

Antenna System Planning and Practical Considerations

Selecting Your Antenna System

Where should you start in putting together an antenna system? A newcomer to Amateur Radio, an amateur moving to a new location, or someone wanting to improve an existing “antenna farm” might ask this question. The answer: In a comfortable chair, with a pad and writing instrument.

The most important time spent in putting together an antenna system is that time spent in planning. It can save a lot of time, money and frustration. While no one can tell you the exact steps you should take in developing your master plan, this section, prepared by Chuck Hutchinson, K8CH, should help you with some ideas.

Begin planning by spelling out your communications desires. What bands are you interested in? Who (or where) do you want to talk to? When do you operate? How much time and money are you willing to spend on an antenna system? What physical limitations affect your master plan?

From the answers to the above questions, begin to formulate goals—short, intermediate, and long range. Be realistic about those goals. Remember that there are three station effectiveness factors that are under your control. These are: operator skill, equipment in the shack, and the antenna system. There is no substitute for developing operating skills. Some trade-offs are possible between shack equipment and antennas. For example, a high-power amplifier can compensate for a less than optimum antenna. By contrast, a better antenna has advantages for receiving as well as for transmitting.

Consider your limitations. Are there regulatory restrictions on antennas in your community? Are there any deed restrictions or covenants that apply to your property? Do other factors (finances, family considerations, other interests, and so forth) limit the type or height of antennas that you can erect? All of these factors must be investigated because they play a major role determining the type of antennas you erect.

Chances are that you won't be able to immediately do all you desire. Think about how you can budget your resources over a period of time. Your resources are your money, your time available to work, materials you may have on hand, friends that are willing to help, etc. One way to budget is to concentrate your initial efforts on a given band or two. If your major interest is in chasing DX, you might want to start with a very good antenna for the 14-MHz band. A simple multiband antenna could initially serve for other frequencies. Later you can add better antennas for those other bands.

SITE PLANNING

A map of your property or proposed antenna site can be of great help as you begin to consider alternative antennas. You'll need to know the size and location of buildings, trees and other major objects in the area. Be sure to note compass directions on your map. Graph paper or quadrille paper is very useful for this purpose. See **Fig 1** for an example. It's a good idea to make a few photocopies of your site map so you can mark on the copies as you work on your plans.

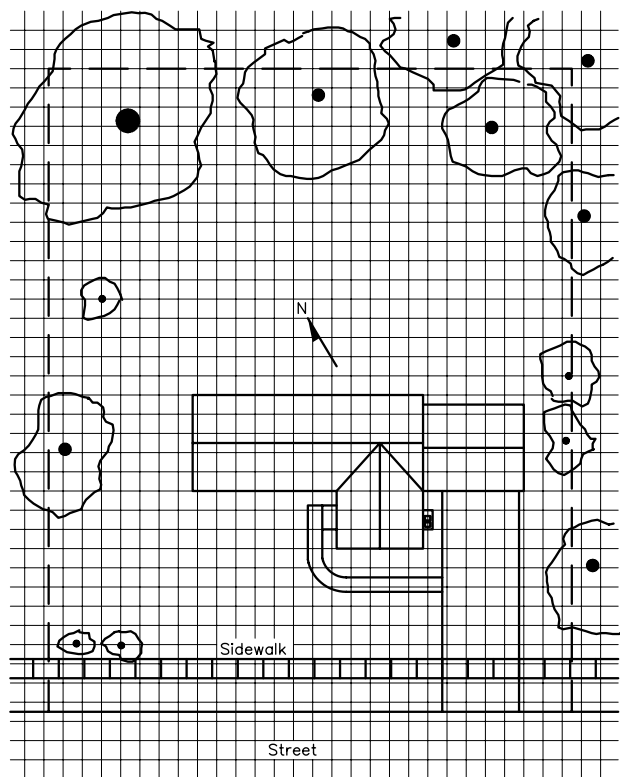


Fig 1—A site map such as this one is a useful tool for planning your antenna installation.

energy from a dipole at that height would be concentrated straight up. This condition is not great for long-distance communication, but can still be useful for DX work and excellent for short-range communication.

Lower heights can be useful for communication. However, it is generally true that “the higher, the better” as far as communications effectiveness is concerned.

There may be cases where it is not possible to install low-frequency dipoles at $\lambda/4$ or more above the ground. A vertical antenna with many radials is a good choice for long-distance communications. You may want to install both a dipole and a vertical for the 3.5 or 7-MHz bands. On the 1.8-MHz band, unless very tall supports are available, a vertical antenna is likely to be the most useful for DXing. You can then choose the antenna that performs best for a given set of conditions. A low dipole will generally work better for shorter-range communications, while the vertical will generally be the better performer over longer distances.

Consider the azimuthal pattern of fixed antennas. You’ll want to orient any fixed antennas to favor the directions of greatest interest to you.

BUILDING THE SYSTEM

When the planning is completed, it is time to begin construction of the antenna system. Chances are that you can divide that construction into a series of phases or steps. Say, for example, that you have lots of room and that your long-range plan calls for a pair of 100-foot towers to support monoband Yagi antennas. The towers will also support a horizontal 3.5-MHz dipole at 100 feet, for DX work. On your map you’ve located them so the dipole will be broadside to Europe. Initially you decide to build a 60-foot tower with a triband beam and a 3.5-MHz inverted-V dipole to begin the project. In your master plan, the 60-foot tower is really the bottom part of a 100-foot tower. The guys, anchors and all hardware are designed for use in the 100 footer.

Initially you buy a heavy-duty rotator and mast that will be needed for the monoband antennas

Use your map to plan antenna layouts and locations of any supporting towers or masts. If your plan calls for more than one tower or mast, think about using them as supports for wire antennas. As you work on a layout, be sure to think in three dimensions even though the map shows only two.

Be sensitive to your neighbors. A 70-foot guyed tower in the front yard of a house in a residential neighborhood is not a good idea (and probably won’t comply with local ordinances!).

ANALYSIS

Use the information in this book to analyze antenna patterns in both horizontal and vertical planes. If you want to work DX, you’ll want antennas that radiate energy at low angles. An antenna pattern is greatly affected by the presence of ground. Therefore, be sure to consider what effect ground will have on the antenna pattern at the height you are considering. A 70-foot high antenna is approximately $1/2$, 1, $1\frac{1}{2}$ and 2 wavelengths (λ) high on 7, 14, 21 and 28 MHz respectively. Those heights are useful for long-distance communications. The same 70-foot height represents only $\lambda/4$ at 3.5 MHz. Most of the radiated

later. Thus, you avoid having to buy, and then sell, a medium-duty rotator and lighter-weight tower equipment. You could have saved money in the long run by putting up a monoband beam for your favorite band, but you decided that for now it is more important to have a beam on 14, 21 and 28 MHz. The second step of your plan calls for installing the second tower. This time you've decided to wait until you can install all 100 feet of that second tower, and put a 7-MHz Yagi on top of it. Later you will remove the top section of the first (60 foot) tower and insert the sections and add the guys to bring it up to 100 feet. You decide that at that time you'll continue to use the tribander for a few months to see what difference the 60 foot to 100-foot height change makes.

COMPROMISES

Because of limitations, most amateurs are never able to build their "dream" antenna system. This means that some compromises must be made. Do not, under any circumstances, compromise the safety of an antenna installation. Follow the manufacturer's recommendations for tower assembly, installation and accessories. Make sure that all hardware is being used within its ratings.

Guyed towers are frequently used by radio amateurs because they cost less than more complicated unguyed or freestanding towers with similar ratings. Guyed towers are fine for those who can climb, or those with a friend who is willing to climb. But you may want to consider an antenna tower that folds over, or one that cranks up (and down). Some towers crank up (and down) and fold over too. See **Fig 2**. That makes for convenient access to antennas for adjustments and maintenance without climbing. Crank-up towers also offer another advantage. They allow antennas to be lowered during periods of no operation, such as for aesthetic reasons or during periods of high winds.

A well-designed monoband Yagi should out-perform a multiband Yagi. In a monoband design the

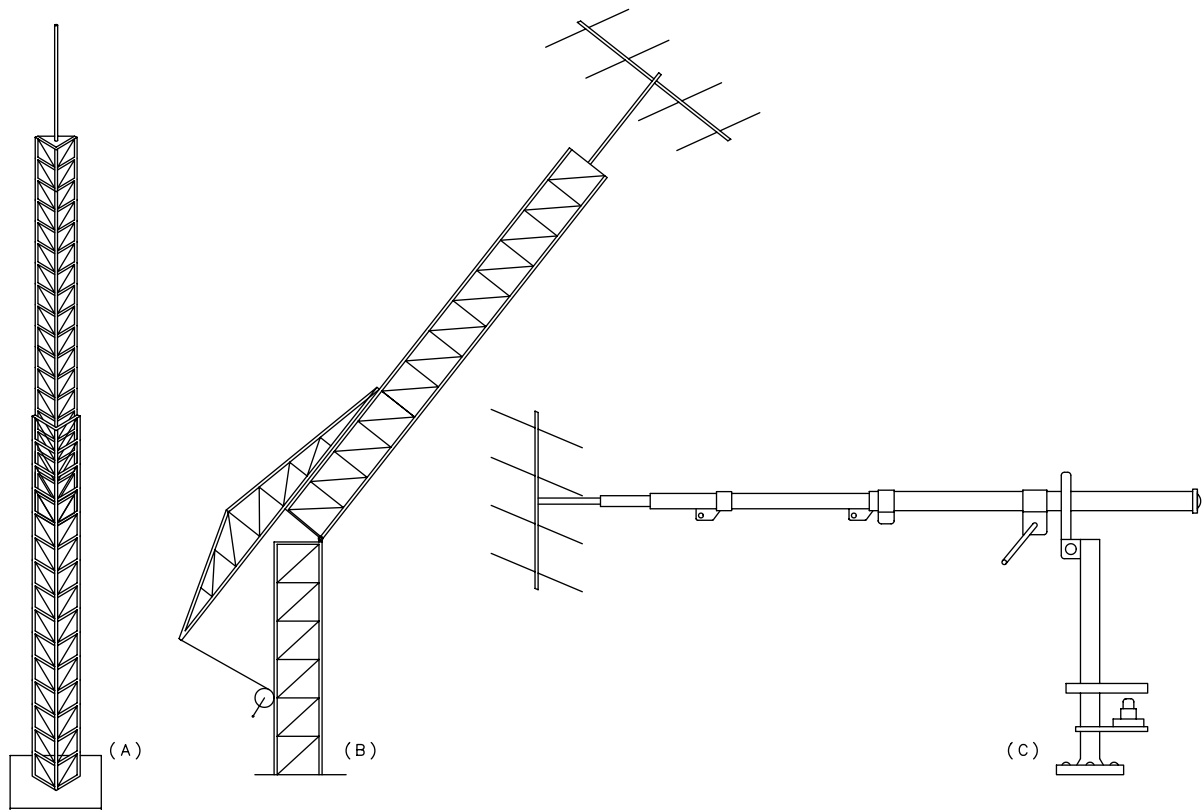


Fig 2—Alternatives to a guyed tower are shown here. At A, the crank-up tower permits working on antennas at reduced height. It also allows antennas to be lowered during periods of no operation. Motor-driven versions are available. The fold-over tower at B and the combination at C permit working on antennas at ground level.

best adjustments can be made for gain, front-to-back ratio (F/B), and matching, *but only for a single band*. In a multiband design, there are always trade-offs in these properties for the ability to operate on more than one band. Nevertheless, a multiband antenna has many advantages over two or more single band antennas. A multiband antenna requires less heavy duty hardware, requires only one feed line, takes up less space, and it costs less.

Apartment dwellers face much greater limitations in their choice of antennas. For most, the possibility of a tower is only a dream. (One enterprising ham made arrangements to purchase a top-floor condominium from a developer. The arrangements were made before construction began, and the plans were altered to include a roof-top tower installation.) For apartment and condominium dwellers, the situation is still far from hopeless. A later section presents ideas for consideration.

EXAMPLES

You can follow the procedure previously outlined to put together modest or very large antenna systems. What might a ham put together for antennas when he or she wants to try a little of everything, and has a modest budget? Let's suppose that the goals are (1) low cost, (2) no tower, (3) coverage of all HF bands and the repeater portion of one VHF band, and (4) the possibility of working some DX.

After studying the pages of this book, the station owner decides to first put up a 135 foot center-fed antenna. High trees in the backyard will serve as supports to about 50 feet. This antenna will cover all the HF bands by using a balanced feeder and an antenna tuner. It should be good for DX contacts on 10 MHz and above, and will probably work okay for DX contacts on the lower bands. However, her plan calls for a vertical for 3.5 and 7 MHz to enhance the DX possibilities on those bands. For VHF, a chimney-mounted vertical is included.

ANOTHER EXAMPLE

A licensed couple has bigger ambitions. Goals for their station are (1) a good setup for DX on 14, 21 and 28 MHz, (2) moderate cost, (3) one tower, (4) ability to work some DX on 1.8, 3.5 and 7 MHz, and (5) no need to cover the CW portion of the bands.

After considering the options, the couple decides to install a 65-foot guyed tower. A large commercial triband Yagi will be mounted on top of the tower. The center of a trap dipole tuned for the phone portion of the 3.5 and 7-MHz bands will be supported by a wooden yard arm installed at the 60-foot level of the tower, with ends drooping down to form an inverted V. An inverted L for 1.8 MHz starts near ground level and goes up to a similar yard arm on the opposite side of the tower. The horizontal portion of the inverted L runs away from the tower at right angles to the trap dipole. Later, the husband will experiment with sloping antennas for 3.5 MHz. If those experiments are not successful, a $\lambda/4$ vertical will be used on that band.

Apartment Possibilities

A complete and accurate assessment of antenna types, antenna placement, and feed-line placement is very important for the apartment dweller. Among the many possibilities for types are balcony antennas, "invisible" ones (made of fine wire), vertical antennas disguised as flag poles or as masts with a TV antenna on top, and indoor antennas.

A number of amateurs have been successful in negotiating with the apartment owner or manager for permission to install a short mast on the roof of the structure. Coaxial lines and rotator control cables might be routed through conduit troughs or through duct work. If you live in one of the upper stories of the building, routing the cables over the edge of the roof and in through a window might be the way to go. There is a story about one amateur who owns a triband beam mounted on a 10-foot mast. But even with such a short mast, he is the envy of all his amateur friends because of his superb antenna height. His mast stands on top of a 22-story apartment building.

Usually the challenge is to find ways to install antennas that are unobtrusive. That means searching

out antenna locations such as balconies, eaves, nearby trees, etc. For example, a simple but effective balcony antenna is a dangling vertical. Attach an “invisible” wire to the tip of a mobile whip or a length of metal rod or tubing. Then mount the rigid part of the antenna horizontally on the balcony rail, dangling the wire over the edge. The antenna is operated against the balcony railing or other metallic framework. A matching network is usually required at the antenna feed point. Metal in the building will likely give a directivity effect, but this may be of little consequence and perhaps even an advantage. The antenna may be removed and stored when not in use.

Frequently, the task of finding an inconspicuous route for a feed line is more difficult than the antenna installation itself. When Al Francisco, K7NHV, lived in an apartment, he used a tree-mounted vertical antenna. The coax feeder exited his apartment through a window and ran down the wall to the ground. Al buried the section of line that went from under the window to a nearby tree. At the tree, a section of enameled wire was connected to the coax center conductor. He ran the wire up the side of the tree away from foot traffic. A few short radials completed the installation. The antenna worked fine, and was never noticed by the neighbors.

See Chapters 6 and 15 for ideas about low-frequency and portable antennas that might fit into your available space. Your options are limited as much by your imagination and ingenuity as by your pocketbook. Another option for apartment dwellers is to operate away from home. Some hams concentrate on mobile operation as an alternative to a fixed station. It is possible to make a lot of contacts on HF mobile. Some have worked DXCC that way.

Suppose that you like VHF contests. Because of other activities, you are not particularly interested in operating VHF outside the contests. Why not take your equipment and antennas to a hilltop for the contests? Many hams combine a love for camping or hiking with their interest in radio.

Antennas for Limited Space

It is not always practical to erect full-size antennas for the HF bands. Those who live in apartment buildings may be restricted to the use of minuscule radiators because of house rules, or simply because the required space for full-size antennas is unavailable. Other amateurs may desire small antennas for aesthetic reasons, perhaps to keep peace with neighbors who do not share their enthusiasm about high towers and big antennas. There are many reasons why some amateurs prefer to use physically shortened antennas; this chapter discusses proven designs and various ways of building and using them effectively.

Few compromise antennas are capable of delivering the performance one can expect from the full-size variety. But the patient and skillful operator can often do as well as some who are equipped with high power and full-size antennas. Someone with a reduced-size antenna may not be able to “bore a hole” in the bands as often, and with the commanding dispatch enjoyed by those who are better equipped, but DX can be worked successfully when band conditions are suitable.

INVISIBLE ANTENNAS

We amateurs don’t regard our antennas as eyesores; in fact, we almost always regard them as works of art! But there are occasions when having an outdoor or visible antenna can present problems.

When we are confronted with restrictions—self-imposed or otherwise—we can take advantage of a number of options toward getting on the air and radiating at least a moderately effective signal. In this context, a poor antenna is certainly better than no antenna at all! This section describes a number of techniques that enable us to use indoor antennas or “invisible” antennas outdoors. Many of these systems will yield good-to-excellent results for local and DX contacts, depending on band conditions at any given time. *The most important consideration is that of not erecting any antenna that can present a hazard (physical or electrical) to humans, animals and buildings. Safety first!*

Clothesline Antenna

Clotheslines are sometimes attached to pulleys (**Fig 3**) so that the user can load the line and re-

trieve the laundry from a back porch. Laundry lines of this variety are accepted parts of the neighborhood “scenery,” and can be used handily as amateur antennas by simply insulating the pulleys from their support points. This calls for the use of a conducting type of clothesline, such as heavy gauge stranded electrical wire with Teflon or vinyl insulation. A high quality, flexible steel cable (stranded) is suitable as a substitute if one doesn’t mind cleaning it each time clothing is hung on it.

A jumper wire can be brought from one end of the line to the ham shack when the station is being operated. If a good electrical connection exists between the wire clothesline and the pulley, a permanent connection can be made by connecting the lead-in wire between the pulley and its insulator. An antenna tuner can be used to match the “invisible” random-length wire to the transmitter and receiver.

Invisible Long Wire

A wire antenna is not actually a “long wire” unless it is one wavelength or greater in length. Yet many amateurs refer to (relatively) long physical spans of conductor as “long wires.” For the purpose of this discussion we will assume we have a fairly long span of wire, and refer to it as an “end-fed” wire antenna.

If we use small-diameter enameled wire for our end-fed antenna, chances are that it will be very difficult to see against the sky and neighborhood scenery. The smaller the wire, the more “invisible” the antenna will be. The limiting factor with small wire is fragility. A good compromise is #24 or #26 magnet wire for spans up to 130 feet; lighter-gauge wire can be used for shorter spans, such as 30 or 60 feet. The major threat to the longevity of fine wire is icing. Also, birds may fly into the wire and break it. Therefore, this style of antenna may require frequent service or replacement.

Fig 4 illustrates how we might install an invisible end-fed wire. It is important that the insulators also be lacking in prominence. Tiny Plexiglas blocks perform this function well. Small-diameter clear plastic medical vials are suitable also. Some amateurs simply use rubber bands for end insulators, but they will deteriorate rapidly from sun and air pollutants. They are entirely adequate for short-term operation with an invisible antenna, however.

Rain Gutter and TV Antennas

A great number of amateurs have taken advantage of standard house fixtures when contriving inconspicuous antennas. A very old technique is the use of the gutter and down spout system on the building. This is shown in **Fig 5**, where a lead wire is routed to the operating room from one end of the gutter trough. We must assume that the wood to which the gutter is affixed is dry and of good quality to provide reasonable electrical insulation.

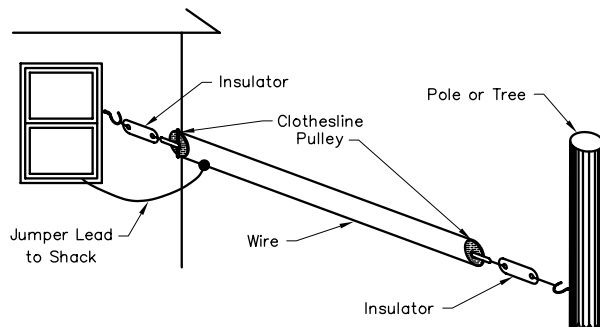


Fig 3—The clothesline antenna is more than it appears to be.

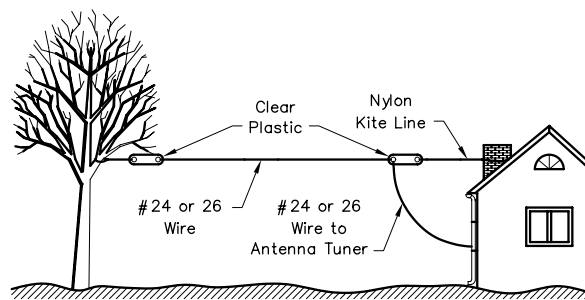


Fig 4—The “invisible” end-fed antenna.

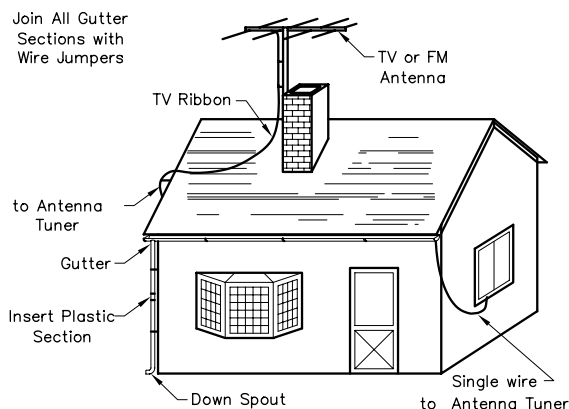


Fig 5—Rain gutters and TV antenna installations can be used as inconspicuous Amateur Radio antennas.

The rain gutter antenna may perform quite poorly during wet weather or when there is ice and snow on it and the house roof.

All joints between gutter and down spout sections must be bonded electrically with straps of braid or flashing copper to provide good continuity in the system. Poor joints can permit rectification of RF and subsequently cause TVI and other harmonic interference. Also, it is prudent to insert a section of plastic down spout about 8 feet above ground to prevent RF shocks or burns to passersby while the antenna is being used. Improved performance may result if the front and back gutters of the house are joined by a jumper wire to increase the area of the antenna.

Fig 5 also shows a TV or FM antenna that can be employed as an invisible amateur antenna. Many of these antennas can be modified easily to accommodate the 144 or 222-MHz bands, thereby permitting the use of the 300- Ω line as a feeder system. Some FM antennas can be used on 6 meters by adding #10 bus wire extensions to the ends of the elements, and adjusting the match for an SWR of 1:1. If 300- Ω line is used it will require a balun or antenna tuner to interface the line with the station equipment.

For operation in the HF bands, the TV or FM antenna feeders can be tied together at the transmitter end of the span and the system treated as a random length wire. If this is done, the 300- Ω line will have to be on TV standoff insulators and spaced well away from phone and power company service entrance lines. Naturally, the TV or FM radio must be disconnected from the system when it is used for amateur work! Similarly, masthead amplifiers and splitters must be removed from the line if the system is to be used for amateur operation. If the system is mostly vertical, a good RF ground system with many radials around the base of the house should be used to improve performance.

A very nice top-loaded vertical can be made from a length of TV mast with a large TV antenna on the top. Radials can be placed on the roof or at ground level with the TV “feed line” acting as part of the vertical. An extensive discussion of loaded verticals and radial systems is given in Chapter 6.

Flagpole Antennas

We can exhibit our patriotism and have an invisible amateur antenna at the same time by disguising our antenna as shown in Fig 6. The vertical antenna is a wire that has been placed inside a plastic or fiberglass pole.

The flagpole antenna shown is structured for a single amateur band, and it is assumed that the height of the pole corresponds to a quarter wavelength for the chosen band. The radials and feed line can be buried in the ground as shown. In a practical installation, the sealed end of the coax cable would protrude slightly into the lower end of the plastic pole.

If a large-diameter fiberglass pole were available, a multiband trap vertical may be concealed inside it. Or we might use a metal pole and bury a water-tight box at its base, containing fixed-tuned matching networks for the bands of interest. The networks could then be selected remotely by means of relays inside the box. A 30-foot flagpole would provide good results in this kind of system, provided it was used in conjunction with a buried radial system.

Still another technique is one that employs a wooden flagpole. A small diameter wire can be stapled to the pole and routed to the coax feeder or matching network. The halyard could by itself constitute the antenna wire if it were made from heavy duty insulated hookup wire. There are countless variations for this type of antenna, and they are limited only by the imagination of the amateur.

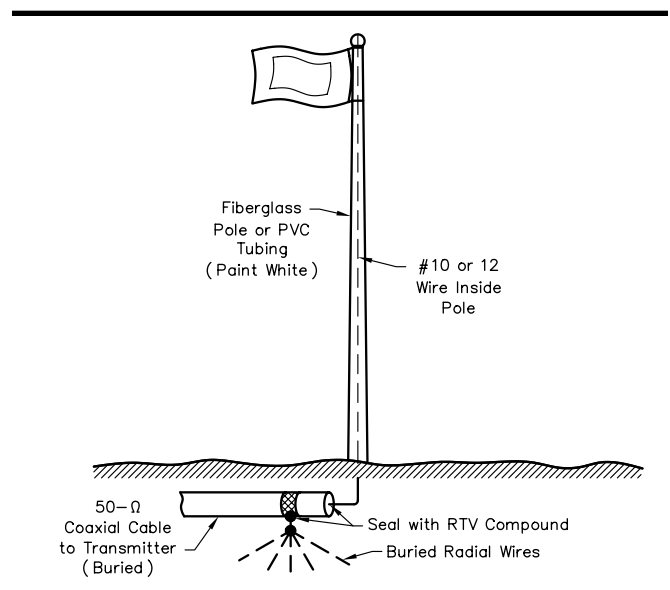


Fig 6—A flagpole antenna.

Other Invisible Antennas

Some amateurs have used the metal fence on apartment verandas as antennas, and have had good results on the upper HF bands (14, 21 and 28 MHz). We must presume that the fences were not connected to the steel framework of the building, but rather were insulated by the concrete floor to which they were affixed. These veranda fences have also been used effectively as ground systems (counterpoises) for HF-band vertical antennas put in place temporarily after dark.

One New York City amateur uses the fire escape on his apartment building as a 7-MHz antenna, and reports good success working DX stations with it. Another apartment dweller makes use of the aluminum frame on his living room picture window as an antenna for 21 and 28 MHz. He works it against the metal conductors of the baseboard heater in the same room.

Many jokes have been told over the years about “bedspring antennas.” The idea is by no means absurd. Bedsprings and metal end boards have been used to advantage as antennas by many apartment dwellers as 14, 21, and 28 MHz radiators. A counterpoise ground can be routed along the baseboard of the room and used in combination with the bedspring. It is important to remember that any independent (insulated) metal object of reasonable size can serve as an antenna if the transmitter can be matched to it. An amateur in Detroit once used his Shoptsmith craft machine (about 5 feet tall) as a 28-MHz antenna. He worked a number of DX stations with it when band conditions were good.

A number of operators have used metal curtain rods and window screens for VHF work, and found them to be acceptable for local communication. Best results with any of these makeshift antennas will be had when the “antennas” are kept well away from house wiring and other conductive objects.

INDOOR ANTENNAS

Without question, the best place for your antenna is outdoors, and as high and in the clear as possible. Some of us, however, for legal, social, neighborhood, family or landlord reasons, are restricted to indoor antennas. Having to settle for an indoor antenna is certainly a handicap for the amateur seeking effective radio communication, but that is not enough reason to abandon all operation in despair.

First, we should be aware of the reasons why indoor antennas do not work well. Principal faults are: (1) low height above ground—the antenna cannot be placed higher than the highest peak of the roof, a point usually low in terms of wavelength at HF, (2) the antenna must function in a lossy RF environment involving close coupling to electrical wiring, guttering, plumbing and other parasitic conductors, besides dielectric losses in such nonconductors as wood, plaster and masonry, (3) sometimes the antenna must be made small in terms of a wavelength and (4) usually it cannot be rotated. These are appreciable handicaps. Nevertheless, global communication with an indoor antenna is still possible, although you must be sure that you are not exposing anyone in your family or nearby neighbors to excessive radiation. See Chapter 1 on Safety.

Some practical points in favor of the indoor antenna include: (1) freedom from weathering effects and damage caused by wind, ice, rain and sunlight (the SWR of an attic antenna, however, can be affected somewhat by a wet or snow-covered roof), (2) indoor antennas can be made from materials that would be altogether impractical outdoors, such as aluminum foil and thread (the antenna need support only its own weight), (3) the supporting structure is already in place, eliminating the need for antenna masts and (4) the antenna is readily accessible in all weather conditions, simplifying pruning or tuning, which can be accomplished without climbing or tilting over a tower.

Empiricism

A typical house or apartment presents such a complex electromagnetic environment that it is impossible to predict theoretically which location or orientation of the indoor antenna will work best. This is where good old fashioned cut-and-try, use-what-works-best empiricism pays off. But to properly determine what really is most suitable requires an understanding of some antenna measuring fundamentals.

Unfortunately, many amateurs do not know how to evaluate performance scientifically or compare one antenna with another. Typically, they will put up one antenna and try it out on the air to see how it “gets out” in comparison with a previous antenna. This is obviously a very poor evaluation method because there is no

way to know if the better or worse reports are caused by changing band conditions, different S-meter characteristics, or any of several other factors that could influence the reports received.

Many times the difference between two antennas or between two different locations for identical antennas amounts to only a few decibels, a difference that is hard to discern unless instantaneous switching between the two is possible. Those few decibels are not important under strong signal conditions, of course, but when the going gets rough, as is often the case with an indoor antenna, a few dB can make the difference between solid copy and no possibility of real communication.

Very little in the way of test equipment is needed for casual antenna evaluation, other than a communications receiver. You can even do a qualitative comparison by ear, if you can switch antennas instantaneously. Differences of less than 2 dB, however, are still hard to discern. The same is true of S-meters. Signal strength differences of less than a decibel are usually difficult to see. If you want that last fraction of a decibel, you should use a good ac voltmeter at the receiver audio output (with the AGC turned off).

In order to compare two antennas, switching the coaxial transmission line from one to the other is necessary. No elaborate coaxial switch is needed; even a simple double throw toggle or slide switch will provide more than 40 dB of isolation at HF. See **Fig 7**. Switching by means of manually connecting and disconnecting coaxial lines is not recommended because that takes too long. Fading can cause signal-strength changes during the changeover interval.

Whatever difference shows up in the strength of the received signal will be the difference in performance between the two antennas in the direction of that signal. For this test to be valid, both antennas must have nearly the same feed-point impedance, a condition that is reasonably well met if the SWR is below 2:1 on both antennas.

On ionospheric propagated signals (sky wave) there will be constant fading, and for a valid comparison it will be necessary to take an average of the difference between the two antennas. Occasionally, the inferior antenna will deliver a stronger signal to the receiver, but in the long run the law of averages will put the better antenna ahead.

Of course with a ground-wave signal, such as that from a station across town, there will be no fading problems. A ground-wave signal will enable the operator to properly evaluate the antenna under test in the direction of the source. The results will be valid for ionospheric-propagated signals at low elevation angles in that direction. On 28 MHz, all sky-wave signals arrive and leave at low angles. But on the lower bands, particularly 3.5 and 7 MHz, we often use signals propagated at high elevation angles, almost up to the zenith. For these angles a ground-wave test will not provide a proper evaluation of the antenna, and use of sky-wave signals becomes necessary.

Dipoles

At HF the most practical indoor antenna is usually the dipole. Attempts to get more gain with parasitic elements will usually fail because of close proximity of the ground or coupling to house wiring. Beam antenna dimensions determined outdoors will not usually be valid for an attic antenna because the roof structure will cause dielectric loading of the parasitic elements. It is usually more worthwhile to spend time optimizing the location and performance of a dipole than to try to improve results with parasitic elements.

Most attics are not long enough to accommodate half-wave dipoles for 7 MHz and below. If this is the case, some folding of the dipole will be necessary. The final shape of the antenna will depend on the dimensions and configuration of the attic. Remember that the center of the dipole carries the most current

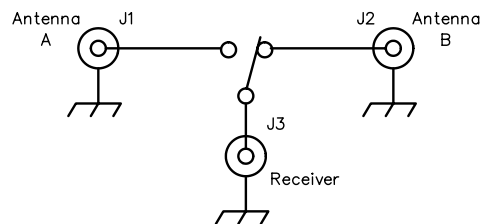


Fig 7—When antennas are compared on fading signals, the time delay involved in disconnecting and reconnecting coaxial cables is too long for accurate measurements. A simple slide switch will do well for switching coaxial lines at HF. The four components can be mounted in a tin can or any small metal box. Leads should be short and direct. J1 through J3 are coaxial connectors.

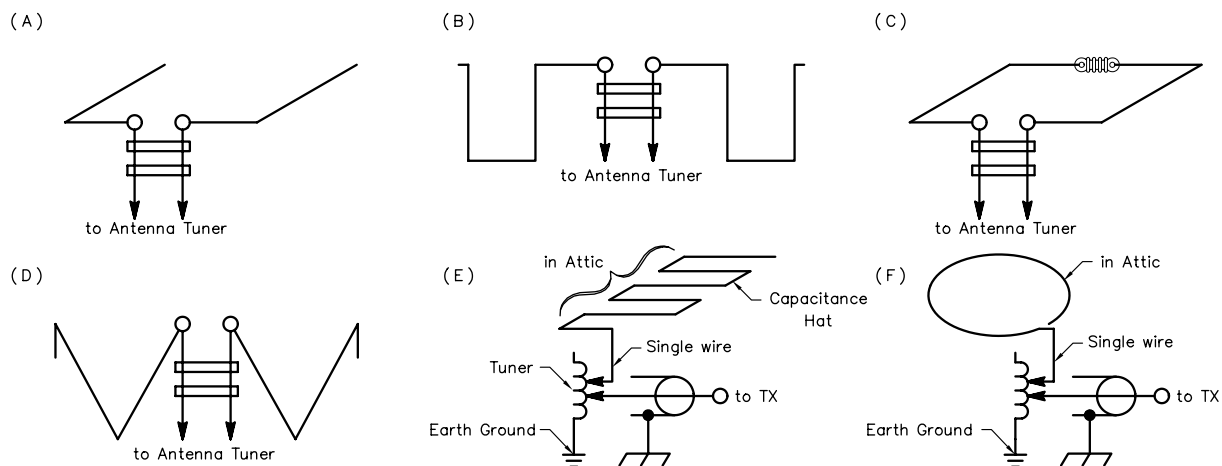


Fig 8—Various configurations for small indoor antennas. See text for discussion.

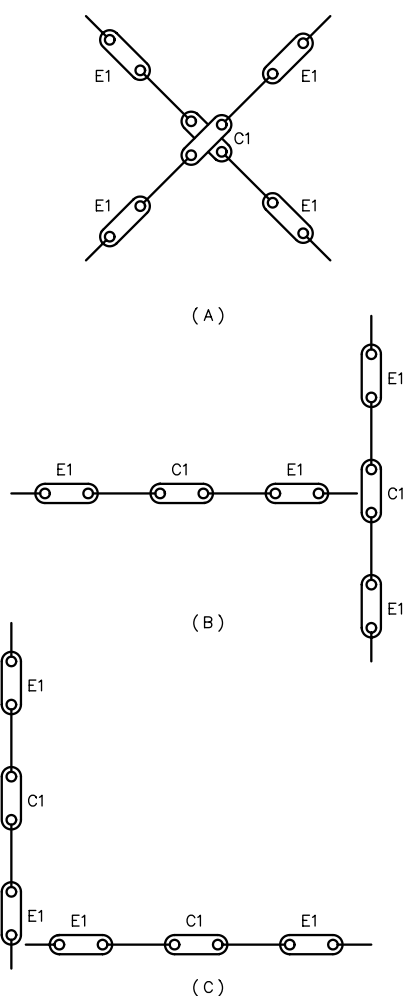


Fig 9—Ways to orient a pair of perpendicular dipoles. The orientation at A and B will result in no mutual coupling between the two dipoles, but there will be some coupling in the configuration shown at C. End (E1) and center (C1) insulators are shown.

and therefore does most of the radiating. This part should be as high and unfolded as possible. Because the dipole ends radiate less energy than the center, their orientation is not as important. They do carry the maximum voltage, nevertheless, so care should be taken to position the ends far enough from other conductors to avoid arcing.

The dipole may end up being L-shaped, Z-shaped, U-shaped or some indescribable corkscrew shape, depending on what space is available, but reasonable performance can often be had even with such a nonlinear arrangement. **Fig 8** shows some possible configurations. Multiband operation is possible with the use of open-wire feeders and an antenna tuner.

One alternative not shown here is the aluminum-foil dipole, which was conceived by Rudy Stork, KA5FSB. He suggests mounting the dipole behind wallpaper or in the attic, with portability, ease of construction and adjustment, and economy in design among its desirable features. This antenna should also display reasonably good bandwidth resulting from the large area of its conductor material. If coaxial feed is used, some pruning of an attic antenna to establish minimum SWR at the band center will be required. Tuning the antenna outdoors and then installing it inside is usually not feasible since the behavior of the antenna will not be the same when placed in the attic. Resonance will be affected somewhat if the antenna is bent.

Even if the antenna is placed in a straight line, parasitic conductors and dielectric loading by nearby wood structures can affect the impedance. Trap and

loaded dipoles are shorter than the full-sized versions, but are comparable performers. Trap dipoles are discussed in Chapter 7; loaded dipoles in Chapter 6.

Dipole Orientation

Theoretically a vertical dipole is most effective at low radiation angles, but practical experience shows that the horizontal dipole is usually a better indoor antenna. A high horizontal dipole does exhibit directional effects at low radiation angles, but you will not be likely to see much, if any, directivity with an attic-mounted dipole. Some operators place two dipoles at right angles to each other with provisions at the operating position for switching between the two. Their reasoning is the radiation patterns will inevitably be distorted in an unpredictable manner by nearby parasitic conductors. There will be little coupling between the dipoles if they are oriented at right angles to each other as shown in **Figs 9A and 9B**. There will be some coupling with the arrangement shown in Fig 9C, but even this orientation is preferable to a single dipole.

With two antennas mounted 90° apart, you may find that one dipole is consistently better in nearly all directions, in which case you will want to remove the inferior dipole, perhaps placing it someplace else. In this manner the best spots in the house or attic can be determined experimentally.

Parasitic Conductors

Inevitably, any conductor in your house near a quarter wave in length or longer at the operating frequency will be parasitically coupled to your antenna. The word parasitic is particularly appropriate in this case because these conductors usually introduce losses and leave less energy for radiation into space. Unlike the parasitic elements in a beam antenna conductors such as house wiring and plumbing are usually connected to lossy objects such as earth, electrical appliances, masonry or other objects that dissipate energy. Even where this energy is reradiated, it is not likely to be in the right phase in the desired direction; it is, in fact, likely to be a source of RFI.

There are, however, some things that can be done about parasitic conductors. The most obvious is to reroute them at right angles to the antenna or close to the ground, or even underground—procedures that are usually not feasible in a finished home. Where these conductors cannot be rerouted, other measures can be taken. Electrical wiring can be broken up with RF chokes to prevent the flow of radio-frequency currents while permitting 60-Hz current (or audio, in the case of telephone wires) to flow unimpeded. A typical RF choke for a power line can be 100 turns of #10 insulated wire close wound on a length of 1-inch diameter plastic pipe. Of course one choke will be needed for each conductor. A three-wire line calls for three chokes. The chokes can be simplified by winding them bifilar or trifilar on a single coil form.

THE RESONANT BREAKER

Obviously, RF chokes cannot be used on conductors such as metal conduit or water pipes. But it is still possible, surprising as it may seem, to obstruct RF currents on such conductors without breaking the metal. The resonant breaker was first described by Fred Brown, W6HPH, in Oct 1979 *QST*.

Fig 10 shows a method of accomplishing this. A figure-eight loop is inductively coupled to the

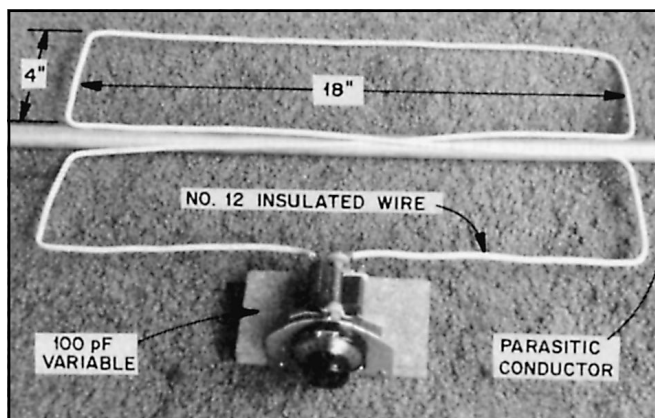


Fig 10—A “resonant breaker” such as shown here can be used to obstruct radio-frequency currents in a conductor without the need to break the conductor physically. A vernier dial is recommended for use with the variable capacitor because tuning is quite sharp. The 100-pF capacitor is in series with the loop. This resonant breaker tunes from 14 through 29.7 MHz. Larger models may be constructed for the lower frequency bands.

parasitic conductor and is resonated to the desired frequency with a variable capacitor. The result is a very high impedance induced in series with the pipe, conduit or wire. This impedance will block the flow of radio-frequency currents. The figure-eight coil can be thought of as two turns of an air-core toroid and since the parasitic conductor threads through the hole of this core, there will be tight coupling between the two. Inasmuch as the figure-eight coil is parallel resonated, transformer action will reflect a high impedance in series with the linear conductor.

Before you bother with a “resonant breaker” of this type, be sure that there is a significant amount of RF current flowing in the parasitic conductor, and that you will therefore benefit from installing one. The relative magnitude of this current can be determined with an RF current probe of the type described in [Chapter 27](#). According to the rule of thumb regarding parasitic conductor current, if it measures less than $1/10$ of that measured near the center of the dipole, the parasitic current is generally not large enough to be of concern.

The current probe is also needed for resonating the breaker after it is installed. Normally, the resonant breaker will be placed on the parasitic conductor near the point of maximum current. When it is tuned through resonance, there will be a sharp dip in RF current, as indicated by the current probe. Of course, the resonant breaker will be effective only on one band. You will need one for each band where there is significant current indicated by the probe.

Power-Handling Capability

So far, our discussion has been limited to the indoor antenna as a receiving antenna, except for the current measurements, where it is necessary to supply a small amount of power to the antenna. These measurements will not indicate the full power-handling capability of the antenna. Any tendency to flash over must be determined by running full power or, preferably, somewhat more than the peak power you intend to use in regular operation. The antenna should be carefully checked for arcing or RF heating before you do any operating. Bear in mind that attics are indeed vulnerable to fire hazards. A potential of several hundred volts exists at the ends of a dipole fed by the typical Amateur Radio transmitter. If a power amplifier is used, there could be a few thousand volts at the ends of the dipole. Keep your antenna elements well away from other objects. *Safety first!*

Construction Details and Practical Considerations

Ultimately the success of an antenna project depends on the details of how the antenna is fabricated. A great deal of construction information is given in other chapters of this book. For example the construction of HF Yagis is discussed in [Chapter 11](#), Quad arrays in [Chapter 12](#), VHF antennas in [Chapter 18](#) and in [Chapter 20](#) there is an excellent discussion of antenna materials, particularly wire and tubing for elements. Here is still more helpful antenna construction information.

END EFFECT

If the standard expression $\lambda/2 \approx 491.8/f(\text{MHz})$ is used for the length of a $\lambda/2$ wire antenna, the antenna will resonate at a somewhat lower frequency than is desired. The reason is that in addition to the effect of the conductor diameter and ground effects (Chapter 3) an additional “loading” effect is caused by the insulators used at the ends of the wires to support the antenna. The insulators and the wire loops that tie the insulators to the antenna add a small amount of capacitance to the system. This capacitance helps to tune the antenna to a slightly lower frequency, in much the same way that additional capacitance in any tuned circuit lowers the resonant frequency. In an antenna this is called *end effect*. The current at the ends of the antenna does not quite reach zero because of the end effect, as there is some current flowing into the end capacitance. Note that the computations used to create Figs 2 through 7 in [Chapter 2](#) did not take into account any end effect.

End effect increases with frequency and varies slightly with different installations. However, at frequencies up to 30 MHz (the frequency range over which wire antennas are most commonly used), experience shows that the length of a practical $\lambda/2$ antenna, including the effect of diameter and end

effect, is on the order of 5% less than the length of a half wave in space. As an average, then, the physical length of a resonant $\lambda/2$ wire antenna can be found from:

$$\lambda = \frac{491.8 \times 0.95}{f(\text{MHz})} \approx \frac{468}{f(\text{MHz})} \quad (\text{Eq 1})$$

Eq 1 is reasonably accurate for finding the physical length of a $\lambda/2$ antenna for a given frequency, but does not apply to antennas longer than a half wave in length. In the practical case, if the antenna length must be adjusted to exact frequency (not all antenna systems require it) the length should be “pruned” to resonance.

INSULATORS

Wire antennas must be insulated at the ends. Commercially available insulators are made from ceramic, glass or plastic. Insulators are available from many Amateur Radio dealers. Radio Shack and local hardware stores are other possible sources. Acceptable homemade insulators may be fashioned from a variety of material including (but not limited to) acrylic sheet or rod, PVC tubing, wood, fiberglass rod or even stiff plastic from a discarded container. **Fig 11** shows some homemade insulators. Ceramic or glass insulators will usually outlast the wire, so they are highly recommended for a safe, reliable, permanent installation. Other materials may tear under stress or break down in the presence of sunlight. Many types of plastic do not weather well.

Installing Transmission Lines

Many wire antennas require an insulator at the feed point. Although there are many ways to connect the feed line, there are a few things to keep in mind. If you feed your antenna with coaxial cable, you have two choices. You can install an SO-239 connector on the center insulator, as shown by the center example in **Fig 12**, and use a PL-259 on the end of your coax, or you can separate the center conductor from the braid and connect the feed line directly to the antenna wire as shown in the other two examples in Fig 12 and the example in **Fig 13**. Although it costs less to connect direct, the use of connectors offers several advantages. Coaxial cable braid soaks

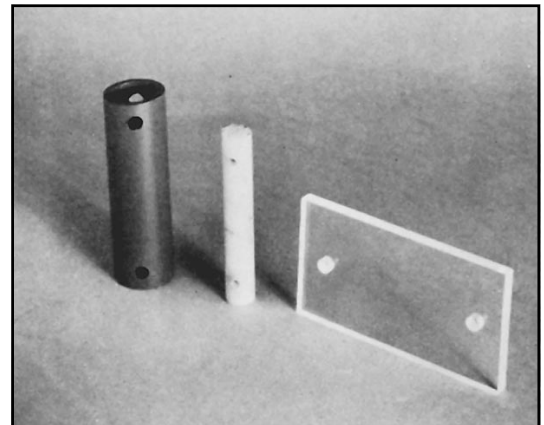
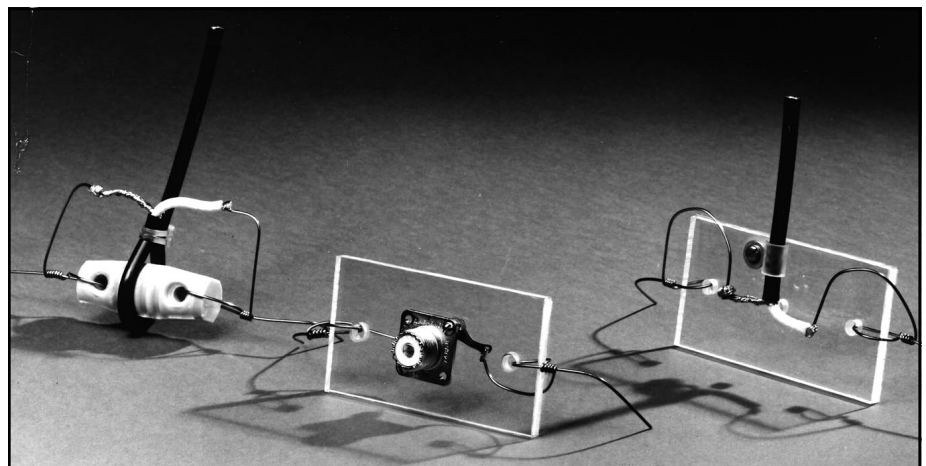


Fig 11—Some ideas for homemade antenna insulators.

Fig 12—Some homemade dipole center insulators. The one in the center includes a built-in SO-239 connector. Others are designed for direct connection to the feed line.



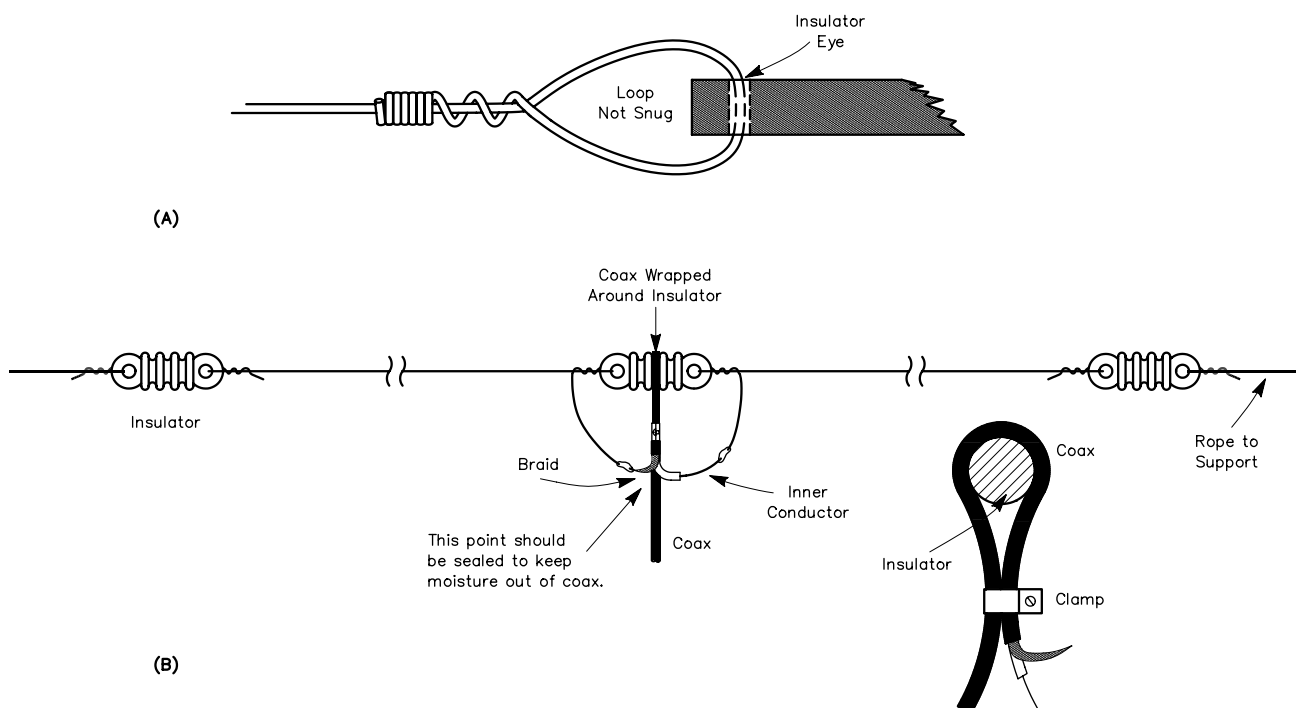


Fig 13—Details of dipole antenna construction. At A, the end insulator connection is shown. At B, the completed antenna is shown. A balun (not shown) is often used at the feed point, since this is a balanced antenna.

up water like a sponge. If you do not adequately seal the antenna end of the feed line, water will find its way into the braid. Water in the feed line will lead to contamination, rendering the coax useless long before its normal lifetime is up.

It is not uncommon for water to drip from the end of the coax inside the shack after a year or so of service if the antenna connection is not properly waterproofed. Use of a PL-259/SO-239 combination (or connector of your choice) makes the task of waterproofing connections much easier. Another advantage to using the PL-259/SO-239 combination is that feed-line replacement is much easier, should that become necessary.

Whether you use coaxial cable, ladder line, or twin lead to feed your antenna, an often overlooked consideration is the mechanical strength of the connection. Wire antennas and feed lines tend to move a lot in the breeze, and unless the feed line is attached securely, the connection will weaken with time. The resulting failure can range from a frustrating intermittent electrical connection to a complete separation of feed line and antenna. Fig 13 and Fig 14 illustrate different ways of attaching either coax or ladder line to the antenna securely.

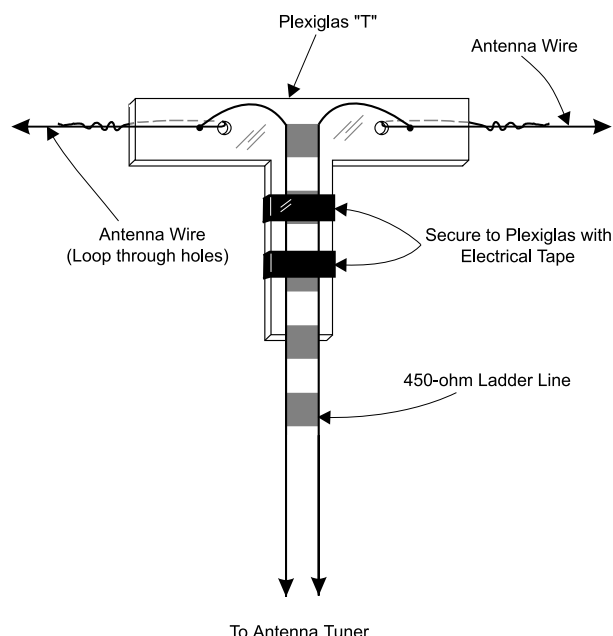


Fig 14—A piece of cut Plexiglas can be used as a center insulator and to support a ladder-line feeder. The Plexiglas acts to reduce the flexing of the wires where they connect to the antenna. Use thick Plexiglas in areas subject to high winds.

When open-wire feed line is used, the conductors of the line should be anchored to the insulator by threading them through the eyes of the insulator two or three times, and twisting the wire back on itself before soldering. A slack tie wire should then be used between the feeder conductor and the antenna, as shown in Fig 14. (The tie wires may be extensions of the line conductors themselves.) When window-type line is suspended from an antenna in a manner such as that shown in Fig 14, the line should be twisted—at several twists per foot—to prevent stress hardening of the wire because of constant flexing in the wind.

When using plastic-insulated open-wire line, the tendency of the line to twist and short out close to the antenna can be counteracted by making the center insulator of the antenna longer than the spacing of the line, as shown in Fig 14. In severe wind areas, it may be necessary to use 1/4-inch thick Plexiglas for the center insulator rather than thinner material.

RUNNING THE FEED LINE FROM THE ANTENNA TO THE STATION

Chapter 24 contains some general guidelines for installing feed lines. More detailed information is contained in this section. Whenever possible, the transmission line should be lead away from the antenna at a 90° angle to minimize coupling from the antenna to the transmission line. This coupling can cause unequal currents on the transmission line, which will then radiate and it can detune the antenna.

Except for the portion of the line in close proximity to the antenna, coaxial cable requires no particular care in running from the antenna to the station entrance, other than protection from mechanical damage. If the antenna is not supported at the center, the line should be fastened to a post more than head high located under the center of the antenna, allowing enough slack between the post and the antenna to take care of any movement of the antenna in the wind. If the antenna feed point is supported by a tower or mast, the cable can be taped to the mast at intervals or to one leg of the tower.

Coaxial cable rated for direct burial can be buried a few inches in the ground to make the run from the antenna to the station. A deep slit can be cut by pushing a square-end spade full depth into the ground and moving the handle back and forth to widen the slit before removing the spade. After the cable has been pushed into the slit with a piece of 1-inch board 3 or 4 inches wide, the slit can be tamped closed.

Solid ribbon or the newer “window” types of line should be kept reasonably well spaced from other conductors running parallel to it for more than a few feet. The “rule of thumb” is to space open-wire line away from other conductors by at least twice the spacing between the wires in the line. TV-type standoff insulators with strap clamp mountings can be used for running this type of line down a mast or tower leg. Similar insulators of the screw-in type can be used in supporting the line on wooden poles for a long run.

Open-wire lines with bare conductors require frequent supports to keep the lines from twisting and shorting out, as well as to relieve the strain. One method of supporting a long horizontal run of heavy open-wire line is shown in Fig 15. The line must be anchored securely at a point under the feed point of the antenna. Window-type line can be supported similarly with wire links fastened to the insulators.

To keep the line clear of pedestrians and vehicles, it is usually desirable to anchor the feed line at the eaves or rafter line of the station building (see Fig 16), and then drop it vertically to the point of entrance. The points of anchorage and entrance should be chosen to permit the vertical drop without crossing windows.

If the station is located in a room on the ground floor, one way of bringing coax transmission line into the house is to go through the outside wall below floor level, feed it through the basement or crawl space, and then up to the station through a hole in the floor. When making the entrance hole in the side of the building, suitable measurements should be made in advance to be sure the hole will go through the sill 2 or 3 inches above the foundation line (and between joists if the bore is parallel to the joists). The line should be allowed to sag

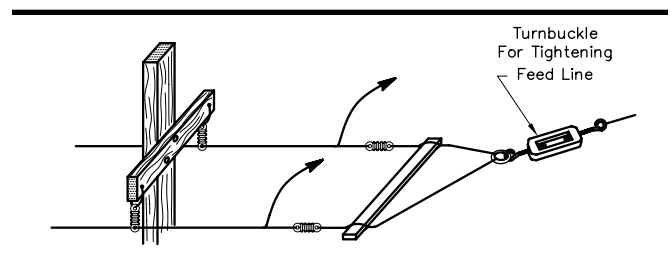


Fig 15—A support for open-wire line. The support at the antenna end of the line must be sufficiently rigid to stand the tension of the line.

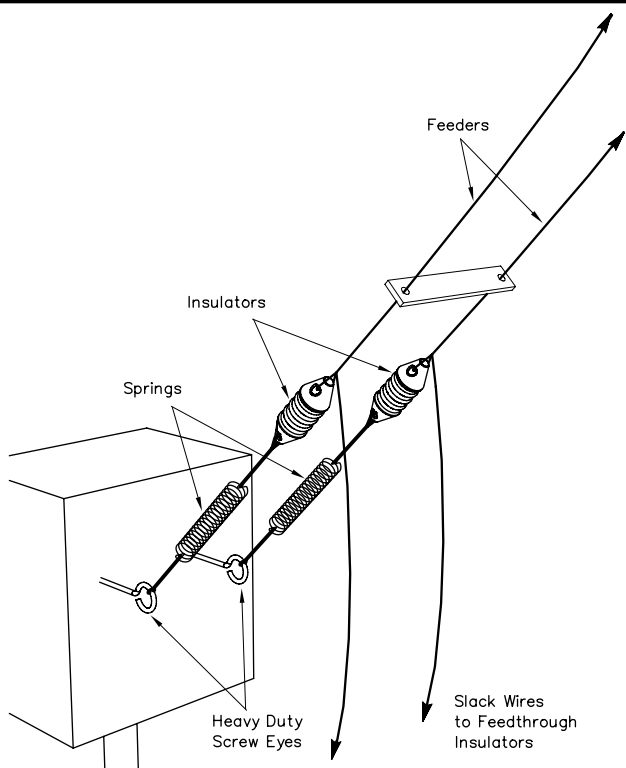


Fig 16—Anchoring open-wire line at the station end. The springs are especially desirable if the line is not supported between the antenna and the anchoring point.

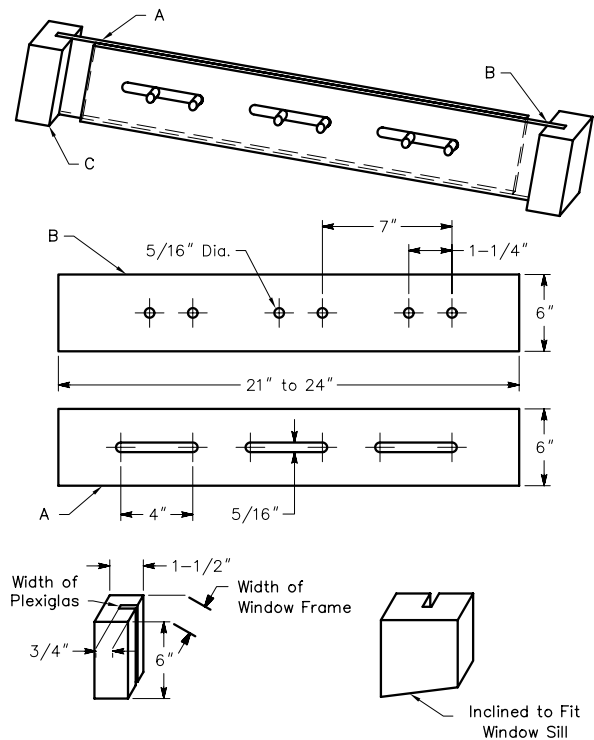


Fig 17—An adjustable window lead-in panel made up of two sheets of Lucite or Plexiglas. A feedthrough connector for coax line can be made as shown in Fig 18. Ceramic feedthrough insulators are suitable for open-wire line. (W1RVE)

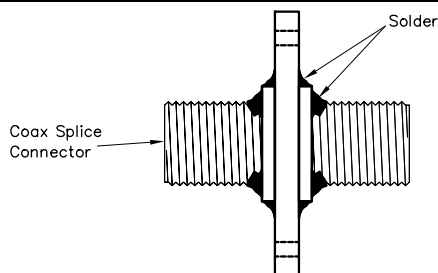


Fig 18—Feedthrough connector for coax line. An Amphenol 83-1J (PL-258) connector, the type used to splice sections of coax line together, is soldered into a hole cut in a brass mounting flange. An Amphenol bulkhead adapter 83-1F may be used instead.

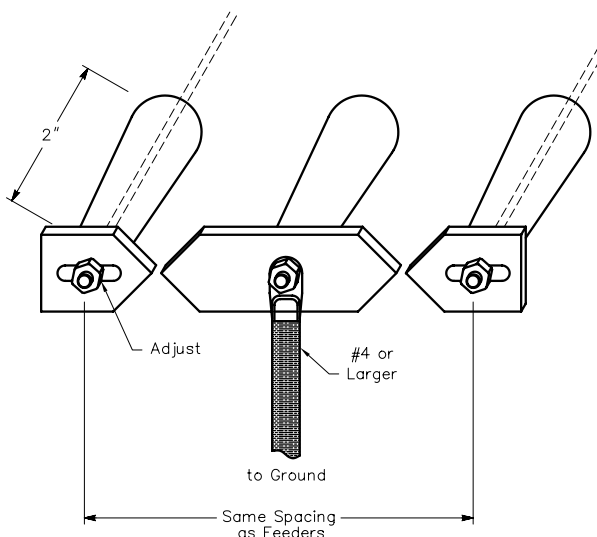


Fig 19—A simple lightning arrester for open-wire line made from three standoff or feedthrough insulators and sections of 1/8 x 1/2-inch brass or copper strap. It should be installed in the line at the point where the line enters the station. The heavy ground lead should be as short and as direct as possible. The gap setting should be adjusted to the minimum width that will prohibit arcing when the transmitter is operated.

below the entrance hole level outside the building to allow rain water to drip off.

Open-wire line can be fed in a similar manner, although it will require a separate hole for each conductor. Each hole should be insulated with a length of polystyrene or Lucite tubing. If available, ceramic tubes salvaged from old-fashioned “knob and tube” electrical installations, work very well for this purpose. Drill the holes with a slight downward slant toward the outside of the building to prevent rain seepage. With window ladder line, it will be necessary to remove a few of the spreader insulators, cut the line before passing through the holes (allowing enough length to reach the inside), and splice the remainder on the inside.

If the station is located above ground level, or if there is other objection to the procedure described above, entrance can be made at a window, using the arrangement shown in **Fig 17**. An Amphenol type 83-1F (UG-363) connector can be used as shown in **Fig 18**; ceramic feedthrough insulators can be used for open-wire line. Ribbon line can be run through clearance holes in the panel, and secured by a winding of tape on either side of the panel, or by cutting the retaining rings and insulators from a pair of TV standoff insulators, and clamping one on each side of the panel.

LIGHTNING PROTECTION

Two or three types of lightning arresters for coaxial cable are available on the market. If the antenna feed point is at the top of a well-grounded tower, the arrester can be fastened securely to the top of the tower for grounding purposes. A short length of cable, terminated in a coaxial plug, is then run from the antenna feed point to one receptacle of the arrester, while the transmission line is run from the other arrester receptacle to the station. Such arresters may also be placed at the entrance point to the station, if a suitable ground connection is available at that point (or arresters may be placed at both points for added insurance).

The construction of a homemade arrester for open-wire line is shown in **Fig 19**. This type of arrester can be adapted to ribbon line an inch or so away from the center member of the arrester, as shown in **Fig 20**. Sufficient insulation should be removed from the line where it crosses the arrester to permit soldering the arrester connecting leads.

Lightning Grounds

Lightning-ground connecting leads should be of conductor size equivalent to at least #10 wire. The #8 aluminum wire used for TV-antenna grounds is satisfactory. Copper braid $\frac{3}{4}$ inch wide (Belden 8662-10) is also suitable. The conductor should run in a straight line to the grounding point. The ground connection may be made to a water pipe system (if the pipe is not plastic), the grounded metal frame of a building, or to one or more $\frac{5}{8}$ -inch ground rods driven to a depth of at least 8 feet. More detailed information on lightning protection is contained in **Chapter 1**.

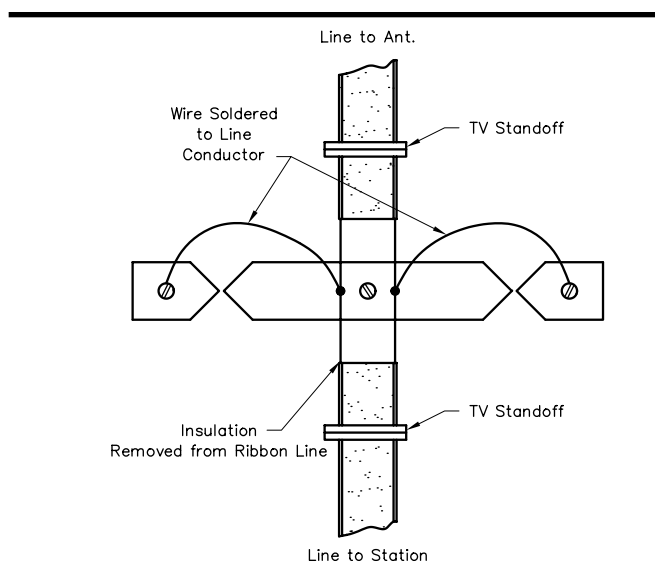


Fig 20—The lightning arrester of **Fig 19** may be used with 300- Ω ribbon line in the manner shown here. The TV standoffs support the line an inch or so away from the grounded center member of the arrester.