding amateur might want to install.

A description of antenna rotators would not be complete without the mention of the prop pitch class. The prop pitch rotator system consists of a surplus aircraft propeller blade pitch motor coupled to an indicator system and a power supply. There are mechanical problems of installation, however, resulting mostly from the size and weight of these motors. It has been said that a prop pitch rotator system, properly installed, is capable of turning a house. Perhaps in the same class as the prop pitch motor (but with somewhat less capability) is the electric motor of the type used for opening garage doors. These have been used successfully in turning large arrays.

Proper installation of the antenna rotator can provide many years of trouble free service; sloppy installation can cause problems such as a burned out motor, slippage, binding and casting breakage. Most rotators are capable of accepting mast sizes of different diameters, and suitable precautions must be taken to shim an undersized mast to assure dead center rotation. It is very desirable to mount the rotator inside and as far below the top of the tower as possible. The mast absorbs the torsion developed by the antenna during high winds, as well as during starting and stopping.

Some amateurs have used a long mast from the top to the base of the tower. Rotator installation and service can be accomplished at ground level. A mast length of 10 feet or more between the rotator and the antenna will add greatly to the longevity of the entire system. Another benefit of mounting the rotator 10 feet or more below the antenna is that any misalignment among the rotator, mast and the top of the tower is less significant. A tube at the top of the tower (a sleeve bearing) through which the mast protrudes almost completely eliminates any lateral forces on the rotator casing. All the rotator must do is support the downward weight of the antenna system and turn the array.

While the normal weight of the antenna and the mast is usually not more than a couple of hundred pounds, even with a large system, one can ease this strain on the rotator by installing a thrust bearing at the top of the tower. The bearing is then the component that holds the weight of the antenna system, and the rotator need perform only the rotating task.

### **Indicator Alignment**

A problem often encountered in amateur installations is that of misalignment between the direction indicator in the rotator control box and the heading of the antenna. With a light duty rotator, this hap-



because the 500- $\mu$ F capacitor across the relay coil increases the control voltage, thereby causing approximately a 15° error between readings. The additional 200- $\mu$ F capacitor increases the control voltage such that identical readings are obtained during rotation or at rest. This modification also causes the unit to read position whenever it is plugged in. An ON-OFF switch is easily added.

To increase the indicator lamp life, change the lamps to 28-V types. The relay is approximately  $\frac{1}{2} \times \frac{5}{8}$  inch and fits nicely near the left front just above the screwdriver-adjust calibration control. The capacitors are fitted easily near the rear of the meter.

## A Delayed Brake Release for the Ham-II

Not only is it wise to delay braking in a rotator system, but it is even more important that rotation in the opposite direction is not initiated until the system is at rest. The circuit presented in Fig 40 offers

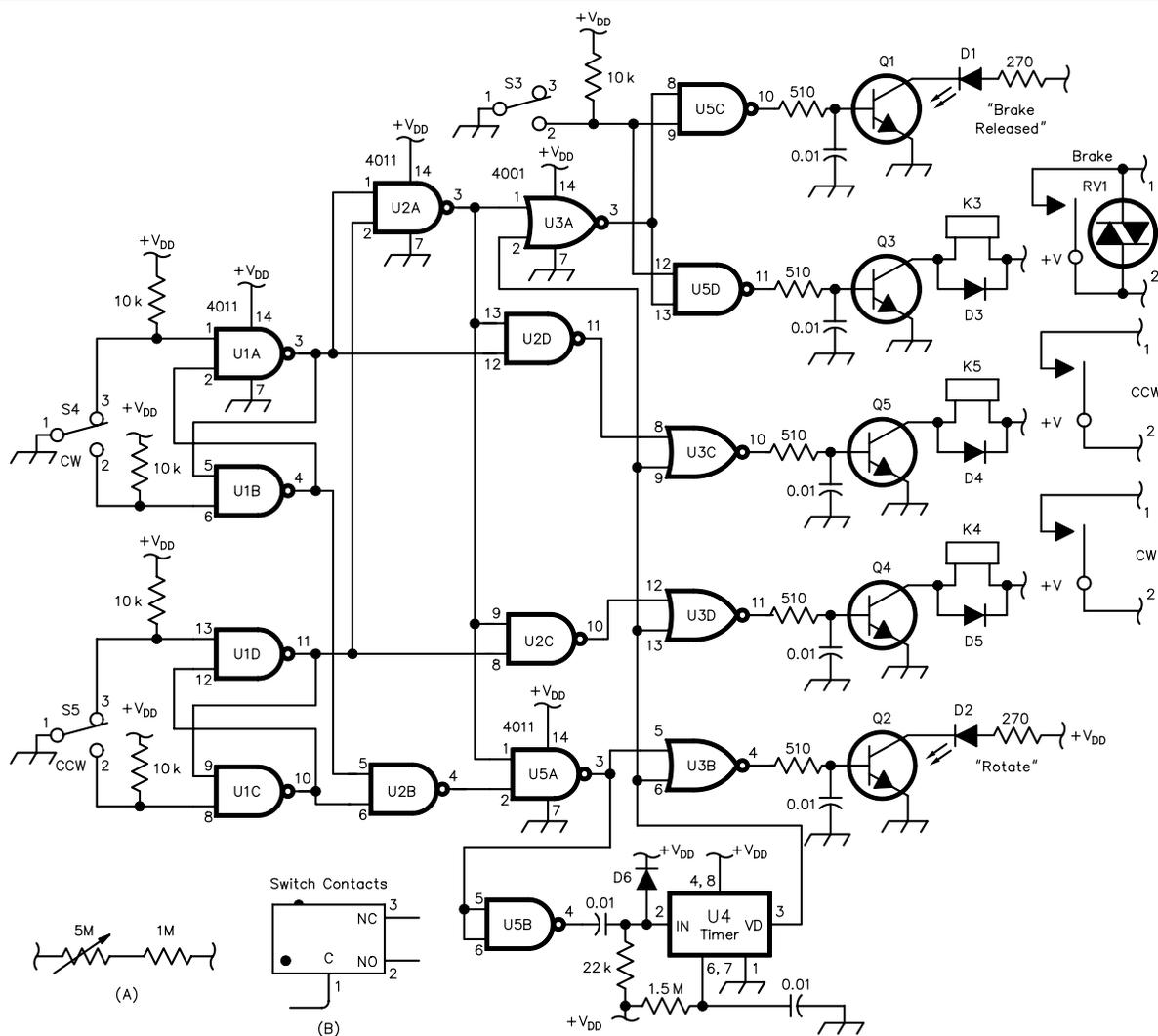


Fig 40—The circuit for a brake-delay system for protection of the Ham-II rotator and antenna.

D1, D2—Light-emitting diode, Motorola type MLED600 or equiv.

D3-D6, incl.—Silicon signal diode, 1N914 or equiv.

K3-K5, incl.—Switching relay, 12 V dc, 1200  $\Omega$ , 10 mA; contact rating 1A; 125 V ac; Radio Shack 275-003 or equiv.

Q1-Q5, incl.—Silicon NPN transistor, 2N3904 or equiv.

RV1—Varistor, GE 750 or equiv.

U1, U2, U5—CMOS quad NAND-gate IC RCA CD-4011A or equiv.

U3—CMOS quad NOR-gate IC, RCA CD-4001A, or equiv.

U4—Timer IC, 555 or equiv.

the protection of delayed braking, and it also disables the direction selector switches. In this manner, the antenna system coasts to a stop before rotation may begin in the opposite direction. The automatic delay prevents damage to the antenna system and rotator, even during a contest when the operator's attention is not on the rotator control.

In the circuit of Fig 40, S3, S4 and S5 are the existing Ham-II control unit brake release and direction switches. S4 selects clockwise (cw) rotation and S5 selects counter-clockwise (ccw) rotation. These switches are replaced by K3, K4 and K5, respectively, in the modified control unit.

A pair of NAND gates in U1 form a debouncing circuit for each direction switch to prevent false triggering of the brake from contact bounce. Pressing S4 causes pin 3 of U2 to go high (+V<sub>DD</sub>), or to a logical 1, which forces pin 3 of U3 low (near 0 V), pin 11 of U5 high, and energizes both the brake-release relay K3 and the BRAKE RELEASED LED, D1. In addition, pressing only S4 forces pin 10 of U2 low and pin 11 of U3 high, energizing K4, the cw rotation control relay. When S4 is released, a short pulse appears at pin 2 of U4, triggering the monostable multivibrator. While pin 3 of U4 is high, the brake remains released, and the selection switches are disabled by the logical 1 on pins 9 and 13 of U3. In a similar fashion, pressing S5 energizes the brake-release relay K3, LED D1, and the cw rotation control relay, K5. Whenever one of the direction control relays is energized, the ROTATE LED, D2, illuminates to indicate the rotator is turning.

The circuit has been designed to detect the simultaneous selection of both rotation directions using a NAND gate in U2. If both are pressed, a transition to 0 at pin 4 of U2 triggers the monostable multivibrator, forcing a brake delay period. In this way, the rapid rocking of the antenna back and forth is eliminated. After the end of the delay cycle, if both direction switches are still pressed, neither control relay is energized, because both pins 8 and 12 of U3 are high, keeping Q4 and Q5 off.

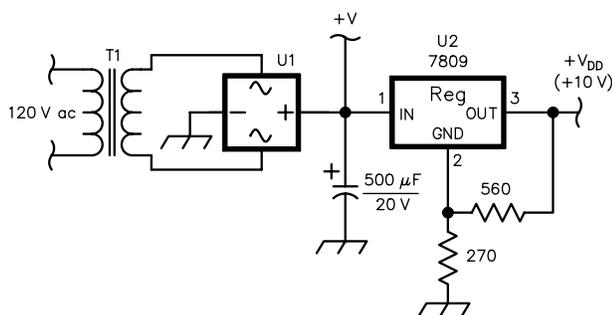
If a longer delay is desired, the brake can be released manually with S3. D1 signals when the brake-release is energized, but no delay cycle is initiated.

U4, the delay timer (NE555) is connected in a monostable multivibrator configuration. The components R and C at pins 6 and 7 determine the length of the delay. The values shown provide a delay period of about 3 seconds. An alternative is to use a potentiometer for R as shown in Fig 40A to yield a variable delay of 2 to 8 seconds.

## Construction

CMOS integrated circuits were used in this design because of their high noise margin, low power dissipation, and tolerance of varying supply voltage. CMOS units operate with a V<sub>DD</sub> ranging from 3 to 15 V, although the 10-V regulator shown in Fig 41 is used in this unit. TTL circuits may be substituted, but some RF immunity is sacrificed and, of course, the pin connections of the devices are different.

The transistor drivers Q1 through Q5 are necessary, as the CMOS devices cannot sink enough current to energize either the relays or the LEDs. The 0.01-μF capacitor on the base of each transistor



**Fig 41—Regulated power supply for the delayed brake release system.**

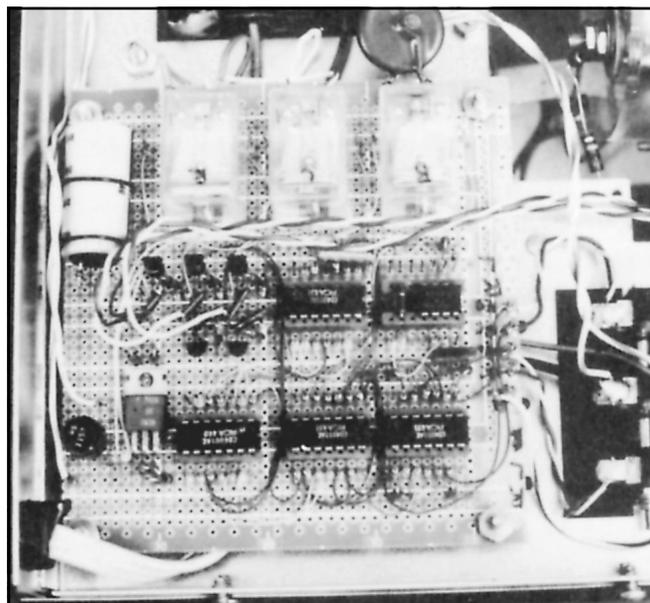
- T1**—Power transformer; pri. 120 V; sec. 12 V, 300 mA; Radio Shack 273-1385 or equiv.
- U1**—Bridge rectifier, 50 PIV, 1.5 A; Radio Shack 267-1151 or equiv.
- U2**—Monolithic three-terminal positive-voltage regulator, 9 V, 500 mA; Fairchild 7809 or equiv.

is included to eliminate false keying of the relays by stray RF. An added precaution is the transient suppressor shown across the contacts of K3. The brake-release relay connects the line voltage to the primary of the brake and rotation power transformer. Without the suppressor, the contacts of K3 would pit badly because of arcing when the relay contacts open.

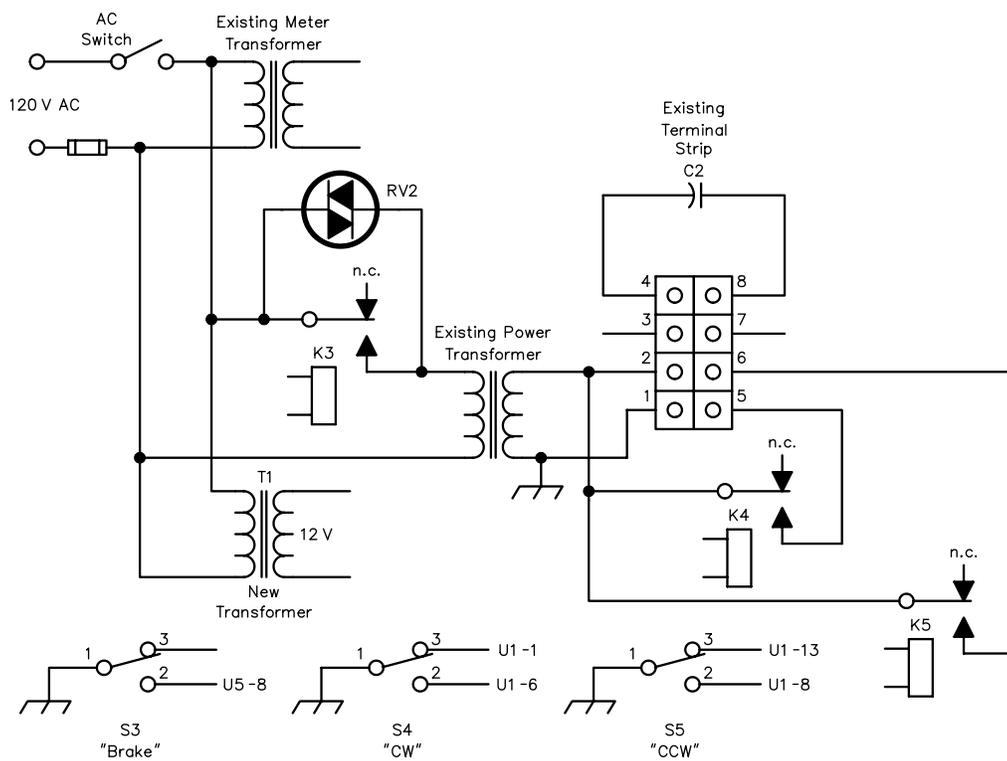
The circuit as shown in **Fig 42** is constructed on a Vector IC circuit breadboard using IC sockets and standard wire-wrap techniques. Homemade printed-circuit boards or other fabrication techniques could also be used, as the layout is not critical.

**Fig 43** illustrates the Ham-II circuit modifications. Relays K3, K4 and K5 replace S3, S4 and S5 in the original diagram, and the primary of a small 12-V power transformer is connected to the control unit ac power switch.

There is more than enough room beneath the Ham-II chassis to mount the delay-circuit card. It may be necessary to relocate the phasing capacitor, C2, above the chassis. The wires that were originally connected to S3, S4 and S5 are relocated, connecting them to the corresponding relay contacts. The switches are connected to the delay circuit inputs. These are single-pole double-throw microswitches with the contact configuration shown in **Fig 40B**.



**Fig 42—Modification of the Ham-II control unit showing the Vector circuit board and components.**

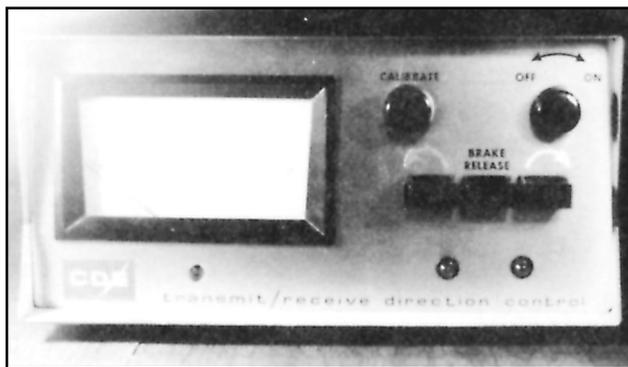


**Fig 43—The Ham-II circuit modifications. T1 is the power supply transformer shown in Fig 41.**

The LEDs are mounted below the switches in the front panel, as pictured in **Fig 44**.

### Operation

The modified rotator control unit is used in the same manner as always, except that the operation of S3 (the brake release) is now automatic. Both LEDs, D1 and D2, are illuminated during rotation and D1 (BRAKE RELEASED) remains on through the brake delay cycle after rotation. Because an average size antenna coasts approximately 10°, the operator must release the rotation switch about 10° before the antenna reaches the desired heading. With practice, the early release becomes natural.



**Fig 44**—A view of the control panel of the Ham-II rotator.

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