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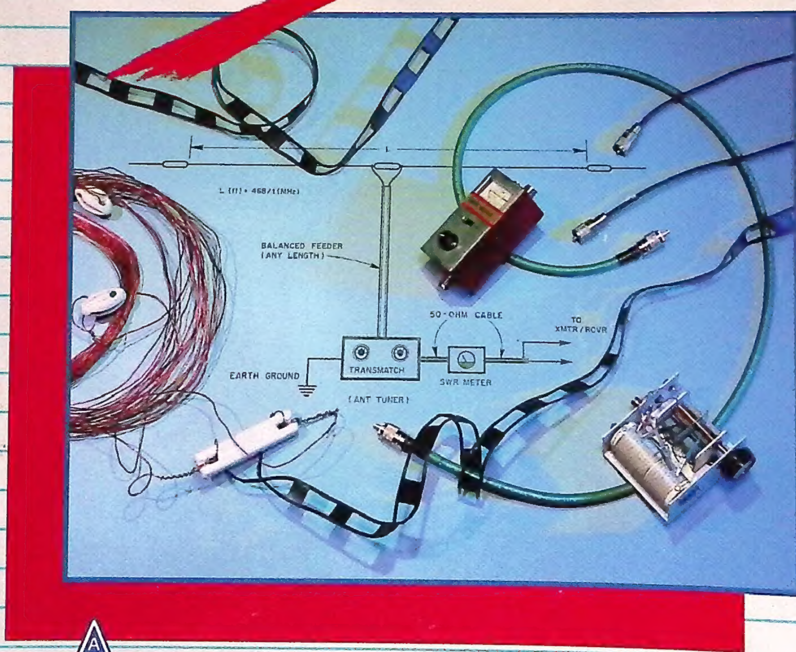
NEW IDEAS FOR BEGINNING HAMS

NOVICE ANTENNA NOTEBOOK



By Doug DeMaw, W1FB

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Novice Antenna Notebook

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FOREWORD

Novices need basic information about antennas that will work for them, in language they can understand. Doug DeMaw, W1FB, has been writing articles about antennas for many years. His previous book, **W1FB's Antenna Notebook** has been very well received, and highly praised for its easy-to-understand approach and down-to-earth explanations of antennas.

This is the third in a series of Notebooks by Doug. We are planning to add more to the series in the future. Doug does his antenna, and other, experiments from his home in Luther, Michigan. Doug is a regular contributor to **QST**, the ARRL membership journal. He is also the Commissioner for Lake County, which means he is the head of county government in this beautiful area of upstate Michigan.

We hope this book will encourage you to put up an antenna that works. Your enjoyment of Amateur Radio will increase as you enjoy solid contacts with other amateurs, wherever they may be.

David Sumner, K1ZZ
Executive Vice President

Newington, Connecticut
May, 1988

PREFACE

You are new to Amateur Radio. Your learning period has begun, and part of this grand experience is related to antennas! After all, the most important part of an effective ham station is the antenna system. Expensive transceivers and mediocre antennas do not complement one another if you want to communicate over long-distance paths. A simple truism indicates that your amateur station is only as effective as your antenna permits it to be.

Low power and an efficient, well-designed antenna is often more effective than high power and a poor antenna. The cost-effectiveness of the latter condition is questionable: high power transmitters and amplifiers are expensive.

The overall cost of your new ham station can be reduced if you are willing to construct your own antennas. They are easy to build and erect, and you will learn more about your new pastime if you take part in the fascinating hobby building these radiators. A homemade wire antenna should not cost nearly as much as does an equivalent commercial system. You will not only save dollars, but pride will accompany the construction and use of something you constructed at home.

This notebook is written in plain language that you can understand. Antenna pictorial drawings are supplied herein, along with dimensions for Novice and Technician band use. You need not be a mathematician to duplicate the standard antennas I have described in this publication. Furthermore, you don't need to be a mechanical engineer to build and erect the support structures that are presented in this book.

You will learn also how antennas operate, and what governs their effectiveness for short- and long-distance communication. The effects of antenna height above ground are discussed also, along with the properties of earth ground and artificial ground systems.

I am able to recognize the confusion associated with antennas when a person is first licensed. I began my Amateur Radio career as a Novice/Technician (WN8HHS/W8HHS, 1950). I labored for many weeks as I attempted to select an antenna that would work well on the Novice frequencies. I wrote this notebook in an effort to help you avoid the time and effort I wasted as a beginner. I hope this publication will provide your route to reliable communications over short and long communications paths.

Doug DeMaw, W1FB

Chapter 1

YOUR ANTENNA'S PERSONALITY

Isn't it amazing that we amateurs can string up a piece of wire or erect a length of metal tubing that will help us to send and receive radio signals? Our signals may be heard even if our antenna is made from hair-fine copper wire. On the other hand, we may also use metal conductors that are several feet in diameter, and of proper length, to form an amateur antenna.

This description of an antenna is grossly oversimplified, because many factors are related to acceptable antenna performance. In other words, we can't toss a random length of wire into a tree and expect to communicate around the world -- or even across town! We must follow design "recipes" that help to ensure acceptable antenna performance. We will discuss many of these requirements as we work our way through this notebook.

Before we commence our discussion about antennas and how to build them, let me assure you that it is not necessary for you to be an electronics engineer or technician in order to construct a good ham antenna. You need not be a skilled machinist or carpenter when it comes to making insulators and antenna support structures. Only one qualification is required: you must have the initiative to build, rather than buy, your ham-radio antennas. There will be some antennas, such as multi-band Yagis, that are difficult to build from scratch. You will probably purchase this type of antenna. But, wire antennas and many single-band vertical antennas are within your physical and economic means with respect to home construction. These antennas can be fascinating and fun to build.

Antenna Wire and Tubing

Some newcomers are confused about the proper type of conductors to use for antennas. I have been asked, for example, "Can I use wire that has plastic insulation?" Another common inquiry is, "What is the best wire gauge or diameter for my dipole?" Still another question is, "Which is best? Stranded or solid wire?"

These are good questions, and I fault no one for asking them. Consider the first question. After all, insulation is used to confine ac and dc voltage in circuit wiring. This prevents unwanted short circuits, and the insulation protects us from electrical shock. Therefore, it is reasonable for a beginner to assume that RF (radio-frequency) energy cannot be radiated through the insulation. Actually, this insulating layer has little effect on the radiation of an antenna. It will, however, slow down the passage of RF energy at the higher frequencies, such as VHF and UHF signals. It introduces what is known as a propagation or velocity factor. When this happens we must shorten the wire slightly to compensate for the velocity factor. At HF (high frequency), the effects of insulation are so minor that we can ignore them.

The thinner the insulating material on wire, the better. This is because insulation adds to the weight of the wire, and we may have a problem supporting an insulated-wire antenna because of its weight. It may sag or cause the support masts to bow or break. It is for this reason that most amateurs use bare stranded no. 14 copper wire for antennas. Others prefer enameled single-conductor wire. The insulation is beneficial because it prevents the copper conductor from becoming corroded in the presence of contaminants in the air. This enameled wire will, however, break more readily from flexing in the wind than will stranded copper wire of the same gauge. Furthermore, soft-drawn single-conductor copper wire will stretch with time, and this will change the resonant frequency of the antenna (move it lower in frequency). For this reason you should make certain that you purchase hard-drawn copper wire.

A stronger type of wire is available. It is known as Copperweld (TM), to signify that it has a steel core with a copper coating. It is difficult to work with because it is quite springy and hard to manage. It is very rugged wire, and it should stay aloft for years. You should avoid kinking it during handling. Avoid sharp bends in the wire also. Kinking and radical bending ruptures the copper covering, and this allows moisture and pollutants to reach the steel core. This will, in time, cause the wire to break.

Wire gauges 12 and 14 are the most popular among amateurs. These sizes offer good strength, cross-sectional area and acceptable weight. This does not mean that you can't use other gauges of wire. I have used 130-foot spans of no. 26 enameled wire for "invisible" end-fed antennas. The systems worked fine, but needed to be replaced frequently from breakage. I have also used no. 8 solid copper wire (heavy!) for dipoles and end-fed antennas. The larger the wire diameter the lower the antenna Q (quality factor). This won't degrade the antenna performance. Rather, the lower the Q the greater the antenna bandwidth. For example, an 80-meter dipole made from no. 18 wire might have an SWR bandwidth (frequency between the 2:1 SWR points) of, say, 50 kHz. The same antenna, if made from no. 10 copper wire, might have a 75-kHz SWR bandwidth.

Vinyl-covered electrical house wiring is entirely suitable for building antennas, but it is quite heavy. I do not use it for long horizontal spans. I find that it is OK for use in inverted-V and similar antennas that have drooping elements. The vinyl covering adds strength, and this can be helpful if you live in an area where high wind and ice storms are frequent.

Many types of commonly available wire may be used for building antennas. For example, I have made a variety of antennas from no. 18 insulated speaker wire. I split the two conductors, which can be pulled apart easily. This gives me twice as many feet of wire per roll than before the separation is done. Electric fence wire is used by a number of amateurs. It is very inexpensive, and comes in no. 18 Copperweld or aluminum materials. Check with your area farm-supply store, or Sears, for this and other suitable wire.

Some beam antennas and verticals can be made from common items that may be found locally. Commercial antennas of this kind are fashioned from aluminum tubing of a specified tensile strength and hardness. This material is not only hard to find, but it is expensive. You may prefer to make your small beam antenna or vertical from thin-wall electrical conduit. The antenna will be heavier than if aluminum were used, and it will eventually become rusty unless you paint the metal.

I have made a number of vertical antennas from copper tubing that I purchased at a plumbing-supply store. The 1/2- or 3/4 inch copper tubing may be supported on standoff insulators that are attached to a wooden mast. I have also employed thin wall electrical conduit for the conductor of a vertical antenna Aluminum downspout (gutter) sections may be joined to form a guyed vertical antenna for 40 meters and higher. I know a ham operator who has access to used irrigation pipe. He made a lovely guyed, 80-meter vertical from this stock.

It is important that you be innovative when selecting material for your homemade antennas. Not only will you save money, you will be able to acquire the components quickly. Although iron is not as ideal a conductor as aluminum or copper, it will perform well for medium- and high-frequency operation.

Your Antenna Height

Height above ground is an important factor in antenna performance. Few amateurs realize the importance of antenna height above ground. You should try to erect your antennas as high in the air as practicable. The greater the height the farther away your signals will be heard. You will also hear distant signals better with height. Best performance will result when you install your antenna one half wavelength or higher at the operating frequency. By way of illustration, a half wavelength for the Novice HF bands is: 80 m = 133 feet; 40 m = 69 feet; 15 m = 23 feet; 10 m = 17 feet. I realize that a height of 133 feet is impractical for most of us. We should, however, try to erect the 80-m antenna at least 50-60 feet above ground (horizontal antennas). The closer to ground that we install it, the higher the radiation angle and the less directivity it will have. High angles of radiation (respective to the horizon) are useful for distances out to 500-600 miles on 80 meters, but high-angle signals are ineffective for DX work. A horizontal antenna, such as a dipole, that is erected close to ground (less than 1/4 wavelength) is likely to be omnidirectional in characteristic. The classic figure-8 pattern for this antenna does not exist in this situation. Rather, there will a spherical ball of energy around the antenna, which causes it to radiate almost equally in all directions.

The height of the horizontal antenna has a marked effect on the feed-point impedance. Depending on the antenna height, the feed impedance of a half-wave dipole may vary from 25 to 100 ohms. I recommend that you use the greatest antenna height you can at your location.

Proximity Effects

The personality of your antenna is affected also by conductive objects in the immediate area of the antenna. House wiring, power and telephone drop lines, metal fences, aluminum house siding and even large trees can affect the antenna pattern and general performance. Because of these influencing objects, you need to erect your antenna as high above the conductive clutter as practicable. Not only do these objects absorb some of the signal energy, they can distort the radiation pattern.

Because of the foregoing effects, ground-mounted vertical antennas will often perform poorly. The same antennas, if roof or tower mounted, may work extremely well. The higher the operating frequency, the more pronounced the influence of nearby conductive objects.

Other problems develop when we place our antennas close to phone and power lines: our antennas may pick up QRN (man-made noise), and this will spoil reception. This effect can be minimized if we locate the antenna at right angles to these lines. A parallel installation is the worst kind! Also, TVI (TV interference) and RFI (radio-frequency interference) in nearby entertainment devices will probably be increased when our antennas are close to phone and power lines.

WARNING: *Under no circumstances should you place any antenna under or over the power lines. Similarly, never erect a tower or mast near a power line. Many amateurs have lost their lives because they did not follow these rules.*

Feed-Line Considerations

The "vitality" of your signal depends to some measure upon the feed line you use with your antenna. Some feeders are very lossy, and in a bad-case example you may deliver 100 watts of RF power to the feed line, only to have 25 watts appear at the antenna feed terminals. This is scarcely an ideal situation! How can this happen? This large loss can become manifest if a severe mismatch exists between the feed line and the antenna, or between the transmitter and the feeder. The worse the quality of the feed line the more pronounced this effect. We must recognize an important principle: maximum power transfer can occur between two terminals only when the dissimilar impedances are matched. To illustrate this point, imagine yourself using a 50-ohm coaxial feed line with an antenna that has a 300-ohm feed impedance. This represents a severe mismatch. It will prevent maximum power transfer from the feeder to the antenna. The power loss will be even greater if your transmitter has an SWR shut-down circuit. Most modern transceivers contain this protective circuit: the higher the SWR the lower the transmitter output power. This will not happen, however, if you are using a Transmatch (tuner) between your transmitter and the feed line. A Transmatch may be used to modify the SWR condition so that the transmitter sees a 50-ohm termination. This allows maximum power output from the transmitter, but it does not correct the mismatch problem at the antenna feed point. So, power will still be lost because of incorrect matching. I will discuss the subject of matching later in this book.

Your overall antenna efficiency is affected also by the quality and type of feed line used. A "penny wise and pound foolish" philosophy should never be applied in Amateur Radio. I am referring to a ham who might purchase a $1000 transceiver, but tries to save a few dollars by purchasing low-cost feed line. It is a common phenomenon. He may buy a 100-foot roll of WW-II surplus RG-8 coaxial cable. Owing to the age of this feed line, it is probably contaminated, which makes it very lossy. New RG-8 may have cost him 28 cents a foot, but he chose the old surplus cable because it was priced at only 10 cents per foot. The surplus feeder allows 15 watts to reach his antenna on 10 meters, whereas the new RG-8 line permits 90 watts to arrive at the antenna! The signal difference is 7.8 decibels -- significant! You would have to increase your transmitter output power from 100 to 600 watts to achieve a 7.8-dB signal increase.

The smaller the diameter of the coaxial cable the greater the loss per 100 feet (versus frequency). A number of hams buy RG-58 cable (small diameter) instead of RG-8 line. This is because both cables have a 50-ohm impedance, but the smaller feed line is less costly. Once again we can observe an error in judgement: the larger the cable diameter the lower the loss.

The insulating material within the feed line plays an important role in its performance too. Some coaxial cables have solid polyethylene insulation between the center conductor and the shield braid. Other lines contain foam polyethylene inner insulation. Generally speaking, the foam insulation exhibits lower loss per hundred feet, and it is a more flexible cable. The least lossy inner insulation is air. Commercial broadcast stations use air-dielectric (insulation) copper lines of large diameter. Sometimes the air inside the line is dehydrated to reduce moisture and minimize losses. Some of the large transmission lines are filled with gas (helium) to ensure low losses and reduced moisture. These feed lines are too expensive and esoteric for amateur use, even though some hams have been known to utilize this high-cost feed line. Our needs can be met satisfactorily with smaller, less costly cable.

Coaxial cable is called unbalanced feed line, owing to the concentric arrangement of the inner and outer conductors. Some amateur antennas require a balanced feeder. We may use a variety of transmission lines to satisfy this need. For example, you may use 300-ohm TV ribbon as a balanced feeder. We may purchase 450-ohm ladder line, or we may elect to make our own balanced line from two lengths of wire and insulating spreader rods or tubes. This is known as open-wire line. For the most part, the insulation between the parallel wires is air. As we learned earlier, air-dielectric lines exhibit the least signal loss per 100 feet. You will find examples of balanced and unbalanced feed lines later in this book. We can easily recognize that the feed line we use has a direct bearing on the "personality" of our antennas.

Antenna Ground Screens

All antennas are affected by the ground beneath them. The signal from our antenna is reflected skyward by the earth below the antenna. The better the quality (conductivity) of the ground the more predictable the antenna performance. The gain and directivity information we find in reference books is based on a perfectly conducting ground at a given antenna height above ground. A perfect natural ground screen does not exist, but some regions provide better ground quality than may be found in other sectors of the world. The conductivity is determined by the soil composition (moisture content, chemical and mineral makeup). Wet ground near salt water is considered highly conductive, and hence excellent as an earth ground. Conversely, dry sand in arid wastelands is poor. The same is true of most regions that have granite or similar rock for many feet below the earth surface. The **ARRL Antenna Book** has information on this subject and contains a chart that shows the earth conductivity in the USA. You may wish to study this chart to learn how your area is rated for conductivity.

Some amateur antennas are not entirely dependent on the earth below them. The radiation angle of the signal that departs from the antenna is dependent upon the effective height of the antenna above ground, but the antenna will otherwise work normally, irrespective of the quality of the ground. The actual height of your antenna above effective ground will vary from one location to another. Depending upon the soil conductivity, your effective ground may be only inches below the surface of the earth, or it may be many feet below the surface.

Antennas that do not depend on the earth ground for correct performance are one half wavelength long, or even multiples thereof. Quarter-wavelength antennas (or odd multiples thereof) require a quality earth ground, since the missing half of the antenna (image half) must occur in the ground. A quarter-wavelength vertical antenna is an example of a radiator that is dependent on a good earth ground. An example of this need may be seen in the case of a 5/8-wavelength mobile antenna for VHF. In reality, the 5/8-wave mobile whip represents a 3/4-wavelength antenna, because the matching coil at the base of the whip causes the system to be an electrical 3/4 wavelength. The vehicle body serves as the ground system. Without this ground plane the antenna would be difficult to tune to resonance, and it would perform badly.

Artificial Grounds

We will experience the need to develop an artificial ground screen or counterpoise for some of our antennas. A simple substitute for a perfect ground does not exist. Some amateurs are led to believe that a long metal post or rod that is driven into the soil will serve as a suitable antenna ground. This is not true. Although an 8-foot rod, or group of rods, that is driven into the soil may suffice as an electrical ground for your ham station (safety measure), it will not take the place of a ground screen below your radiator. In a like manner, some hams believe that the cold-water pipes in their homes are an acceptable substitute for a ground system. Again, it's not true. I will say, however, that those kinds of grounds are better than none, and in some instances they may help the personality of your quarter-wave antenna.

What may we do toward creating a proper antenna ground screen? Typically, we amateurs develop what is known as a ground radial system. This requires many feet of wire laid on or buried in the ground under the antenna. The radial wires converge at the base of the antenna and extend outward like the spokes of a wheel. Each wire, in an ideal installation, is 1/4 wavelength or greater in length at the operating frequency. The ideal number of radials is approximately 120, although good results can be had with far fewer wires. The wires are joined at the convergence point. This junction serves as the ground connection for the feed line or matching network. It should also be tied into the main station ground.

Once again you can perceive a relationship between the personality of your antenna and the effective ground below it. We will discuss ground systems in greater depth elsewhere in this manual.

Antennas with Gain

Another antenna-personality trait is called gain. This term implies that something is "gained." Radiated RF power may be increased effectively by using a gain type of antenna. The amount of gain is measured in dB (decibels), as is the case with audio-power measurements. Each time the power is doubled (100 to 200 watts, for example), there will be a 3-dB increase in power.

When we deal with antenna gain, we use a half-wavelength dipole as our reference. In other words, the dipole is assumed to have 0 dB gain. Therefore, most measurements are referenced to a dipole. You will see published gain figures that read, for example, 6 dBd (6 dB gain over a dipole). If the specification was, instead, 3 dBi, it would mean that the antenna under discussion has 3 dB of gain over an isotropic source or antenna. An isotropic source is a theoretically ideal antenna that is perfectly spherical and located in free space. It would radiate equally in all directions (no feed line). Such an antenna cannot be realized. Beware of dBi references when you buy an antenna. This rating greatly inflates the true, practical gain of the antenna, as referenced to a dipole.

You may also see a reference to dBm. This means that power measurements are referenced to 1 mW (milliwatt). The term dBW is referenced to 1 watt.

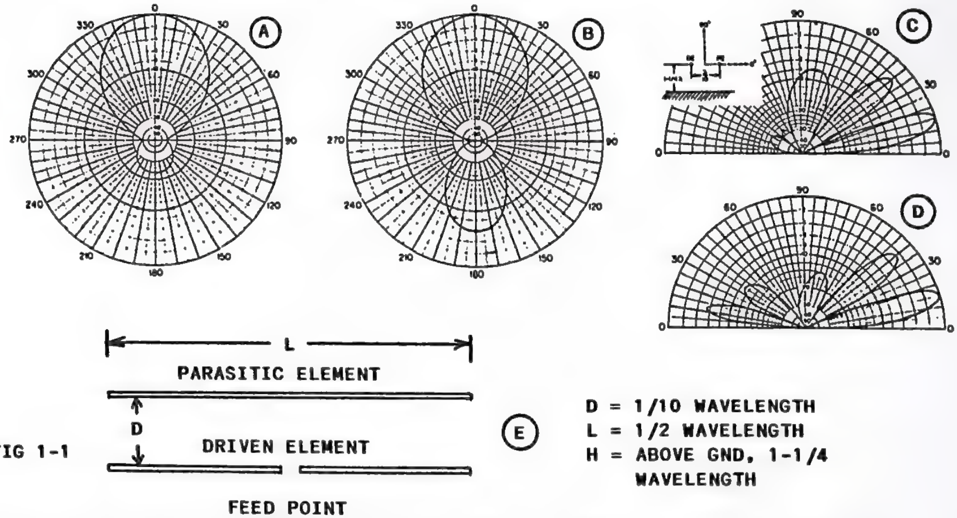
A gain antenna is sometimes longer than 1/2 wavelength. We may erect a long-wire antenna. The true long wire is one wavelength or greater, overall -- not just a long piece of wire, despite the common misnomer. Other gain antennas, such as the Yagi, consist of two or more elements that are roughly one half wavelength each, overall. These antennas concentrate the radiation in one direction (beam), and this has the effect of boosting the radiated power of the station. A three-element Yagi antenna, for example, may have a forward gain (direction of the lobe) of some 8 dB. Suppose your transmitter delivers 100 watts to the antenna feed point. This antenna has an 8.1-dB gain over a dipole. This means that you have increased the effective radiated power (ERP) of your station to 650 watts in the favored direction of the beam antenna!

Your beam antenna will have nulls off the sides and back. Therefore, you will have less than 100 watts ERP in those directions. This characteristic helps to reject unwanted QRM from compass points other than the desired one. Once more we can see how the antenna design affects the personality of the radiator.

Radiation Angles

An antenna may have more than one lobe. The significant lobe is known as the major lobe. Smaller lobes occur, and these are called minor lobes. These lobes have different radiation angles, respective to the horizon. Some illustrations are seen in Fig 1-1.

FIG 1-1



Horizontal directive patterns of antenna E with (A) the parasitic element tuned as a director for max gain. At B, the parasitic element is tuned as a director for self-resonance rather than max gain. Vertical pattern C is for the condition shown at A. Vertical pattern D relates to the condition seen at B. Patterns C and D clearly illustrate major and minor lobes at various radiation angles. The parasitic element may be tuned also as a reflector for max front-to-back ratio or for maximum forward gain. Antenna patterns courtesy of **The ARRL Antenna Book.**

The major lobes for Fig 1-1C and D are those shown at the lower right of the patterns. These lobes are the best for DX work because they are very low, respective to the horizon. The higher lobes are still useful, as they are more effective for short-skip communications than is the major lobe. Patterns A and B of Fig 1-1 are shown as though you were in the air above the beam antenna, looking down at the radiation pattern. Patterns C and D are shown as viewed from ground level, along side the antenna.

The patterns in Fig 1-1 apply only for dimensions D, L and H listed in the figure. A beam antenna with additional elements will have a different pattern characteristic than those shown in Fig 1-1. Height above ground, spacing between elements and the number of parasitic elements determines the personality of the antenna. The forward gain of the two-element antenna of Fig 1-1E, when tuned for maximum forward gain, is on the order of 6 dB (an effective power increase from 100 to 400 watts). The radiation pattern of any antenna is affected also by nearby conductive objects, as mentioned earlier. These undesired objects can distort the lobes of an antenna. A series imbalance at the feed point of the antenna can also cause pattern distortion or skewing. Balun transformers (balanced to unbalanced transformation) are frequently used at the feed point of a dipole when unbalanced (coaxial) feed line is used. The balun transformer creates a condition of balanced feed for the antenna driven element. We will discuss balun transformers and how to construct them later in this volume.

Chapter Summary

My objective in this chapter has been to provide an overview, however simplified, of the antenna and its personality. Most of the topics I introduced are expanded upon in subsequent chapters. What has been treated here will serve as the foundation for discussions of greater depth in the pages that follow. Expansion of all of the topics in this book are given in **The ARRL Antenna Book.** I recommend that text for those who wish to acquire precise knowledge about antennas and how to design them. I also recommend a middle-ground book that is available from The ARRL -- **W1FB's Antenna Notebook.**

The ARRL Antenna Book contains a complete treatment of propagation. This subject is lengthy and somewhat beyond the intent of this volume. You can learn how the signals are reflected from the ionospheric layers at various times of the day, and in accordance with the operating frequency. You will learn also how the solar flares on the sun affect radio propagation. Day- and night-time periods provide vastly different propagation conditions for Amateur Radio. You will learn about this in the referenced publication.

Chapter 2

BUILDING AND USING DIPOLE ANTENNAS

Perhaps the most common amateur antenna in use today is the dipole. It is inexpensive to construct, and it provides good results for local and DX communications if it is erected high above ground. A dipole antenna is a 1/2-wavelength conductor that is fed at the electrical center. Gain types of directional antennas, such as the log periodic dipole array consists of a group of dipoles. In other words we can combine a number of dipoles to form a wideband log-periodic beam antenna.

A single dipole antenna has no gain, but it does exhibit a bidirectional radiation pattern if it is a half wavelength or greater above ground, and if it is erected for horizontal polarization (parallel to the earth). The radiation pattern for this type of dipole resembles a figure 8. Maximum radiation is off the broad side of the antenna.

We learned in chapter 1 that a dipole antenna loses its directional characteristics when it is placed close to ground (less than approximately 0.5 wavelength). The resultant radiation pattern for a dipole that is, say, 1/20 wavelength above ground (e.g., 53 feet for 3.7 MHz), is pretty much circular. In other words, the signal is radiated almost equally in all directions. Also, the radiation angle will be very high, which is not ideal for long-distance communications.

Dipoles may be erected horizontally or vertically. They may also be configured as inverted Vs. This is a popular format because only one tall support pole or tower is needed. The center of the dipole is held aloft by the tall supporting structure, and the halves of the dipole droop toward ground at approximately 45 degrees. You may also use your dipole as a sloper (sloping dipole). In this example (see Fig 2-1) we tie one end of the dipole to a tall mast or tower and slope the entire antenna toward ground at approximately 45 degrees. The lower end of the antenna (as with an inverted V) is just a few feet above ground in a typical case where the tower or mast height is 50-60 feet.

Radiation angles and patterns vary in accordance with the manner in which we erect our dipole antennas. A vertical dipole, for example, has an omnidirectional radiation pattern, and it exhibits a relatively low radiation angle. Sloping dipoles and inverted Vs with an enclosed angle of 90 to 100 degrees will also radiate a vertically polarized signal. The sloper will have a unidirectional pattern off the slope of the antenna (directivity rather than gain) if it is supported by a metal mast or tower: the metal support device acts somewhat as a reflector. If the sloper is supported on a wooden pole, the radiation pattern will be omnidirectional. Inverted-V antennas also have an omnidirectional pattern if they are erected in a symmetrical manner, respective to the tower and placement of the antenna legs.

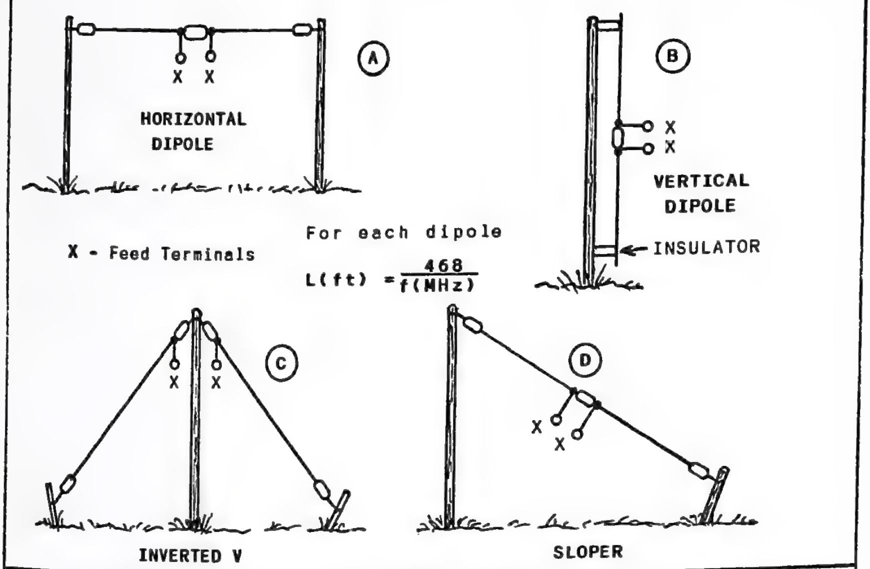


Fig 2-1 -- Examples of how half-wave dipoles may be erected. A figure-8 radiation pattern results from the arrangement at A. Antenna B has an omni-directional pattern and vertical polarization. Antennas C and D also have vertical polarization and omnidirectional patterns assuming the enclosed angle at C is 90-100 degrees, and when antenna D slopes approximately 45 degrees toward ground from a nonconductive mast (see text).

The feed impedance of the antennas in Fig 2-1 ranges from approximately 35 to 75 ohms. The actual value is dependent upon the height above ground, and in the case of antennas C and D, the angle of the wires respective to mast. For most amateur operation you may use 50-ohm coaxial cable to feed these antennas, provided the feeder length is 100 feet or less. The losses from the moderate SWR (standing-wave ratio) at high frequency will be minimal if quality cable is used, such as RG-8 line. The antennas in Fig 2-1 are for single band use when coaxial feed line is employed. Multiband operation is possible if you use tuned feed line and a Transmatch. See

Fig 2-2 for this hookup. If you wish to take advantage of the multiband concept with your dipole, you should cut it to length for the lowest operating frequency of interest. By way of illustration, your dipole should be dimensioned for 80 meters if you plan to use it from 80 through 10 meters. The formula for half-wave dipoles is given in Fig 2-1. Thus, a dipole for 3.7 MHz will be roughly 126 feet, 6 inches long, overall. I said "approximately" because the final length is determined by the installation. Height above ground and nearby conductive objects will affect the initial 468/f(MHz) dimension somewhat. You may need to cut a few inches of wire off the ends of the dipole halves in order to obtain minimum SWR An SWR bridge is used when making the final adjustments.

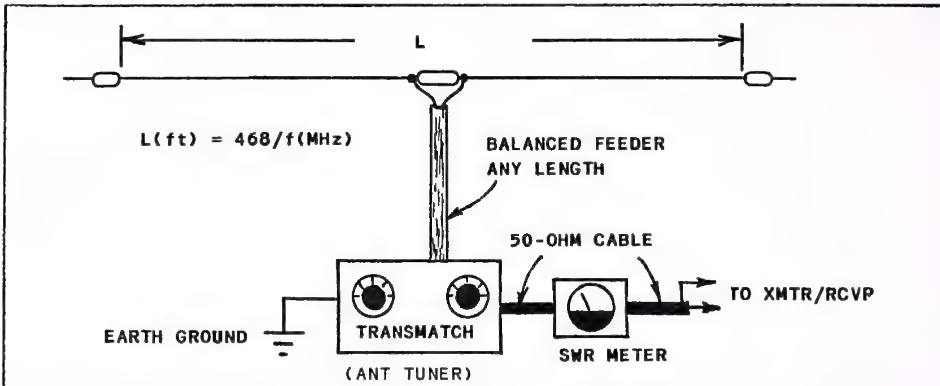


Fig 2-2 -- Example of a multiband dipole that has balanced, tuned feeders. The feed-line impedance is not critical provided it is between 300 and 600 ohms. TV ribbon line may be used, or the line may be 450-ohm ladder type. Homemade open-wire feed line is the best in the interest of minimum RF power loss. The Transmatch (transmitter to feed-line matcher) should be designed for balanced feed line. If not, a 4:1 balun transformer must be used between the balanced feeder and the Transmatch. The SWR is adjusted for a 1:1 condition while observing the SWR meter (minimum reflected power) for each frequency of operation.

The Folded Dipole

A folded dipole has two conductors in parallel, as you can see in Fig 2-3. This antenna has a high feed impedance (300 ohms). You may use a 4:1 balun transformer (see later chapter on baluns) to convert the 300-ohm balanced line to 75-ohm coaxial cable. A folded dipole may be used in the same manner as the single-wire dipoles in Fig 2-1.

The advantage of a folded dipole is that it provides slightly greater bandwidth between the 2:1 SWR points (most modern transmitters have a protective circuit that reduces the power as the SWR increases) than is characteristic of a single-wire dipole. For example, an 80-meter single wire dipole might have an SWR bandwidth (2:1 SWR boundries) of 75 kHz. A folded dipole for the same frequency may have an SWR bandwidth of 100 kHz. Apart from this consideration there is nothing to be gained from choosing a folded dipole. I have included it in this chapter for your enlightenment.

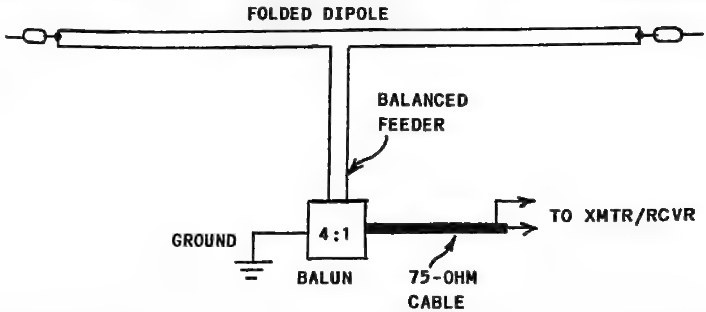


Fig 2-3 -- Example of a folded-dipole antenna. The characteristic feed impedance is 300 ohms. A 4:1 balun transformer converts the balanced feeder to a 75-ohm unbalanced line (RG-11 cable). This antenna may be fabricated from 300-ohm TV ribbon line or 450-ohm ladder line. The outer ends of the dipole are shorted as shown by the dots near the end insulators.

Finding the Correct Dipole Length

We have discussed the standard formula for cutting a dipole to length [L = 468/f(MHz)]. First, you may wonder why 468 is used instead of the free-space factor of 492 for a half wavelength. This is a good question: If our dipole was in free space and with no feed line, the length would be greater than that obtained from the 468 factor. The end effects of the insulators and guy lines, plus antenna proximity to trees, the earth and other influences, causes the antenna to have stray-capacitance effects that tune it lower in frequency. You may think of the dipole as an inductance, and stray capacitance appears in parallel with it, just like in other tuned circuits. These effects are compensated for by changing the length factor from 492 to 468.

Let's assume that you have cut your dipole wires in accordance with 468/f, as discussed earlier. How can you be certain that this is the correct length (antenna installed) for your chosen frequency of operation, say, 3.7 MHz? First, you need to know that the lowest SWR occurs at the resonant frequency of your antenna. It may not be the ideal 1:1 ratio we seek. Rather, it may be 1.5:1 or even 2.3:1. If the SWR is high at the resonant frequency of the dipole, you will know that the feed line is not matched to the antenna feed point. The SWR will rise either side of the resonant frequency as you change the operating frequency up and down.

You will need an SWR indicator or bridge, as they are called, in order to check your antenna resonance and SWR. The SWR indicator must be designed for the impedance of your feed line, such as a 50-ohm bridge for 50-ohm coaxial line. The SWR instrument is installed between your transmitter and the feed line. Next, check across the amateur band for which your dipole is cut, observing the SWR reading every 25 kHz or so. Note the frequency at which you obtain the lowest SWR reading (minimum reflected power). This will occur at the resonant frequency of the antenna. If the lowest SWR occurs lower in the band than your design calls for, remove small amounts of wire from the ends of the dipole until the lowest SWR is noted at the preferred antenna resonance point. If the lowest SWR reading is observed higher than your chosen frequency, you must add a small amount of wire to the ends of the dipole. Continue this process until the lowest SWR occurs at the chosen operating frequency.

You may use a dip meter for checking the resonance of your antenna. You may do this by connecting a three- or four-turn small coil between the shield braid and inner conductor of your coaxial cable (antenna erected, and feed line attached). A solid-state or tube type of dipper may be used. Insert the dip-meter coil into the small coupling coil on the feeder. Adjust the dipper through its range and locate the frequency at which a deep dip is noted on the meter. Listen to the dip-meter operating frequency by means of your receiver, and note the frequency. Adjust the dipole length until the dip meter indicates resonance at your preferred operating frequency.

We will discuss methods for mismatch correction, later in in this notebook. A minor mismatch (1.5:1 SWR or less) is not of concern to us for routine operation, provided the transmitter is designed to deliver normal output power at low values of SWR.

The Noise Bridge

There is another instrument that you may use for resonance tests. It is known as a noise bridge. It is connected between your receiver and the feed line to the antenna. Your antenna will be purely resistive at resonance, so the null in the noise from the bridge will be the deepest at the frequency of antenna resonance. The reactance controls on the noise bridge will be at zero when this null occurs. The bridge will provide a resistance reading when fully nulled, and this will indicate not only antenna resonance, but allow you to read the feed-point impedance (resistive) of the antenna. In order for this instrument to be accurate, you must use an electrical half wavelength of coaxial feeder between the antenna and the bridge. The instrument generates white noise, and this is heard in the receiver output (speaker of phones). The bridge controls are adjusted for minimum noise to indicate antenna resonance. You will need to tune your receiver to various frequencies in the ham band of interest in order to locate the resonant frequency of the antenna. The noise bridge is readjusted for a null at each of these frequencies until you find a frequency that yields a deep null with the reactance controls at zero. This may seem complicated now, but if you study the operating booklet for your noise bridge, things will fall into place easily.

Dipole Conductors

The subject of wire and tubing for various antennas is treated in chapter 1 on pages 1, 2 and 3. I suggest that you review those pages.

The general rule is to use wire for HF-band dipoles -- no. 12 or 14 being the most popular size. Aluminum tubing is used for HF, VHF and UHF Yagi antennas because this material is strong enough to be self-supporting. HF-band Yagis are equipped with elements that telescope. This reduces the overall weight by permitting us to use small-diameter tubing for the outer ends of the elements. The telescoping antenna elements also allow us to make easy adjustments when tuning the system for low SWR and maximum forward gain.

I suggest that you use stranded no. 14 copper wire for your HF-dipole elements. This wire is easily available and it does not cost a great deal of money. It is sufficiently flexible to endure under the stresses of wind and moderate icing, assuming it is supported properly. If the span of the dipole is greater than 130 feet, try to have a center support where the feed line is attached. RG-8 coaxial cable is quite heavy, and this places considerable stress on the dipole. RG-8X, on the other hand, is smaller and lighter, and may not cause too much stress at the center of the dipole. RG-8X will safely handle up to 1000 watts of RF power if the SWR on the line is less than 2:1. It is approximately the same diameter as 75-ohm RG-59 cable.

Antenna Insulators

Later in this book we will learn about common materials that you can use for insulating hardware when building antennas. Homemade insulators are inexpensive. I encourage you to make them, especially for your dipoles.

High-quality insulators are mandatory for good performance. A half-wave dipole has very high RF voltage at the outer ends. This means that your end insulators must have a high dielectric factor (high breakdown voltage and infinite resistance). I suggest that you use insulators that are made from polyethylene rod or tubing (available from industrial plastic vendors). High-impact polystyrene rod or tubing is also good. Plexiglass

(TM) is also a good insulating material, but it is brittle and shatters easily, especially during cold weather. It is best to avoid this material for long dipoles. You should also avoid nylon insulators, as they may heat and burn when subjected to high RF voltage. PVC pipe and tubing is similarly poor in the presence of high RF voltage.

If you purchase commercially made insulators, try to obtain glazed porcelain ones. Another acceptable commercial insulator is made from molded polyethylene. Radio Shack stores stock this type of end insulator. They are available also from farm stores that sell electric-fence components. Fig 2-4 shows how to fashion your own insulators from tubing and solid rod.

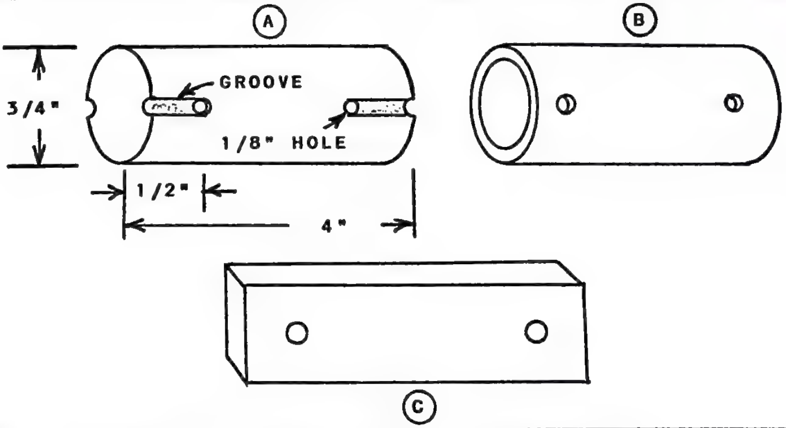


Fig 2-4 -- Examples of homemade antenna insulators. The unit at A is made from solid plastic rod. Grooves may be cut at the ends, as shown, with a router. This relieves the stress on the antenna wire and helps to keep the wire from shifting position on the insulator. Suggested dimensions are given for developing a strong insulator. Example B shows how to make an insulator from plastic tubing. A rectangular plastic block (C) is also suitable as an insulator. Grooves can be added to the ends of this unit also.

If you are willing to spend additional money when building high quality homemade insulators, please consider the use of Delrin or Teflon rod. These materials are also available from industrial plastics dealers.

For short-term emergency situations you can make your dipole end insulators from 4-inch pieces of 3/4-inch dowel rod. Drill the holes in the wood, then boil the wooden insulators in canning wax for 10 minutes. The wax will impregnate the wood, which will prevent it from absorbing moisture and becoming lossy. Alternatively, you may soak the dowel-rod insulators in exterior polyurethane varnish for 24 hours. Allow them to dry thoroughly before using them.

How to Make the Center Insulator

High quality insulating material is necessary also for the center insulator on your dipole. A single-band dipole that is fed with coaxial cable will have low values of RF voltage presented to it, as opposed to the very high RF voltages that are found at the outer ends of a dipole. In other words, low RF voltage occurs at low impedances. The lower the impedance the greater the RF current and the lower the voltage. Because of this phenomenon, the dielectric quality of your dipole center insulator need not be as high as for your end insulators PVC or nylon sheeting can be used for the center insulator without a need to worry about heating and melting. This type of material should not be used in a multiband dipole (Fig 2-2), because the feed point will present a high impedance on some of the bands. Fig 2-5 shows how you can fabricate your own center insulator for a dipole.

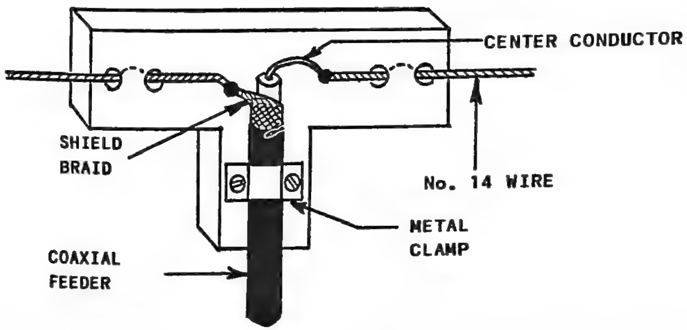


Fig 2-5 -- A homemade dipole center insulator is made easily from plastic sheeting. Two holes are drilled at the right- and left-hand sides of the T. The antenna wire is threaded through the holes, as shown, to secure the dipole halves to the insulator. Grooves may be cut at the outer holes to reduce stress on the wire, as in Fig 2-4A. A cable clamp secures the feed line to the block. The open end of the coaxial cable should be sealed with epoxy cement or Coax Seal (TM) to prevent moisture from entering the feeder.

Materials such as phenolic, PVC, high-impact polystyrene, Lexan and Delrin are suitable for dipole center blocks. In any event, the open end of the coaxial line should be sealed in order to prevent dirt and moisture from migrating down the inside of the transmission line. A saber saw may be used to cut the plastic sheeting to the shape shown in Fig 2-5. The metal cable clamp should be snug on the cable, but not so tight that it compresses the cable to an oval shape. Two clamps may be used to make the assembly even more secure.

Dipoles that are supported at the center require a slightly different insulating block than that shown in Fig 2-5. You can see the necessary changes by referring to Fig 2-6. In this example we will assume that 450-ohm ladder line is used as the feeder in order to allow multiband operation (tuned feeders). Therefore, a small retainer (also made from plastic stock) is bolted to the lower part of the center insulator. This piece is used to clamp the 450-ohm line to the larger plastic unit. Ladder line has no. 18 Copperweld conductors. This wire will flex in the wind, and it will eventually break. The retainer block helps to reduce breakage. This is because it is clamped over a portion of the feeder that has the polyethylene insulation intact. The polyethylene contributes to the strength of the two wires at this stress point. If coaxial cable is used instead of tuned feed line, you may substitute a cable clamp (Fig 2-5) for the retainer block.

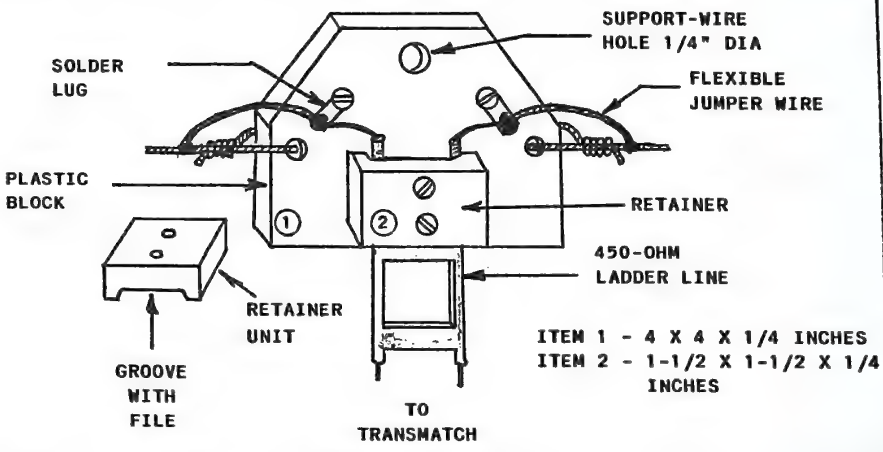


Fig 2-6 -- Example of a center insulating block for horizontal or inverted-V dipoles that are supported at the center. Other styles of feed line may be used if the retainer block (item 2) is modified to accommodate the alternative feeder, such as 300-ohm TV ribbon or coaxial cable. This home-made center insulator can be cut from sheet plastic by means of a hack saw or electric saber saw. A nylon halyard or wire support line is attached at the upper center hole of the insulator.

You will notice a channel that is filed into one surface of the retainer block (item 2, Fig 2-6). This is done to prevent excessive compression of the feed line. The groove is just deep enough to allow moderate pressure on the feeder. The two attachment screws are tightened to ensure a snug fit. No. 8-32 screws, lock washers and solder lugs are suitable for this assembly. Solder the feed-line wires and flexible jumpers to the solder lugs.

Proper Electrical Connections

You should avoid electrical joints in your antenna system that are merely twisted together. Splices of this type are physically weak if they are not done correctly. Worse still, as they corrode from air pollutants they develop a layer of oxidation that acts as an insulator or semiconductor. Antennas with these joints may become intermittent, especially when the wind is blowing. The usual symptoms of a defective electrical connection are (1) changing SWR; (2) Manifestation of TVI (television interference) and/or RFI (radio frequency interference) that was not present previously. A bad antenna joint can act as a rectifier diode. This unwanted diode rectifies the RF energy when you transmit, at which time strong harmonic currents develop by way of the diode action. These harmonics can seriously disrupt TV or FM reception in your neighborhood.

A rectifying antenna connection can affect your amateur reception also. If you live near another ham, or if you have broadcast stations (AM, TV or FM) nearby, the powerful signals from those broadcasters can be rectified by your poor antenna joint. This will cause all manner of interference to your reception of amateur signals. You will hear blurps, hum and voices from one end of a given amateur band to the other as you tune your receiver. This malady is still another symptom of a defective joint in your antenna system.

Make an effort to solder the joints and splices in your antenna. Use plenty of heat to ensure a quality solder joint. Too little heat from the soldering iron may result in a "rosin-core" or "cold" solder joint. These inferior connections can also act as diodes and cause problems. Scrape the oxidation from the wires and other conductive components before you commence soldering. Noncorrosive solder is mandatory. Avoid acid-core solder for all electrical work. Similarly, if you use soldering paste, be certain it is the noncorrosive type.

Mechanical Considerations

Stress on the antenna wires and feed lines must be minimized to the best of our ability. A case in point is illustrated in Fig 2-6. Note that the jumper wires between the solder lugs and the dipole wires or legs are looped to allow flexing in the wind. This slack is important on windy days when the dipole may swing up and down between the support poles. In a like manner, there is a small loop where the dipole legs connect to the insulating block in Fig 2-6. This allows the dipole wires to shift laterally in the presence of wind. Were these leg ends snugged tightly to the center block, the edges of the block would eventually cut through the antenna wire.

Screws, nuts and lock washers that are used for antenna hardware should be nonferrous when possible. Plated brass hardware (nuts and bolts) is good. Iron nuts and bolts, other than stainless steel units, will rust and become weak after a few months of exposure to the elements. It is wise, on general principles, to avoid using ferrous hardware in any RF power field, since this type of hardware may, in some situations, absorb RF power and become quite hot.

Coaxial cables in particular need to be sealed against dirt and moisture at the antenna feed point. A coaxial line can become very lossy when it is allowed to fill up with water and dirt. Caulking compound, Coax Seal, RTV sealant and epoxy cement work well as sealing agents for the open end of coaxial line.

Coaxial connectors that must remain out of doors should also be sealed against dirt and moisture. If this is not done, you will probably find a build-up of oxidation inside the connector after a few months of exposure to the elements. Coax Seal or caulking compound can be used to encapsulate the connectors. This will prevent them from deteriorating. You may simply wrap these metal fittings with two layers of vinyl electrical tape, rather than encasing them in a sticky compound that will be hard to remove later. Electrical tape does not offer as much protection as Coax Seal, and it will not last as long when exposed to the elements. Taped connectors may require retaping each year to ensure the integrity of the protective covering.

Halyards for Dipoles and Other Antennas

I prefer 1/4-inch diameter marine-grade nylon rope for my antenna halyards. This is generally available at marinas and large variety stores that sell marine products. Many farm-supply dealers handle this type of rope also.

Clothesline ropes have relatively short life spans. Polypropylene clothesline is especially prone to rapid deterioration from UV radiation (sunlight) and weathering. It becomes brittle and weak within a few months. I have had good results with high-quality cotton clothesline after I treated it with a weatherproofing solution, such as liquid silicone. This is the compound that is sold for waterproofing your shoes.

A pulley is required for your halyard. It will minimize stress on the halyard, as opposed to pulling a rope over a tree limb or through an eye bolt. Make sure the pulley wheel is smooth. If it has burrs it will eventually fray the halyard at the point where it rests in the pulley. I prefer nylon or similar plastic pulley wheels for minimum stress on the halyard.

Physically Short Dipoles

It is wise to remember that we amateurs seldom "get something for nothing." Compromises in the antenna system are sometimes necessary, because we may live on a property of small size. In other words, a full-size dipole might extend beyond the property boundry. In this compromising situation we must accept performance tradeoffs in the antenna department. Remember, it is better to have a less-than-optimum dipole than to have no antenna whatsoever! Many amateurs who are forced to use shortened antennas have very good results, both during local and DX operation. A great deal depends upon your location, height of the antenna above ground, time of day and propagation conditions at a given time.

Folded, Shortened Dipoles

If you lack sufficient property to accommodate a horizontal dipole (80 meters, for example), you may wish to consider bending the antenna elements so they will fit into your yard area. Fig 2-7 shows a number of ways you can shape your dipole to meet the restricted-space criterion. For example, you can bend the outer ends of the antenna toward ground, thus forming a broad-based inverted U (Fig 2-7A). Similarly, your antenna can have the ends bent away from the main portion of the legs in the horizontal plane (Fig 2-7B).

Another popular shortening method is illustrated in Fig 2-7 at C. In this example we find the outer ends of the dipole bent back toward the antenna feed point. This requires that we use insulating spacers to separate the bent-back portion from the main part of the dipole. A spacing of 6 to 12 inches is satisfactory. The spreaders can be made from high-impact polystyrene sheeting, Plexiglass rod, fiberglass tubing or any material with good insulating properties. PVC tubing should not be used at this high-voltage point in the system, owing to its poor dielectric quality. I have used, with success, 10-inch pieces of 3/8-inch dowel rod for my spacers. The pieces were boiled for 10-15 minutes in canning wax to impregnate them against moisture. The holes for the wire should be drilled before the spacers are treated with canning wax. Small retainer wires are used to secure the spreaders (Fig 2-7D). A simpler method for keeping the spacers locked in position is to crimp thin-wall aluminum spacers on the wire, as shown at E of Fig 2-7. Pieces of small-diameter copper tubing may be substituted for the aluminum spacers.

It is sometimes practical to erect a V-shaped dipole (not an inverted V) in order to make it fit into a city lot. The dipole legs are parallel to ground, just like a conventional horizontal dipole. This configuration does not qualify as a V beam unless the legs are one wavelength or greater overall. This antenna is shown in Fig 2-7E. If you build this antenna for 80 meters, and use tuned feeders, it will work nicely as a multiband system. The antenna will act as a V beam at harmonics of 80 meters (40, 20 and 10 meters), and there will be some gain over a dipole (bidirectional pattern).

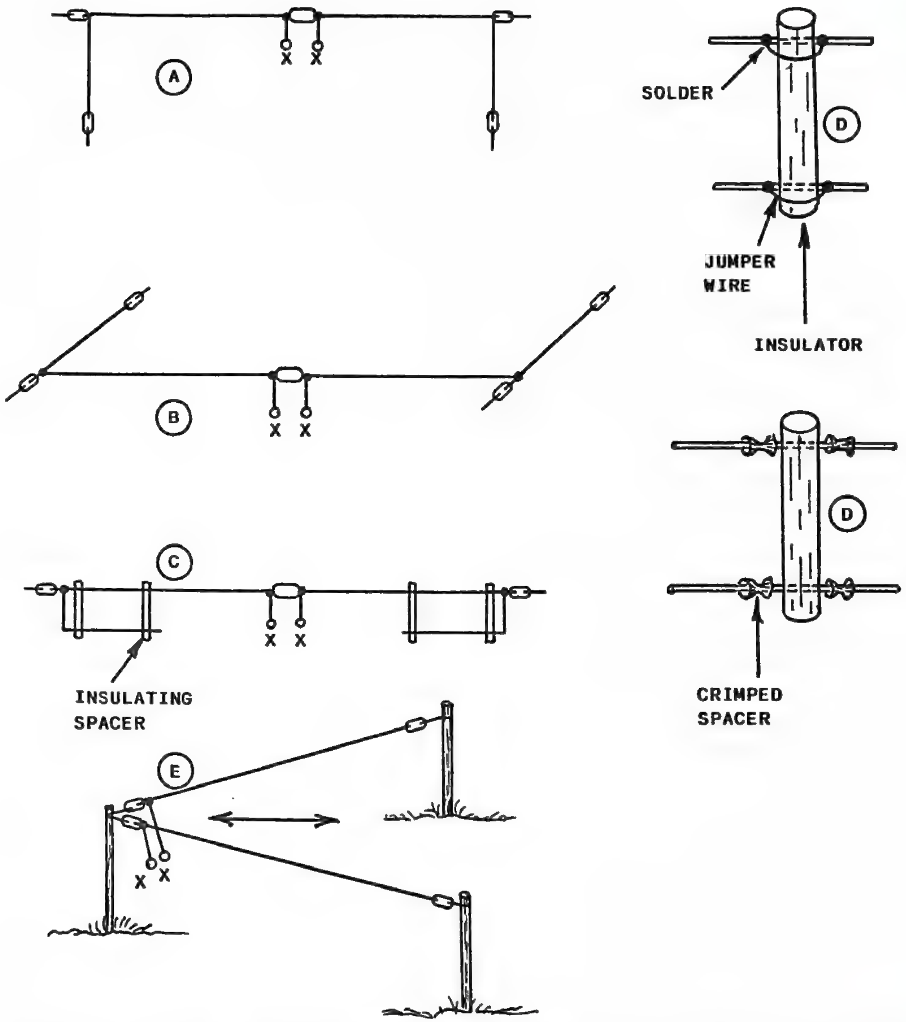


Fig 2-7 -- Dipole antennas may be shaped to fit into small areas. Example A shows how to bend the dipole ends toward earth. Method B illustrates how the dipole ends can be bent horizontally. Technique C demonstrates how to fold the dipole wires back on themselves with insulating spacers. The two spacers at D exhibit alternative methods for holding the spacers in place on the antenna wires (antenna C). Short jumpers are soldered to the wire at the upper drawing. Aluminum spacers or small diameter copper tubing holds the spacers in place in the lower drawing. Antenna E is V shaped in the interest of conserving yard space.

The bidirectional pattern for the antenna of Fig 2-7 becomes more pronounced as the operating frequency is increased. By this I mean, there will more gain at 10 meters than exists at 40 meters. The longer the wires, in terms of wavelength, the greater the gain. The directivity of the V wire increases at the higher operating frequencies also. Radiation is bi-directional, as indicated by the arrows at E of Fig 2-7. The directivity will not be observed at the lowest operating frequency, or the frequency at which the antenna is a half-wave dipole. At this frequency the dipole will have a relatively omnidirectional pattern, especially at low heights above ground.

Inductively Loaded Dipoles

A dipole antenna may be shortened substantially by inserting a loading coil in each leg of the system. This method allows us to vastly shorten a dipole, but at a sacrifice in SWR bandwidth. The shorter the antenna wires the larger the loading coil, and consequently -- the narrower the bandwidth of the system.

Best performance will be experienced with loaded dipoles if we place the coils near the outer ends of the dipole. This is called end loading. The farther out we place the loading coils the greater the current area on the dipole wires, out to the loading coils. Since the current portion of an antenna is responsible for the principal radiation, it is advantageous to maximize this effect. However, the farther out we locate the coils the greater the inductance required. This is because the wire beyond the loading coils acts as a capacitance. This capacitance helps to tune the system to resonance. Thus, the greater the capacitance the smaller the loading coil.

Tuning of an inductively loaded dipole can be a tedious task. It requires lowering and raising the antenna as the inductance is changed. The objective is to prune the coil turns until the antenna is resonant at the desired frequency. Resonance measurements are carried out in the manner described earlier in this chapter. Complete information about loaded dipoles is presented in **The ARRL Antenna Book**. I do not advocate loaded dipoles for beginners. The methods shown in Fig 2-7 are recommended to you when there is insufficient space to erect a full-size dipole.

Performance of Short Dipoles

Let's focus our attention during this discussion on the dipoles depicted in Fig 2-7. What happens when we distort the shape of a dipole? The notable effect from bending the ends of the antenna is a change in radiation pattern. The dipole in Fig 2-7A may have some vertical-radiation components along with the horizontal ones. Chances are that this antenna will be rather omnidirectional with its pattern. Also, this and the other dipoles in Fig 2-7 will not be quite as efficient as is a half-wave dipole that has straight legs. When we fold back the antenna ends there is some cancellation of the signal, however slight it may be. Antenna C of Fig 2-7 suffers the most from this effect. If the enclosed angle of antenna E (Fig 2-7) is 90 degrees or greater, it will have an efficiency on par with an inverted V. Normally, the decrease in signal is not apparent on the S meter of a distant station. Some fairly sophisticated measuring equipment is needed in order to compare the performance of these antennas to that of a dipole with perfectly straight legs. The message here is that you not worry about being heard (and hearing) if it becomes necessary for you to bend your dipole to fit into available space. Don't be reluctant to experiment!

The "G5RV" -- Another Short Dipole

You may be interested in the short multiband dipole that was developed in England by G5RV. This antenna has become quite popular in the U.S. and abroad, owing to the shorter-than-normal dipole legs. The flat-top portion is only 102 feet long.

The G5RV dipole is of simple design, and I have received numerous reports of good performance. You may use this antenna on 80, 40, 15 and 10 meters. It will also work on 12, 20 and 30 meters. If you upgrade to General Class or higher, you can press the G5RV into service on 12, 20 and 30 meters. It may be used also on 160 meters if you tie the feeders together at the ham-shack end of the feed line. The antenna then becomes a top-loaded (flat-top T antenna) vertical radiator of sorts. A Transmatch may be used to obtain an SWR of 1:1 between the transmitter and the shorted feeder. In this configuration the antenna performs as a 1/4-wavelength radiator. A quality earth-ground is needed for best results -- preferably a system of buried or on-ground radial wires.

You can erect the G5RV dipole as shown in Figs 2-1 and 2-7. Details for building this antenna are provided in Fig 2-8.

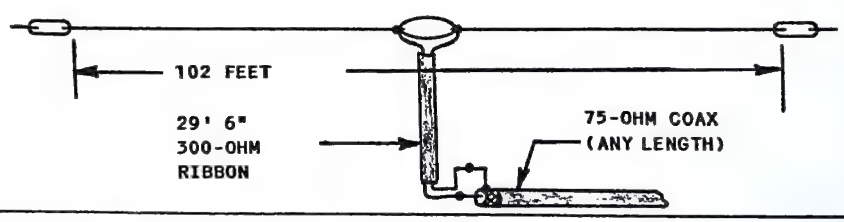


Fig 2-8 -- Electrical details for a 80-10 m G5RV dipole (see text).

Using the 468/f Length Formula

We learned earlier that the starting point for adjusting the dipole for resonance is obtained from L(feet) = 468/f(MHz). Let's try an exercise in length calculation. Suppose you want a dipole that is resonant in the center of the 80-m Novice band (3.725 MHz, or 3725 kHz). Now, if we use our standard dipole formula we have: L = 468/3.725 = 125.637 feet. We can now convert the decimal part of the foot (0.637) to inches by multiplying this number by 12. Therefore, 12 X 0.637 = 7.64 inches, or 7-5/8 inches. Practically, we can forget the fractional part of the inch and settle for 125 feet and 7 inches for the dipole length. Final adjustment of the dipole length may be done with your transmitter and SWR indicator.

Table 2-1 lists the 468/f lengths for dipoles in the HF bands. You may use this for quick reference.

TABLE 2-1

Amateur Band	Low End	Midband	High End
160 M (MF Band)	1.8 MHz 260 FT	1.9 MHz 246.3 FT	2.0 MHz 234 FT
80 M (use midband data for Novice band)	3.5 MHz 133.7 FT	3.75 MHz 124.8 FT	4.0 MHz 117 FT
40 M (use midband data for Novice band)	7.0 MHz 66.85 FT	7.15 MHz 65.45 FT	7.3 MHz 64.1 FT
30 M	10.1 MHz 46.34 FT	-----	10.15 MHz 46.1 FT
20 M	14.0 MHz 33.43 FT	14.175 MHz 33 FT	14.350 MHz 32.6 FT
15 M (use midband data for Novice band)	21.0 MHz 22.28 FT	21.225 MHz 22 FT	21.450 MHz 21.8 FT
12 M	24.890 MHz 18.8 FT	-----	24.990 MHz 18.7 FT
10 M (use midband data for Novice band)	28.000 MHz 16.7 FT	28.850 MHz 16.2 FT	29.700 MHz 15.75 FT

It is important to remember that the above dimensions are approximate. There will be situations where you find these lengths to be perfect for resonance. On the other hand, you may have to lengthen or shorten your dipole slightly. This is especially true when the antenna is very close to ground, or if the elements are bent as shown in Fig 2-7.

Four Dipoles -- One Feed Line

Let's discuss multiband dipole antennas that use a single feed line. Antennas that fit this description are especially convenient for two reasons: (1) A single feed line is less expensive than two or more feeders; (2) Only one or two support poles are needed for these multiband radiators.

Imagine yourself wishing to operate in the 80, 40, 15 and 10-meter Novice bands. Do you need a separate dipole and 50-ohm feed line for each of these bands? Not really, even though it can be argued that separate antennas are better than multi-band ones. If there is a difference, it is so minor that you need not be concerned. How about the disadvantages of having four dipoles connected to a single coaxial feed line? There are two considerations: (1) Some of the dipoles will not be as high above ground as the others; (2) The dipoles are somewhat more difficult to trim for resonance, compared to a single dipole with its own feeder. Practical information about this antenna is presented in Fig 2-9.

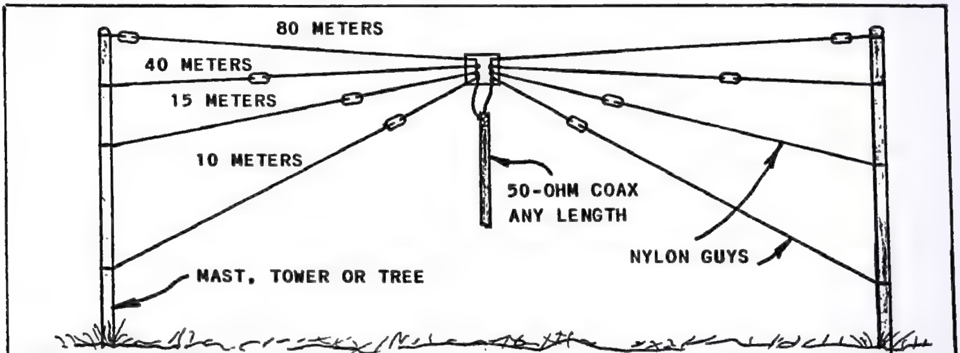


Fig 2-9 -- Four dipoles may be arranged in this manner to permit using a single 50-ohm coaxial feed line. This multiband antenna may be strung between masts, trees or a tower and a mast or tree.

Note that the dipoles in Fig 2-9 are joined at the feed point. Since a 40-meter dipole will operate as a 3/4-wave dipole at 15 meters, you may wish to eliminate the 15-meter wires. You should be aware, however, that the SWR will not be 1:1 for both bands if this is done. If you adjust the length of the 40-meter dipole for an SWR of 1:1, it may exhibit an SWR that is substantially higher on 15 meters. A separate 15-meter dipole, as seen in Fig 2-9, permits you to adjust each antenna for a low SWR. The dipole lengths may be cut as specified in Table 2-1. Start with the 80-meter elements when adjusting the length for the lowest SWR (resonance). Adjust the 40-meter section next, then 15 meters, and finally the 10-meter elements. A halyard on each support pole will make raising and lowering the system less difficult during the tuning period.

Adjusting the wire lengths is necessary because the dipoles detune one another when they are so close together. The greater the fanning distance between the wires the less pronounced this effect.

Nonconductive guy lines are best, since metal guys may be resonant at some of the operating frequencies, and this will disrupt the performance. If metal guys are used, break them up with insulators at nonresonant intervals. No. 14 or 16 stranded copper wire is recommended for this antenna.

Center-Fed Zepp Multiband Dipole

The arrangement shown in Fig 2-2 and Fig 2-10 is popular among amateurs who prefer a single dipole for several bands of operation. The Fig 2-10 version is erected as an inverted-V dipole. This is desirable because you need only one tall support pole, tower or tree. Also, the antenna is relatively omnidirectional with vertical polarization. You may, however, choose to use this antenna as a horizontal radiator. The rules are the same for either type of installation.

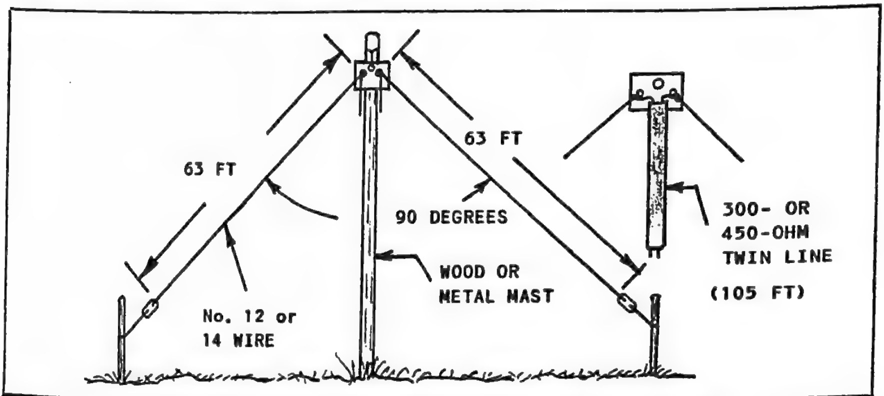


Fig 2-10 -- Multiband inverted-V dipole with tuned feeders. The dimensions provided are for resonance at 3.725 MHz. Feeder length is 1/2 wavelength, inclusive of the velocity factor (0.8) for TV ribbon line. The feeder may be any convenient length near 100 feet. The enclosed angle of the dipole should be between 90 and 110 degrees for best performance.

Your feed line for the antenna in Fig 2-10 should be centered between the legs of the inverted V. It should come straight down to ground level, or nearly so. This ensures electrical symmetry. This is especially important when a metal mast or tower is used to support the antenna. The effects of the tower are cancelled with a symmetrical installation. Best performance with this antenna will be had when the feed point is 60 or more feet above ground. You will still have good results when the height is less than 60 feet and more than 30 feet. An ideal installation would place the feed point of the antenna between 100 and 120 feet above ground, but this is generally beyond the realm of economic practicality for most amateurs.

Trap Multiband Dipoles

You may elect to purchase a ready-made multiband dipole. If this becomes your decision, you will probably acquire one of the many trap dipoles that are available on the ham market. You should understand how these antennas work and what limitations accompany them.

The term "trap" is precisely what the word implies. A trap holds RF energy at a desired electrical boundry. In a literal sense, a trap does not grab RF energy and hold it captive. Rather, it acts like a barrier, and this barrier prevents the RF energy from flowing past a specified point in an antenna. There are two traps in the dipole for each band above the lowest operating frequency. For example, a trap dipole that works on 80, 40 and 20 meters has no 80-meter traps, but there are two traps for 40 meters and two additional ones for 20 meters. In effect, these traps "divorce" some of the antenna sections (conductors) from other antenna sections. The traps function in this manner only when we apply transmitter output power for the band of trap operation. In other words, our 20-meter traps simply become part of the overall antenna on 80 and 40 meters. In fact, on those bands the 20-meter traps act like small loading coils. This causes the overall antenna beyond the 20-meter traps to be shorter than normal, owing to the loading effect of the traps. Fig 2-11 shows the principle of trap-antenna operation.

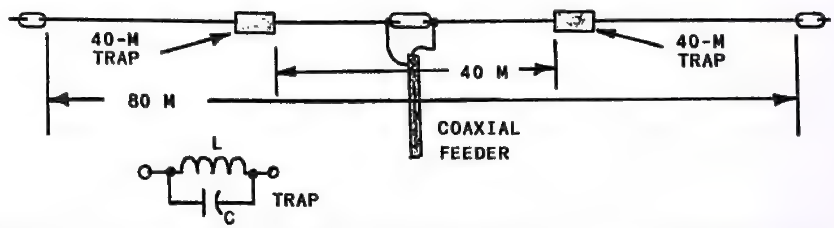


Fig 2-11 -- Example of a trap dipole for 80 and 40 meters. Additional traps may be added to provide coverage of more amateur bands. The inset drawing shows that traps consist of a coil and a capacitor in parallel. The trap is tuned for resonance at its frequency of operation.

During 40-meter operation with the dipole in Fig 2-11 the wires beyond the traps are divorced from the system by the traps. During 80-meter operation the traps act as loading coils, thus becoming a working part of the antenna. A trap acts like a very high resistance (impedance) in the RF path during operation in the band for which the trap is designed.

The principle limitations for trap antennas are: (1) Reduced bandwidth between the 2:1 SWR points, compared to a full-size dipole; (2) Some power is lost in the traps, and this reduces the overall antenna efficiency, comparitively speaking. These antennas are, however, a means to an end when we desire a single, shortened dipole for multiband operation.

Chapter Summary

We have learned that although we cut our dipoles to length according to the 468/f formula, they are sometimes a trifle too long or short. This depends on the individual installation and the near environment. We may need to add or remove a few inches of wire from the ends of the dipole in order to make it resonant in a chosen part of an amateur band. This adjustment is done easily with an SWR indicator. We may also use an antenna noise bridge when adjusting the antenna length. A dip meter is useful for this job too.

Various wire gauges are suitable for HF dipoles. We need not insist on no. 12 or 14 stranded copper wire. Hookup wire, house wiring, electric-fence wire, etc., may be used with success. Larger and smaller gauges of wire are also acceptable for amateur dipoles.

The most important considerations for your dipole antenna are (1) erect it as high above ground (and conductive clutter) as practicable; (2) adjust it for resonance in your favored part of the amateur band; (3) Solder all joints and use a good grade of insulators (low loss); (4) seal your coaxial feed line at the antenna to prevent dirt and moisture from contaminating the cable.

Don't be reluctant to bend the legs of your dipole if you are cramped for space. A slightly deformed dipole may work as well as one that's perfectly straight. In a worst-case situation it is better to have an antenna with reduced performance than to have no antenna at all! You don't have to be the loudest amateur station in your region!

Glossary of Chapter Terms

Antenna - An electrical conductor that radiates RF energy (transmit) and gathers RF signal energy (receive).

Balanced Feeder - A symmetrical two-wire feed line (parallel conductors) that may have solid polyethylene insulation or frequent spreaders (ladder line) to maintain uniform spacing between the wires.

Center Feed - A condition that requires the antenna feed line to be connected at the exact electrical center of the radiator.

Coaxial Cable - A transmission line that has concentric conductors. An inner conductor is surrounded with low-loss insulation. The outer conductor is braided small-diameter wire, and this is covered with vinyl plastic outer insulation. Large coaxial lines are made of copper tubing and may use air or helium as the insulation within the line.

Conductor - A metal object, such as wire, rod or tubing. It allows current to travel continuously along its length.

Dielectric - Insulating material (numerous types) of the type found in antenna insulators and transmission lines. Air, oil and other liquids are also classified as dielectrics.

Efficiency - The ratio of useful output power to the input power. This relates to system losses (feeders, etc.) when associated with antennas.

Feeders - Various types of transmission lines, such as coax, TV ribbon and ladder line that are used to feed power from a transmitter to the antenna feed point, or from an antenna to a receiver.

Harmonic Operation - A half-wave dipole, depending upon the feeder used, may be operated on harmonically related amateur bands, such as an 80-meter dipole with balanced feeders being used on 40 and 20 meters.

Impedance - The value of an antenna feed point, feed line, input or output terminal of a transmitter, receiver or piece of test equipment. An impedance may contain a reactive (capacitive or inductive) as well as a resistive component (complex impedance). Impedance is expressed in ohms.

Inverted V - A half-wave dipole erected as an upside-down V, with the feeder connected at the apex of the V (top). Sometimes called a "drooping doublet."

Load - Electrical device or antenna to which RF power is delivered. A load has a specific impedance, which should be matched to the feed line in order to ensure maximum power transfer.

Matching - The process of causing unlike impedances to be the same in an electrical circuit, such as a feed line to an antenna. A separate device (matching unit or section) is required for this purpose.

Polarization - Polarization of a radio wave from an antenna. The antenna design determines the polarity, such as vertical, horizontal, circular (left- or right-hand circularity) or eliptical.

Radiation Pattern - The directivity lobe of an antenna (omnidirectional, unidirectional or bidirectional, for example) as related to space coordinates and presented in graphic form (see Fig 1-1).

Radiator - An antenna conductor that radiates RF energy. The element to which the feed line is attached. A dipole is a radiator.

SWR - Standing-wave ratio on an antenna feeder (VSWR, or voltage standing-wave ratio). SWR is the ratio of the forward to the reflected voltage on the feed line. A perfect impedance match results in an SWR of 1 (1:1), whereas the greater the reflected voltage the higher the SWR, such as 2:1 or 5:1.

Traps - Resonant circuits of parallel capacitance and inductance (see Fig 2-11) that are used in antennas to provide operation on two or more amateur bands.

Velocity Factor - Sometimes referred to as "propagation factor." It affects the speed of radio waves as they travel through dielectric material, such as air, polyethylene and other insulating substances. A velocity factor of 1 is the reference for light and radio waves in free space. Feed lines, because of their insulation, slow the radio waves.

Zepp Antenna - A half-wave radiator that is fed at one end with tuned feeders (named because of its popularity on Zepplins). A center-fed Zepp (misnomer) is a dipole that has balanced feeders attached to its electrical center. Both types of Zepp are used as multiband HF antennas.

Chapter 3

SELECTING AND USING FEED LINES

The choice of antenna feed lines is anything but casual if you want efficient performance and reliability. All too often I meet amateurs who have several thousands of dollars invested in transceivers, Transmatches, accessory gear and towers, but they purchased bargain-price feed line for their antennas. This is the well known "penny wise and pound foolish" syndrome rising to the fore! You will be wise to buy and use top-of-the-line feeders.

Decibels gained or lost in an amateur station are collective or cumulative. If you gain or save only 3 dB, you have boosted your effective transmit power (or receive capability) by a factor of 2. As I mentioned in an earlier chapter, a 3-dB increase is equivalent to raising the transmitter power from 10 to 20 watts, or 300 watts to 600 watts. Thus, a dB lost here, and another one wasted there, can soon represent a large loss in effective power. Cheap feed line can causes losses far greater than 3 dB!

Coaxial Feeders

Although coax is available in a variety of impedances, we amateurs use 50- and 75-ohm feeders most of the time. Since we discussed dipoles in chapter 2, it is fitting that we talk about feed lines for those and other antennas,in this chapter. The aforementioned 50- and 75-ohm lines are suitable for use with coax-fed, single-band dipoles.

Coax cable comes in many diameters, and each has a different type number associated with it. For example, there is RG-58, RG-59, RG-8 and RG-11, plus many more. Each of these numbers have varations that relate to the insulation and specific structure of the line. By way of an illustration, there is RG-8/U, RG-8/U with foam insulation, and RG-8A/U. How do the lines differ? After all, they are each in the 50-ohm classification. Well, RG-8/U has solid polyethylene inner insulation. It has a 52-ohm characteristic and a VF (velocity factor) of 66. It exhibits 29.5 pF of capacitance per foot (inner to outer conductor). It will handle up to 4000 V RMS safely. We can now compare RG-8/U to RG-8/U (foam). The polyethylene inner insulation has numerous bubbles in it. It weighs less than plain RG-8/U and is more flexible. But, there are other differences too. It has a 50-ohm impedance and a VF of 80 rather than 66. It has less capacitance per foot (25.4), and a lower maximum RMS voltage rating (1500). Outwardly, these two cables look the same. Now, let's compare RG-8A/U to the other two lines. It has solid insulation, a 52-ohm impedance and a VF of 66. It has the highest voltage rating of the three (5000), and the capacitance per foot is 29.5. In terms of dB loss per 100 feet (10-meter example), the RG-8/U and RG-8A/U are the same at 1.2 dB. The foam RG-8/U, conversely, has a loss of 0.9 dB per 100 feet at 10 meters.

Each type of coax cable has variations such as we have just considered. Practically speaking, any one of the three RG-8/U lines can be considered suitable for our HF-band operation. I tend to prefer the foam-filled cables since they are lower in loss and easier to work with because of their flexibility.

Now, let's look at still another coaxial cable in the 50-ohm category. I am thinking of RG-58/U. This is a small-diameter feed line (0.195 inch OD). RG-8/U has an OD of 0.405 inch. The RG-58/U is much less costly and bulky than RG-8/U. But, what are the performance tradeoffs? Here are the characteristics of RG-58/U: Impedance is 53.5 ohms; capacitance per foot is 28.5 pF; VF = 66; maximum RMS voltage is 1900. This reads pretty good, doesn't it? It's similar to RG-8/U (foam). Here is the bad news: 100 feet of RG-58/U (non foam) at 10 meters causes a loss of 2.5 dB! That's almost half your transmitter output power! The fairly low RMS voltage rating (1900) is OK for powers up to, say, 300 watts at low SWR conditions. It might even be used with success at 1 kW, provided the SWR is 1:1. Higher SWRs will cause the voltage in the coax to exceed the maximum rating, and arcing will occur between the inner and outer conductors at high-power levels.

There are other, more expensive, types of 50-ohm coaxial feed line. They are made for low loss and very high power. These products are known as Hardline. These transmission lines have solid copper inner conductors and solid aluminum outer conductors or jackets. RG-210 has a 0.5-inch OD. Larger Hardline may have an OD as great as 0.875 inch. The electrical characteristics of RG-210 (foam filled) are: 50 ohms; VF = 81; capacitance = 25 pF/ft; maximum RMS voltage is 2500. The loss per 100 feet at 10 meters is 0.42 dB. Hardline with an OD of 0.75 inch has a loss of only 0.3 dB at 28 MHz.

If you contemplate a permanent antenna installation, such as a Yagi beam antenna on a tower, it may be well worth your while to spend some extra money and buy 1/2-inch Hardline. It will be low in losses, last a long time and be rated for the power you will use after you upgrade your license to a higher class. A short length of flexible 50-ohm coax can be used between the Hardline and the antenna at the top of the tower. This allows the needed flexibility for rotating the Yagi antenna. The lower the operating frequency the smaller the loss in dB per 100 feet of cable. This is seen in Fig 3-1.

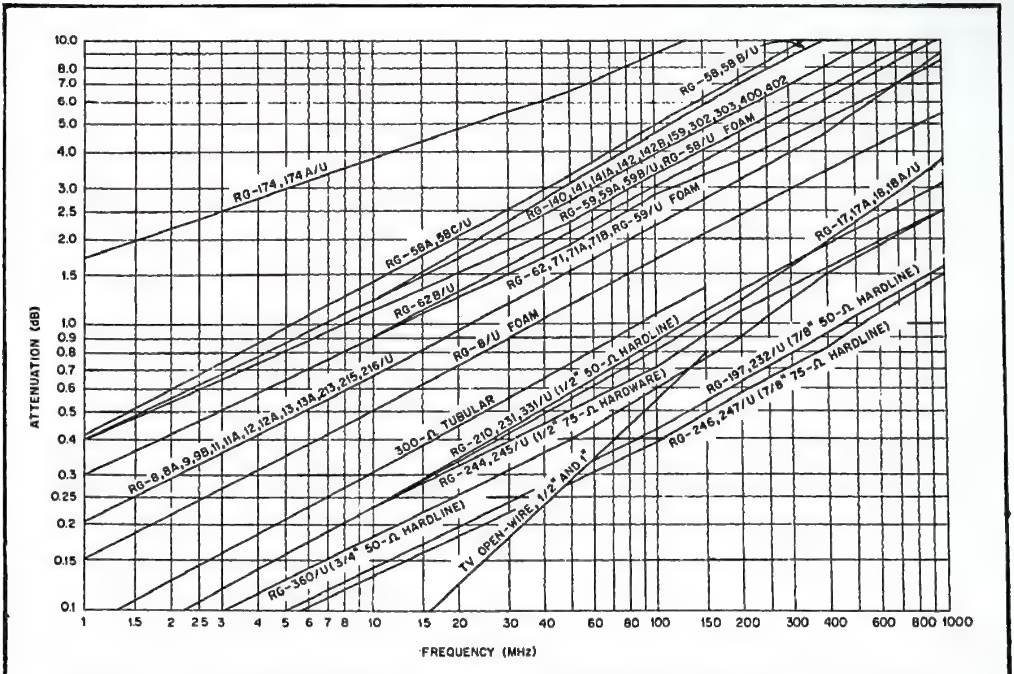


Fig 3-1 -- Curves that show the loss in dB per 100 feet for various popular feed lines. Note that the losses increase as the operating frequency is raised. Data courtesy of **ARRL Antenna Book.**

The dB losses indicated in Fig 3-1 are based on lines that are terminated at each end in the characteristic impedance of the feed line (SWR = 1:1). You can observe that there are many types of coaxial feed line available, as indicated by the numbers in Fig 3-1. Some manufacturers mark their RG feed lines with four numbers, rather than with the RG designators. This can be confusing to a beginner, especially. When you purchase this type of cable, be sure to ask about the equivalent RG type.

Limitations of Foam-Filled Coax

Although foam-filled flexible cable is easy to work with (less rigid than solid polyethylene insulation), it has the shortcomings of (1) lower maximum RMS voltage and (2) if it is kinked or bent severly the inner conductor will move close to the outer conductor at the bend. This disturbs the overall flatness of the line impedance (change in conductor spacing) and voltage can arc across the compressed insulation. You should exercise care when using foam-filled cable. Make gentle bends when routing the cable to your station. RG-8X is subject to the foregoing problem, more so than some other types of flexible coaxial cable. Of course, we must be careful when making bends in Hardline also. It is easy to kink the aluminum outer jacket of this line, and once it is kinked there is no way to repair it.

Balanced Feed Lines

You have heard about balanced or tuned feeders. Perhaps you aren't certain about how they may be used, or whether they are worth considering. Fig 2-10 contains an example of how you can use balanced feed line for a multiband antenna. There are countless other antennas that require balanced feeders, and we will discuss some of them later in this manual.

Balanced transmission line consists of two identical-gauge wires or tubular conductors that are parallel to one another. A constant spacing is maintained between the conductors. The insulating material may be essentially air. A low-loss spacer is used at intervals along the line to help maintain a uniform distance between the two conductors. We refer to this kind of feeder as open-wire line. This is because air serves as the dielectric (insulation) for most of the line. Open-wire feed line is the least lossy of the feeders we can select. Fig 3-1 shows that TV open-wire line (300 ohms) has a loss of only 0.18 dB for 100 feet at 30 MHz. This means that if you apply 100 watts of RF power at one end of a perfectly matched 100-foot open-wire line, there will be 96 watts at the antenna end (30 MHz). A 4-watt loss is inconsequential for a 100-watt signal, even though it would be wonderful to never lose any power in our antenna systems. Unfortunately, 100% efficiency has never been possible in RF circuitry. It's as ideal a concept as is perpetual motion, which has yet to become a reality!

The major shortcomings of open-wire line are (1) fragility and (2) the need to stand it off from conductive objects. I list fragility because the conductors tend to break after they have flexed in the wind for a period. Generally, the wires break at the point where they attach to the antenna or antenna insulating block. Long, unsupported spans of open-wire feeder may twist in the wind. This causes the line to short circuit. You will find it advantageous to support the open-wire line at intervals. This prevents twisting and breakage to some extent.

Commercially made open-wire line is scarce today. Most amateurs construct this type of feeder from available materials. The line impedance is not critical for most applications. You may use impedances that range from 300 to 600 ohms for most of your balanced-feed antennas. Fig 3-2 shows three types of balanced feed line. An equation is included to show you how to calculate the impedance of homemade balanced feeders.

The greater the line impedance the greater the spacing between the conductors. This is beneficial when ice and snow collect on the feeders. Moisture, ice and snow disturb the line impedance and increase the losses. A narrow 300-ohm feed line may become entirely encrusted with show or ice, whereas a 600-ohm feeder may have a 6-inch spacing between the wires, which minimizes the foregoing effects. These considerations are important if you live in an area where winter weather is severe. The high-impedance balanced feeders weigh substantially more than most low-impedance lines. This is because the feeder spreader/insulators are longer, and hence weigh more. This is especially true if the spreaders are made from solid plastic rod rather than thinwall plastic tubing. You may be wondering how far apart the spreaders should be? I add a line spreader every 6 inches for narrow lines, such as 300 ohm feeder. My 600-ohm open-wire lines have spreaders every 12 inches along the line. The closer you place the spreaders the greater the weight of the line, but the less likely will be twisting and short-circuiting.

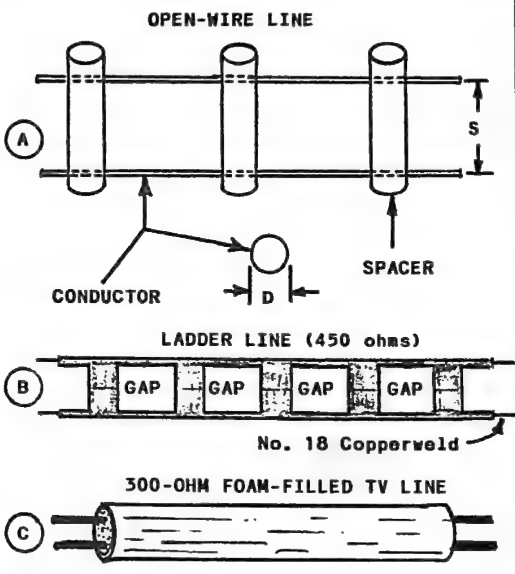


Fig 3-2 -- Three types of balanced feed line. Open-wire line is shown at A. Molded 450-ohm ladder line is depicted at B. Foam TV line is illustrated at C. The characteristic impedance of these lines is determined by the following equation.

$$Z_o = 276 \log \frac{2S}{D} \text{ ohms}$$

where Z_o is the line impedance, S is the center-to-center spacing of the two conductors in inches, and D is the outer diameter of the conductors in inches.

Let's return to Fig 3-2. Three types of line are shown in the drawing.The spacers at A can be affixed to the wires in one of two ways. Details for these methods are provided in Fig 2-7. A wide variety of materials are available for use as feed-line spreaders. Plastic hair-curler tubes are suitable. You may buy these at most department stores for a small investment. You may prefer to buy low-cost plastic clothes hangers for your spreader project. Cut the hangers into appropriate lengths, then drill them to allow the wires to pass through their ends. Tooth-brush handles, throw-away razor handles, and various other common items can be used for your spreaders.

I use strips of Plexiglass for my spreaders. I cut the 1/4-inch sheeting with a low-speed saw, then drill a hole in each end of the rectangular insulator. Industrial plastics dealers may have scrap pieces of Plexiglass, Lexan or polystyrene sheeting available for modest prices. Check your local dealer for bargain plastic material.

Fig 3-2B shows commercial 450-ohm ladder line. It has polyethylene insulation. Gaps are formed in the line to minimize dielectric losses, as shown. This kind of feeder has a velocity factor of roughly 90, according to my tests. It is somewhat easier to handle than is homemade open-wire line, but it is affected more by rain, ice and snow.

Oval-shaped, foam-insulation 300-ohm TV line is depicted at C of Fig 3-2. This kind of transmission line is designed for UHF TV reception. Quality line of this type has fairly large conductors made from stranded copper wire. It will handle 1 kW safely if the SWR is low. It is sometimes sold as "kW twin-lead." Other forms of 300-ohm TV ribbon may also be used for amateur antennas. Try to avoid the cheap, bargain-priced 300-ohm lines, such as those with stiff insulating material and single-wire conductors of small diameter. Most of these lines will deteriorate rapidly when exposed to the weather and sunlight. Also, the single-strand conductors will break easily from stress.

Installing Balanced Feeders

Unlike coaxial cable, balanced transmission lines can't be taped to metal supports or tower legs without serious disruption of performance and increased line loss in dB. You must make certain that these lines are supported by good insulators that keep the feeder several inches from conductive objects. TV standoff insulators are generally acceptable for use with 300-ohm ribbon line. Try to space the line at least 6 inches away from conductive objects. Never bury balanced line in the ground, not even in a plastic pipe. These feeders should be kept above ground and in the clear as much as practicable. Balanced feed lines should also be kept free of trees and other wooden objects, especially if the wood is exposed to moisture.

Polyethylene or ceramic electric-fence insulators work nicely for supporting open-wire or ladder line. Check your farm-supply store for availability of these low-cost standoff insulators. They are excellent also for supporting long, single-wire types of antennas, such as the Beverage antenna.

Do Balanced Feeders Radiate?

Let's imagine that we are using a length of 450-ohm balanced feeder between our transmitter and an antenna. The question arises concerning what part the feed line plays in the radiation pattern of the antenna. Any feed line, if it is terminated by a resistance that is equal in value to the feeder impedance (450 ohms in this example), should not radiate. It is perfectly balanced in this case, and currents of opposite phase along the line cancel one another.

Now, let's envision a 450-ohm feeder that is connected to an antenna which has a 75-ohm feed impedance. This significant mismatch will cause a high SWR on the line, but the feeder will not radiate if the line is balanced. If the antenna is not balanced at the feed point (a dipole, for example, with one leg too long), the feeder will be improperly terminated, and line imbalance will result. The feeder will radiate RF energy under this condition of load imbalance.

You may be wondering what harm, if any, can result from feeder radiation. First, your horizontal dipole will become part of a system that has some radiation of vertical polarization, owing to the feeder radiation. If the feed line is close to your FM or TV receiver antenna, TVI could result, whereas there was no TVI when the feeder was not radiating.

Although feeder radiation may not impair the general performance of your antenna (you are hearing and being heard just fine at great distances), it can have a serious effect on gain types of directional antennas. The generally well-defined lobes of cubical-quad or Yagi beams can be spoiled by radiation from a feed line. The radiation pattern from the transmission line can become part of the overall pattern of the system. When this happens there may be little or no front-to-back ratio for the beam antenna. That is, as you rotate the antenna the strength of a received (or transmitted) signal changes very little. Part of the antenna is horizontal and the remaining part is vertical (most feed lines are erected vertically). It is important in this case to ensure that the transmission line is matched to the antenna, thereby preventing unwanted standing waves on the feeder.

At the start of this section I mentioned feed-line radiation with any type of transmission line. We can experience this problem with coaxial cable as well as balanced line, if there is imbalance in the system.The outer conductor of coaxial cable can radiate as effectively as can the conductors in balanced transmission line. Therefore, proper balance is important in any antenna system that has a flat (no SWR) feeder.

Questions About Coax Shield Braid

I have been asked many times about the outer conductor of coaxial cable, versus the inner conductor, when attaching the feeder to an antenna. Take, for example, a sloping dipole for 40 meters. Amateurs have asked me which half of the dipole (upper or lower) should be connected to the shield braid of coaxial line. They are under the impression that because the shield on the feeder is grounded at the transmitter end, it is also at ground potential at the antenna feed point. They think that, because of this misconception, the shield braid should be joined to the lower leg of the dipole. In reality, it makes no difference which half of the dipole is connected to the outer conductor of the coax. The shield braid of the line is at dc ground, true. It is not at RF ground, except where it attaches to the transmitter chassis or Transmatch cabinet. The RF voltage and current is distributed evenly along the feed line from the transmitter to the antenna, if the SWR is 1:1. You should think of a coaxial feeder in a like manner to balanced feed line, respective to both conductors carrying RF energy. The principal difference between these transmission lines is that one is concentric and unbalanced (coax) while the other line has symmetrical, parallel conductors that are considered to be balanced. If you had an instrument that would permit you to measure the RF voltage at the outer ends of your dipole you would find approximately equal voltages at those points. This is true, irrespective of the type of feeder you use.

Some Other Effects from Standing Waves

You are certain to experience unwanted RF energy in your ham shack, and this will depend upon the antenna and installation at a given time. The higher the SWR on your feed line the more prone your station will be to this problem. Unwanted RF in your station is noticed quickly! You will feel a tingle when you touch your microphone or equipment cabinet during transmit periods. This is known, not so fondly, as a "hot chassis" or "hot mic." In severe cases of excessive RF energy in the shack, your electronic keyer may malfunction and become erratic. You may also get reports of howling and squealing when you try to make a voice transmission. Stray RF energy enters the keyer of speech-amplifier circuits and disrupts the normal operation of these circuits.

This malady is especially common when we attempt to use end-fed wire antennas, with one end of the wire inside the ham shack. If the wire is approximately one half wave long, or a multiple thereof, high RF voltage will be found in the shack, and your troubles will be many in number! Some hams use random-length, end-fed wires for antennas. On some amateur bands they may cause no RF feedback problems, but on other bands (10, 15 and 20 meters in particular) they can cause a total malfunction of a transmitter or keyer. It is best to avoid using any end-fed antenna that is routed directly into the station. If you must use this type of radiator, try to adjust its length to 1/4 wavelength, or an odd multiple thereof. This will result in the current portion of the antenna being in the radio room. This means that there will be no high RF voltage in the shack, and things should operate smoothly.

A high SWR on coaxial or balanced feeders may bring high values of RF voltage into the station also. It is therefore important to match the feed line to the antenna (at the antenna) in order to keep unwanted RF voltage out of the ham shack.

An effective earth ground in your station will help to prevent problems caused by stray RF voltages and currents. You may find it helpful to connect the chassis or cabinet of each piece of station equipment to the ground system. Sometimes it helps to also join the cabinets of the various items to one another by means of a short jumper lead or ground strap, along with the previously mentioned grounding wires to the central ground connection. Modern solid-state amateur equipment is particularly sensitive to stray RF energy. A low SWR is important toward preventing glitches in the station-gear performance.

Are Tuners Necessary?

We may as well discuss Transmatches (transmitter to feed-line matchers) while we are dealing with the subject of feed lines. You will hear people refer to these gadgets as "antenna tuners" or "antenna matchers." A common acronym for these units is ATU, for antenna tuning unit. Actually, this network of coils and capacitors is not an antenna tuner unless it is located at the antenna feed point, or where an end-fed wire connects to your transmitter. Nonetheless, they are known by all of the foregoing names, right or wrong!

Whether or not you need a Transmatch depends on a number of considerations. If you have a coax-fed dipole or vertical that has a low SWR on each band of interest, there is no need for a tuner. The exception to this rule is when your antenna does not have a low SWR across all of the band. Take, for example, 75 and 80 meters. You have just upgraded from Novice to General. Your dipole is tuned for the 80-meter Novice band, but the SWR is very high at 3530 and 3950 kHz. In fact, your modern transceiver won't produce much power at those frequencies, owing to the built-in SWR protective circuit. Now is the time to use a Transmatch. You may adjust it to provide a 1:1 match between your transmitter and the shack end of the coaxial feed line. Bear in mind that this does not correct the mismatch that exists at the antenna feed point. In effect, you have matched the line to the transmitter and provided the transmitter with the 50-ohm load it is designed for. You can now operate anywhere in the 75- and 80-meter band with the original dipole, and the SWR at the transmitter can be held at 1:1.

Most Yagi beam antennas are optimized for one end of a ham band. My triband Yagi, for instance, is tuned for a 1:1 SWR in the CW portions of the bands. When I attempt to operate in the phone segments I observe a fairly high SWR. I use my Transmatch to tune out the reactance and give the transmitter a 50-ohm load to look into. This does not help the antenna to work any better, but my transmitter is able to deliver its full rated power to the feed line.

A Transmatch is essential when you use one of the end-fed wire antennas we considered earlier. The impedance at the end of the wire can range from a few ohms to thousands of ohms, depending upon its length and the operating frequency. A Transmatch permits you to match these varied impedances to your 50-ohm transmitter and receiver.

How Does a Transmatch Work?

Transmatches contain variable elements of L and C (inductance and capacitance). Variable capacitors and roller-coil or tapped inductors with switches are used. A specific setting for the C and L components will yield an SWR of 1:1 when a matched condition is obtained. An ideal antenna needs no Transmatch. In order for it to be ideal (uncommon) it must present to the transmitter or receiver a purely resistive characteristic at the desired ohmic value. In other words, an ideal dipole would have a feed-point that presented a 50-ohm, purely resistive load for the 50-ohm coaxial feed line. No tuner would be required. Although this can happen, it seldom does. It is more likely that the antenna will exhibit, say, 60 ohms resistive. There may be Xc or XL (capacitive or inductive reactance) present also. We must, therefore, cancel sufficient reactance to permit it to add or subtract from the resistive value to obtain a net value of 50 ohms. This is known as a conjugate match. You will hear this term from time to time. Fig 3-3 shows the way a typical Transmatch circuit is arranged.

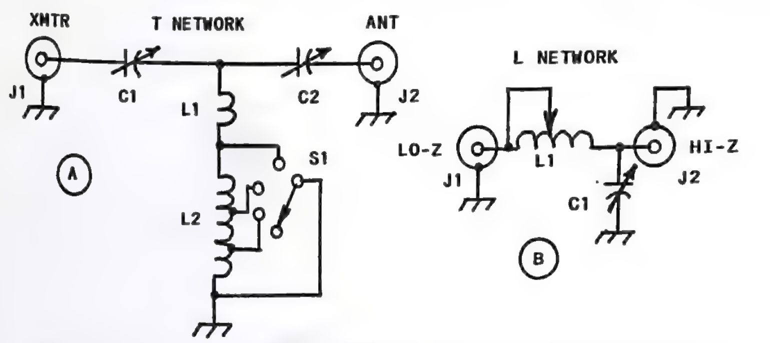


Fig 3-3 -- Examples of two common types of Transmatch circuit. The T network at A is found in most commercially made units. Although a tapped coil is shown, most T-network Transmatches have a roller coil at L2. L1 is a small, separate coil for 10 and 15 meters. The L network at B may be reversed in accordance with the impedance that is presented to the transmitter. The high-Z (high impedance) end of the L network is where C1 is located. A roller coil is used in the example at B. Roller coils allow greater range when adjusting the circuit inductance, compared to tapped coils. An SWR indicator is necessary when adjusting these circuits for a 1:1 SWR.

A Transmatch not only compensates for unwanted reactance, but it acts as an impedance-transformation device. In other words, if your end-fed wire antenna presents a 100-ohm impedance to the transmitter after the reactance is dealt with, you still need to change that value to 50 ohms for your transmitter. The Transmatch adjustments are changed until the transmitter "sees" a 50-ohm resistive load.

Capacitive reactance results when an antenna is too short for the operating frequency. An equal amount of inductive reactance must then be introduced in the antenna circuit to cancel the capacitive reactance. Suppose, for the purpose of illustration, that you are trying to use a 40-foot wire for 3.7 MHz (as a 1/4-wavelength radiator). Actually, the wire needs to be 63 feet long in order for it to be resonant. The 40 feet of wire will exhibit capacitive reactance. Let's say it's 30 ohms of Xc. You must add 30 ohms of inductive reactance in series with the antenna (called a loading coil) in order to cancel the Xc in the system. **The ARRL Handbook** and **The ARRL Antenna Book** treat this subject in greater detail.

Let's take the reverse situation: Your end-fed wire is 80-feet long instead of 63 feet for 3.7 MHz. This length of wire has unwanted XL. In order to cancel the inductive reactance you need to place an equal amount of Xc in series with the antenna. A series capacitor is required. Hams will often use a variable coil or variable capacitor to permit precise adjustment when cancelling reactance. This is useful when changing frequency within a given amateur band, because the values of reactance change with the operating frequency. However, a Transmatch is the preferred means for cancelling reactance and providing an impedance transformation.

This book is not meant as a tool for teaching electronics theory. This brief discussion about reactance is necessary, however, in order to define the function of a Transmatch. A very complex treatment of reactance would be necessary in order to fully explain the workings of a Transmatch. At this point in your amateur career it is important only that you know what a Transmatch does and how to operate one.

Transmatch Adjustment

You need to have an SWR indicator between your transmitter and the Transmatch. Some factory-built Transmatches contain an SWR meter. If you have one of these tuners, you don't need to use an outboard SWR indicator. The SWR instrument permits you to monitor the progress of your Transmatch adjustments. Fig 3-4 shows the normal arrangement for an outboard SWR meter when it is used with a matcher.

I recommend that you obtain a 50-ohm dummy antenna, such as the Heath Cantenna. Hook the dummy load to the output of your Transmatch in place of your antenna. Now, go through the Novice bands you plan to operate in, feeding transmitter power to the dummy load via the Transmatch. Keep a chart of the Transmatch dial settings for each band. Start with each of the Transmatch controls at midrange. Apply only enough transmitter power to permit full-scale deflection of your SWR meter (your **DRIVE** control is used to lower the transmitter output power). Now, adjust the variable inductance for the lowest SWR reading (SWR meter set for **REFLECTED** power). Following this adjustment, move the variable-capacitor controls and set them for the new lowest SWR reading. Repeat this process with each of the adjustable controls on your Transmatch until the SWR is 1:1. This occurs when there is no SWR-meter reading in the **REFLECTED** mode. Log the settings that occur when the SWR is 1:1. These dial readings represent the starting point when adjusting your Transmatch while the antenna is connected to it.

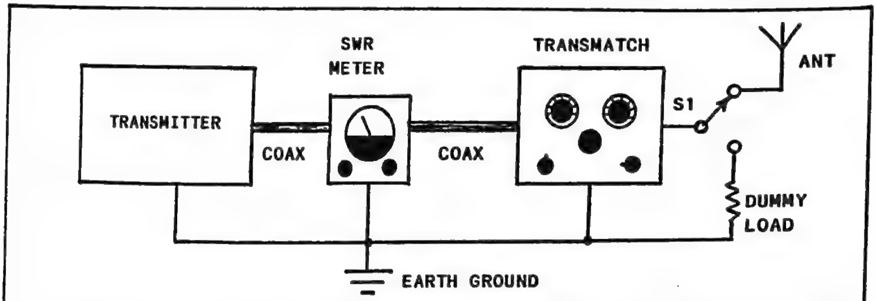


Fig 3-4 -- This is how your SWR meter is used when your Transmatch does not have a built-in SWR indicator. S1 may be included to permit switching from the antenna to a dummy load (see text). Coaxial cable should be used between units (50 ohms), between the Transmatch and the dummy load, and between the Transmatch and S1. The dummy load is used when making transmitter tuning adjustments. It is used also to obtain starting-point settings for the Transmatch.

Be sure to keep your transmitter output power low when you first feed the RF power to the antenna. Final Transmatch adjustment may now be accomplished. Make sure to find a frequency that is not in use. Identify your station by giving your call sign. Adjust the Transmatch controls for an SWR of 1:1. The settings will be somewhat different from those obtained when using the dummy load. Adjust the controls one by one in small increments until the reflected power indication is zero. You may now adjust your transmitter for full rated output power. Draft a permanent logging sheet for the Transmatch settings for each band you operate. These will save time when changing bands. However, if you erect a new antenna, you will need to go through the foregoing adjustment process to obtain a new list of dial readings. The matcher will be set differently for each antenna you use. Reduced transmitter power is necessary during tuning adjustments in order to prevent damage to the final amplifier.

Balanced Feeders and the Transmatch

Figs 3-3 and 3-4 focus on Transmatches that are used with coax-fed or single-wire antennas. You are probably wondering how we can accommodate balanced feed lines with a single-ended matching unit of the type under discussion. There are two ways to deal with balanced feeders. The first method requires using a special type of Transmatch (the Johnson Matchbox is one) that permits balanced feeders to be connected directly to a coil that has taps either side of the coil electrical center. The tap points are different for each band, as is the amount of coil used. Early day amateurs used this type of balanced or "push-pull" tuner most of the time, since tuned feeders were then the order of the day. **The ARRL Antenna Book** describes this type of Transmatch. You may refer to that volume for further information.

The second, and more popular method for matching balanced feed line to your 50-ohm transmitter is to use the type of circuits that are illustrated in Fig 3-3. A balun transformer (balanced to unbalanced) is inserted between the output port of the Transmatch and the balanced feed line. This is a broadband transformer designed for RF use from 1.8 to 30 MHz, normally. Baluns can be designed for any operating frequency, but it is impossible to create one that works properly from, say, 1.8 to 440 MHz. That is more bandwidth than is practical, so the usual practice is to design baluns for a limited range of frequency.

Balun transformers have impedance-transformation ratios of 1:1 and 4:1 for most of our amateur use. They are available, however, for other integers, such as 9:1. An excellent text on the subject of balun transformers is available from The ARRL. It is called **Transmission Line Transformers**, and was written by Jerry Sevick, W2FMI. You may want to obtain a copy of this book if you plan to build baluns.

A number of the commercially made Transmatches contain a balun transformer. It can be used when you employ balanced feeders. It is ignored when the matcher is used with coax-fed or end-fed antennas. Unfortunately, these devices do not function as true baluns under a variety of operating conditions. For example, if your feed line happens to present a rather high impedance (greater than roughly 500 ohms) at a certain frequency, the balun can become overheated, or it may have internal arcing, at very high power levels. You will know when this is happening, because the SWR will change with heating! It is best that your balun never be connected to loads less than 25 ohms or greater than 500 ohms, for best performance. Despite these shortcomings, a balun is a neat way to convert an unbalanced Transmatch to a balanced output condition.

Balun transformers are wound on ferrite rods or toroid cores. There are a number of them available commercially as separate units. Check the **QST** ads and ham-radio flyers for these gadgets. If baluns are used incorrectly at high power levels, the cores will become saturated. When this happens the core becomes hot and its characteristics change. A saturated balun can act like a short circuit in your antenna system. Furthermore, the balun will, under this condition, generate harmonics that will be radiated by your antenna. This can lead to TVI and RFI. It is important, therefore, to be careful about the environment in which you place your balun. Don't expect it to do things it is not designed to handle!

Balun transformers are used frequently at the feed point of antennas. For example, if your antenna has a 200-ohm balanced feed point, you may install a 4:1 balun transformer at the feed point. This transforms 200 ohms to 50 ohms (for using coaxial transmission line), and it converts the balanced condition to an unbalanced one. This is a viable thing to do if the SWR is low (1.5:1 or less). Under this condition the balun should do a decent job for you. However, if the SWR is high, the balun no longer performs as intended, and it can degrade the performance of your antenna system! It may even saturate and cause a higher than normal SWR, and it can cause TVI. In a worst case it may become defective from excessive heating and arcing. In order for a balun to function as intended, it should be connected to a resistive load at low SWR. Normally, this type of environment exists over a narrow frequency range within a specified amateur band. Another shortcoming of balun use, especially at the high end of the HF spectrum (10, 15 and 20 meters, notably), is that the leads from the balun transformer to the antenna feed point can, if they are more than an inch long, add to the length of the driven element. This causes the resonant frequency of the antenna to change (moves it lower in frequency), and up goes the SWR. In this situation you will need to shorten the length of the driven element to compensate for the increase in effective antenna length, caused by the balun leads.

You can determine from this discussion that a balun transformer should be avoided if it isn't essential for proper system performance. It will not increase the strength of your transmitted signal in most instances, and it must be used correctly if it becomes a part of your antenna system. Even in a correct environment, balun transformers cause a small loss. This is because no broadband transformer is 100% efficient. The correct way to pronounce balun is bal (as in balcony) and un (as in until). It is not "baylon, baloon or ballum," as some hams think.

A Practical Transmatch Circuit

There are numerous circuits you can build for use as a Transmatch. I want to describe one that is easy to construct. It is capable of matching most of the standard and odd impedances we amateurs encounter. Fig 3-5 shows the circuit. This is known as a T network matcher. You will have a wider matching range if you use a roller coil for L1. This permits you to select a fraction of a coil turn (very small inductance change), which is sometimes necessary when matching the transmitter to an odd (complex) impedance. Although you may use a tapped coil and a switch to change the inductance value of L1, you will be stuck with fixed-value inductances that may not permit you to obtain an SWR of 1:1 on some frequencies. A tapped coil is OK if you plan to use the same antennas for a long period. In this situation you can experiment with the coil-tap positions before making permanent solder joints on the coil. Each tap is chosen to provide an SWR of 1:1 for each antenna used. The tapped coil and switch will greatly reduce the cost of your tuner, since roller coils are quite expensive. If you are lucky, you may find a surplus roller coil at a ham flea market (or in a surplus catalog), and this will reduce the expenditure for your unit.

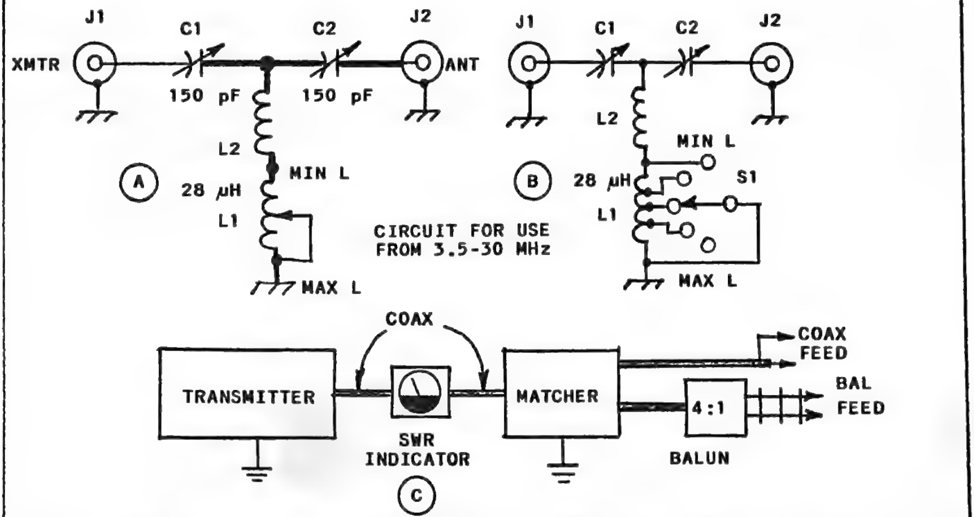


Fig 3-5 -- Practical circuit (A and B) for a T-network Transmatch, showing L1 as a rotary inductor (A) and a tapped coil (B). The heavy lines at A show critical leads that must be kept short to minimize unwanted stray inductance. Heavy conductors, such as 1/4-inch-wide strips of flashing copper are best for this part of the circuit. L2 is for use on 15 and 10 meters. It has 6 turns of no. 10 or 12 wire, 1 inch diameter by 1 inch long. C1 and C2 are transmitting variable capacitors. The spacing between the rotor and stator plates must be 1/8 inch minimum for up to 300 W of RF power. A spacing of at least 1/4 inch is necessary for maximum amateur power levels. S1 at B needs to have heavy contacts, and ceramic insulation is best to prevent arcing and burning. C1 and C2 are insulated from the chassis by mounting them on ceramic standoff posts or sheets of Plexiglass. Insulated shaft couplers are used between the capacitors and the panel knobs. RadioKit, P.O. Box 973, Pelham, NH 03076, sells parts for the circuit at A. The block diagram at C shows how to connect your Transmatch to your transmitter, SWR indicator and antenna.

C1 and C2 of Fig 3-5 may have greater maximum capacitance than 150 pF, which is the least capacitance you should have available. Values up to 300 pF maximum are suitable. You may want to shop for Transmatch parts at Fair Radio Sales (a surplus dealer) in Lima, OH. This company sells variable capacitors and rotary coils. Look for a roller coil from a BC-191 or BC-375 WW-II transmitter. These units have ample inductance, and they have a built-in turns counter dial. Ceramic rotary switches (S1 of Fig 3-5B) are often available as surplus too.

Normally, the tapped coil and switch setup in Fig 3-5B requires more switch positions than those shown. Your coil may need as many as 10 taps in order to provide the matching range you will need. You can wind your own coil for L1 (Fig 3-5B). Use 6 turns per inch of no. 12 bare or enameled wire on a coil form that is 8 inches long and 2 inches in diameter. There will be a space between the turns. Don't let them touch one another if you use bare copper wire. You will need a total of 48 turns of wire to obtain 26 microhenries of inductance. Thin-wall fiberglass or high impact polystyrene tubing is available from industrial plastics dealers. You may close wind the coil turns if you use enameled wire, but it will be more difficult to solder the coil taps with this type of inductor, at least without shorting the desired turn to the adjacent ones. A shorted turn will ruin the Q of the coil, so avoid letting this occur.

The taps are selected experimentally for each antenna used, in accordance with the chosen operating frequency. When you find a tap that permits an SWR of 1:1, while adjusting C1 and C2, make a permanent solder connection to S1. A large piece of Miniductor coil stock (26 uH of inductance) will be easier to deal with if you decide to use a tapped coil.

How to Adjust Your Transmatch

As you learned earlier in this booklet, use your 50-ohm dummy load for locating the approximate settings for your Transmatch dials. Next, apply only enough transmitter power to get a full-scale meter reading (**FWD POWER**) on your SWR indicator, with the antenna connected to the Transmatch. Make sure the frequency is not in use before you do this, and give your call sign, followed by "testing." Alternately adjust L1, C1 and C2 for the lowest **REFLECTED POWER** reading on your SWR indicator. Use the most capacitance possible at C2 to obtain the 1:1 SWR reading. This will minimize power loss through your Transmatch. You will find that juggling the three Transmatch-control settings becomes easier with experience. Tune slowly to avoid passing the point where the reflected power diminishes. When the SWR reading is 1:1 you may increase your transmitter output power to the normal amount. These tuning instructions apply also to commercial Transmatches.

You can also preadjust your Transmatch to approximate settings by listening to your receiver and adjusting the matcher for maximum receiver response to background noise. If you tune in a weak signal, you may use it also for coarse adjustment of your Transmatch. Antenna noise bridges (see **QST** for December 1987) may be used for adjusting a Transmatch precisely. This instrument enables the operator provide an impedance match without transmitting a signal during tuneup.

Homemade Transmatches

You need not enclose your Transmatch in a cabinet. TVI is not generated by a matching unit. Conversely, some types of Transmatch (depending upon the design) will help to reduce TVI, since the circuit can suppress harmonic energy. We should assume that the transmitter harmonics are already suppressed to an acceptable level before they reach the Transmatch. Therefore, the tuner need not be shielded. You can build your unit on a piece of wood and use a plastic panel, if that is your wish.

It is wise, however, to enclose an antenna tuner. This will prevent dust from accumulating on the components: dust and other dirt can cause arcing between the plates of the tuning capacitors. Another justification for enclosing your Transmatch is that a cover will prevent accidental contact with the parts that carry high RF voltage. This voltage can cause a nasty burn if flesh comes in contact with components that are alive with RF energy!

Attaching Feeder Connectors

Good electrical and mechanical bonds are essential to reliable antenna performance. This truism is important to keep in mind when you attach connectors to your coaxial feed lines. Also, you need to trim the inner and outer conductors of coaxial cable for critical dimensions in order to ensure a proper fit for the connector you use. Pictorial charts that show how to prepare the cable for a variety of popular connectors are listed in **The ARRL Antenna Book** and in **The ARRL Handbook.**

Crimp-on quick connectors are satisfactory for short-term outdoor use. I do not recommend them for long-term service, owing to their vulnerability to corrosion at the contact points. You will fare better by using the types of coaxial connectors that require the inner and outer conductors of the cable to be soldered to them. It is prudent also to seal the completed unit with tape or Coax Seal. The latter product is made commercially, and is advertised in most amateur magazines. A sealed connector is less likely to collect dirt and moisture, internally, and this retards unwanted oxidation. It also helps to prevent water from migrating into the coaxial cable and flowing between the outer conductor and the insulation. A water-logged feed line is lossy, and it will eventually become contaminated from acids that are borne by the rain.

Chapter Summary

The subject of SWR is popular, as evidenced when we listen to amateur conversations over the air. Unfortunately, a large amount of the free advice you may receive will be incorrect. I urge you to research this and other subjects in books that are known for their accuracy, such as **The ARRL Antenna Book.** A well-meaning ham may convey misinformation that he obtained from a faulty source, and this can cause you all manner of technical difficulty and needless expense.

Here are some facts that should be useful to you when considering SWR and its effects:

1) Reflected power (SWR) does not, in itself, cause an RF power loss. The basic feed-line attenuation and the SWR must be very high in order for large losses to be incurred in the feeder as a result of high SWR. This is not a matter of great concern in the HF spectrum, but can become a serious matter at VHF and higher.
2) Reflected power does not flow back into the transmitter and cause damage. Improper matching of the transmitter to the feed line can, however, cause the transmitter to deliver reduced output power, if it has a built-in SWR shut-down (protection) circuit.
3) Reducing the SWR below approximately 2:1 will not increase the antenna radiation at HF, assuming the SWR protection circuit in the transmitter will tolerate a 2:1 SWR without automatically reducing the transmitter power. The measurable difference between a 1:1 and a 2:1 SWR, in terms of effective radiated power, is negligible.
4) A low SWR over a wide frequency range with a given antenna does not mean that the antenna is efficient. To the contrary, this condition suggests that the antenna has high resistive losses from bad connections, very lossy feeders or an inferior antenna ground system (radials, for example). In this situation the antenna may be highly inefficient, despite the low SWR and extreme apparent bandwidth.
5) Adjustment of the Transmatch at the transmitter end of the feed line does not correct a mismatch at the antenna.
6) A high SWR does not cause the feed line to radiate. Feeder radiation is caused, rather, by imbalance at the point where the feeder connects to the antenna.
7) In order for an SWR meter to be accurate, it must be designed for the impedance of the coaxial cable with which it is used. A 50-ohm SWR bridge will not yield accurate readings if, for example, it is used with 75-ohm feed line.
8) A high SWR does not cause TVI and RFI. An imbalance in the feed system may, however, increase TVI or RFI by virtue of unwanted feeder radiation. This may occur if the feeder is close to a TV or FM receiver antenna feed line.
9) Changing the feed-line length does not change the SWR.

When in doubt about any antenna subject, look for the answer in **The ARRL Antenna Book.**

Chapter 4

BUILDING AND USING VERTICAL ANTENNAS

You may wonder how we amateurs choose between horizontal and vertical antennas. Which of the two are best for our needs? How do these antennas compare for DX operation? What are the electrical advantages of a vertical antenna, if any?

For the most part, simple vertical antennas are chosen because they occupy less space than does a dipole for the same operating frequency. A vertical is usually 1/4-wavelength high, whereas a dipole is 1/2 wavelength long (twice as long as the vertical). Amateurs who live in crowded urban locations may have a tiny city lot, or no lot whatsoever, across which a dipole may be stretched. This is when a vertical antenna comes into its own! It goes up rather than out, and there may be ample room to deploy it.

Another advantage from using a vertical antenna is that it will provide a low radiation angle (desirable for DX work) if it is constructed properly. It can do this even when it is mounted at ground level. In order for a dipole to yield equivalent DX performance it would need to be very high above ground -- at least 1/2 wavelength, and it would require two tall supports (inverted-V and sloper dipoles excepted). Whereas a 40-meter vertical would be approximately 32 feet high, a 40-meter dipole would be roughly 64 feet long and an equivalent height above ground, at least for comparable DX performance.

The case I have presented for vertical antennas may appear rather convincing at this juncture, but there is a catch! In order for a 1/4-wavelength vertical to perform efficiently and have the desired low radiation angle, it must be used with a quality ground screen. In other words, we must provide the missing or image half of the dipole if we want our vertical antenna to operate correctly. The image half of the antenna occurs in the ground and is an invisible entity. We must place numerous 1/4-wavelength wires in or on the ground, fanning them out from the base of the vertical radiator. These are called radial wires or radials. They comprise the ground screen for the antenna. The maximum effective number of radials is considered to be 120, although many amateurs report good results with as few as 10 or 15 radials. The effectiveness of your system when only a few radials are installed is dependent in part on the conductivity of the earth in your geographical location. Marsh land sites that have wet soil are especially good for installing vertical antennas. A high salt content at such a spot is also conducive to good performance. Conversely, it is difficult to create a good ground screen on layers of rock or in arid regions where there is little soil moisture. The chemical and mineral makeup of the earth in a given location plays a role in how well a ground system performs, which adds to the list of things we need to consider when building a ground system.

Some amateurs try to get by with a few metal rods driven into the soil near the vertical antenna. These rods are joined by means of large diameter wire or cable braid. Although they may provide a ground reference for the overall system, the rods do not take the place of a radial-wire screen. The ground losses with this inferior vertical-antenna system result in a very inefficient radiator that may be no better, if as good as, a half-wave dipole a few feet above ground.

There is still another consideration connected with vertical antennas -- one that suggests they are by no means a cure-all for limited-space problems. A vertical or any other type of ham antenna should be clear of nearby conductive objects and trees if it is to perform correctly. This means that nearby phone and power lines can affect the radiation of the antenna, since they tend to absorb power and distort the antenna pattern. The same is true of homes with aluminum siding, chain-link fences and so on. In an ideal installation the vertical antenna would be above the power lines, trees and other clutter. This is seldom practical for us amateurs, so we must make do with what is available by way of practical space and height. In any event, good performance may be realized if we keep the antenna as far away from conductive objects as is practicable. Degraded antenna performance is always better than no performance, which would be the case if we had no antenna whatsoever!

Vertical Antennas in General

A single vertical radiator has an omnidirectional radiation pattern. This means that it responds equally to signals from all directions. The performance is the same during transmit. The omnidirectional characteristic can present a problem on receive, since QRM from undesired directions can interfere with reception of the signal we wish to copy. A rotary beam antenna, on the other hand, is aimed at the station of interest, and signals off the sides and back of the beam antenna are reduced in strength at our location. But, a vertical antenna eliminates the need to rotate the antenna, and this can be an advantage at times.

You should be aware that if you are using a vertical antenna during communication with a nearby (ground wave) station that has a horizontal antenna, a situation of cross polarization exists. This causes a signal attenuation of 20 dB or greater. Typical ground-wave distance, during which the signal follows the earth's surface, rather than being reflected back to earth via the ionosphere, for 80 meters is approximately 60 miles. On 40 meters it is 45 miles and on 10 meters it is roughly 10 miles. Therefore, if you are using a vertical antenna on, say, 80 meters, and you are working a station 30 miles away that is equipped with a horizontal dipole, there will be a signal loss between the antennas of 20 dB or greater. On the other hand, if both stations had vertical or horizontal antennas (same polarization), that loss would not occur. Generally, cross-polarization is a minor concern for HF-band operation, but it can be a serious matter at VHF and UHF. The polarization of the wave is not a major consideration during skip operation, wherein our radio waves are reflected back to earth from the ionosphere. During this process the wave polarity shifts almost constantly. It may arrive at your antenna with horizontal or vertical polarization, or even with some in-between polarization. A vertically polarized antenna should provide greater ground-wave range than can be expected from an antenna with horizontal polarization, such as a dipole. This is because a well-designed vertical has a very low radiation or wave angle.

Noise Pickup

A vertical antenna is more responsive to man-made noise (power lines, appliances, etc.) than is a horizontal antenna. This is because most man-made noise is radiated vertically from house wiring. This represents a disadvantage if you live in an area that is particularly "noisy." Industrial locations are especially bad in this regard. The same is true of locations where high-tension power lines are nearby. You should consider this matter when choosing the antenna you will use. Man-made QRN can be so severe that the noise masks all but the strongest signals that enter your receiver. The noise blanker in your receiver is not very effective in reducing most man-made noise. Blankers work best for pulse noise of short duration, such as automotive spark-plug pulses.

Some amateurs prefer to use a vertical antenna, even though there is substantial man-made noise present. They use a separate antenna for receiving, such as a small loop, horizontal dipole or Beverage type. The foregoing antennas are less receptive to vertically polarized man-made noise.

Image Half of the Antenna

Earlier in this chapter I referred to the image part of vertical antennas. Fig 4-1 illustrates the principle. This image occurs in the ground at a depth which is equivalent to the antenna height. You can see in Fig 3-1 that the image half of the antenna is of opposite polarity to the real half. Therefore, the currents for the antenna halves are 180 degrees out of phase, just as they are on the two legs of a half-wave dipole. This image part of the system is caused by the reflected ray from the portion of the antenna that is above ground. We can think of the image as a reflection in a mirror that is reversed from the real object. You need to be aware that there is an image antenna in the ground when we use horizontal antennas as well. This is why a good ground screen is important under an antenna when the conductivity of the earth is poor -- hence our need for a system of radial wires under a vertical antenna. relative to maximum antenna performance.

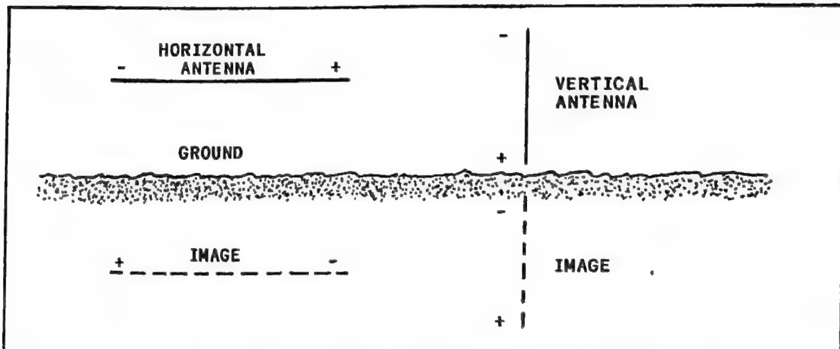


Fig 4-1 -- Horizontal and vertical antenna representations along with their in-ground image halves. Note the polarity change for the image portions.

You can see from Fig 4-1 that a vertical antenna is essentially one half of a dipole. The missing half of the dipole is in the ground. The feed impedance of a properly designed and adjusted 1/4-wave vertical is, therefore, roughly half that for a half-wave dipole. A 30-ohm feed impedance is typical for a 1/4-wave vertical that is ground-mounted and used with a system of radial ground wires. This means that there will be a mismatch between the antenna and the feed line if 50-ohm coaxial cable is used. Later in this chapter we will discuss methods for matching the feeder to the antenna in order to obtain an SWR of 1:1.

Above-Ground Verticals

Your vertical radiator need not be installed at ground level. In fact, many hams prefer to elevate the system as high above ground as is practicable. This is an easy task when the vertical is designed for the upper part of the HF spectrum (14.0 MHz and up). VHF and UHF verticals are always erected high above ground.

This type of antenna is generally referred to as a ground-plane vertical, since the radials are in a plane (above ground) that is parallel to earth. This artificial ground usually consists of four or more 1/4-wavelength radial wires. The spacing between the radials is 90° when four wires are used. The antenna feed impedance is approximately 30 ohms when the radials are at right angles to the driven element (radiator). The radial wires may be drooped to increase the feed impedance to 50 ohms. The correct pitch angle may be determined while observing the SWR with a bridge or other SWR indicator. Fig 4-2 shows how an above-ground vertical is configured.

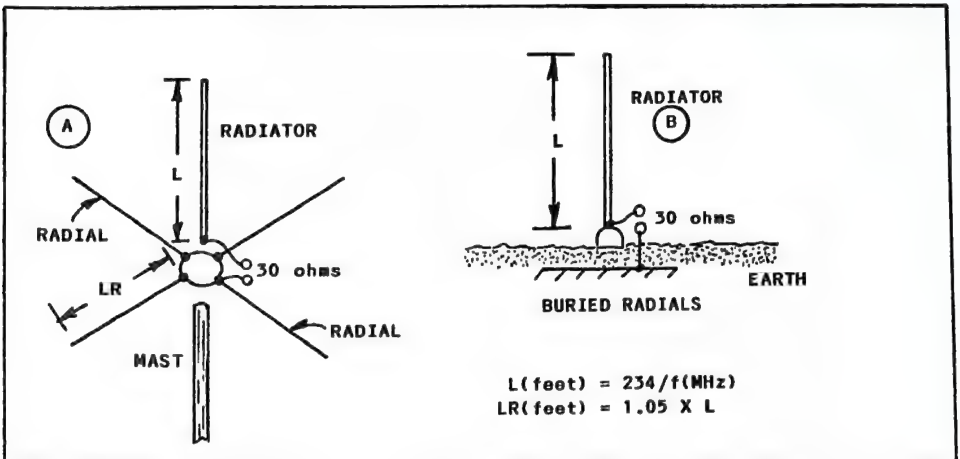


Fig 4-2 -- Two examples of 1/4-wave vertical antennas. The drawing at A shows an above-ground vertical that has four radials (LR). These conductors are 5% longer than the radiator, and they are at right angles to the radiator. The four radials are joined at the base of the radiator, as shown. The mast is insulated from the radials and the radiator. A ground-mounted vertical is seen at B. It rests on an insulator and is used with a system of buried or on-ground radial wires. Both antennas have the same feed impedance. The radials at A may be drooped to raise the feed impedance (see text).

You can calculate the length of the radiator for your vertical by using the formula in Fig 4-2. For example, let's suppose you want to design a vertical for use on 15 meters, say, 21.125 MHz. The length in feet is 234/21.125 = 11.077. This is equivalent to 11 feet and 1 inch. The radials at Fig 4-2A would be 5% longer (11.077 X 1.05 = 11.63 feet), or 11 feet, 7-1/2 inches. The budied radials at B of Fig 4-2 may be calculated by the standard 234/f(MHz) formula.

Sloping Radiators

Quarter-wave and half-wave radiators are often sloped from a tower, mast or tree when there is not enough support-structure height to allow the radiator to be completely vertical. These antennas are known as quarter-wave or half-wave slopers. If the slope of the wire is 45° or less, the radiated wave will be vertically polarized. Thus, you may slope a dipole from your tower if you desire vertical polarization. A quarter-wave wire may be used in a similar fashion (more on this later).

It is important to remember that a sloping 1/4-wavelength wire or dipole has a directional characteristic (directivity) when it is supported by a metal mast or tower. Let's suppose, for example, that you have a 50-foot tower on which you erect a dipole that slopes to the west. Maximum signal directivity for this antenna is west because the tower or mast is behind the dipole and acts like a reflector. A radiation lobe sends maximum signal westward, but it is not a major concern. You will still be able to communicate effectively with stations that are east, south and north of you. The difference is that your signal will not be quite as loud in those directions. Fig 4-3 shows a quarter-wave (half sloper) and a half-wave (full sloper) sloper as they would be configured with a metal mast.

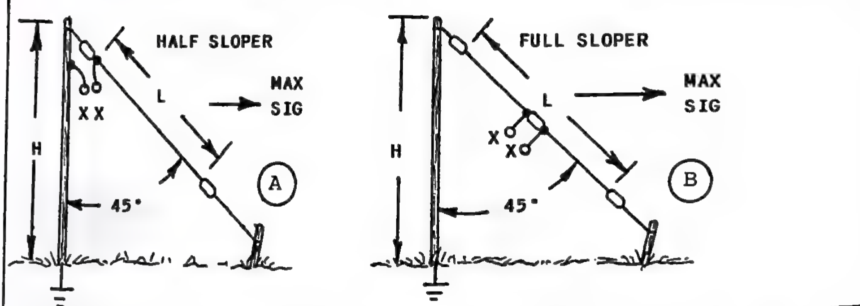


Fig 4-3 — Example A shows a quarter-wave "half sloper." H may any dimension that is convenient for both types of sloper. L(feet) at A is obtained from 234/f(MHz). The inner conductor of 50-ohm coaxial cable is connected to the upper end of the wire at A. The shield braid is attached to the mast at points X. The feeder is then taped to the mast and brought to ground level. Antenna B is a full sloper that is made from a half-wave dipole. The feeder (50-ohm cable or balanced twin line) is connected at points X and routed away from the antenna at a right angle to the lower part of the mast, where it is taped in place. The dimensions for antenna B, in feet, are obtained from 468/f(MHz)

We must recognize that the metal mast is a working part of the half sloper of Fig 4-3A, owing to the coaxial cable shield braid being connected to the top of the mast or tower. Even though the tower is at dc ground from top to bottom, it is not at RF ground, except at the bottom end where it is attached to the earth ground. Therefore, the height (H) of the mast will affect the final adjustment of the system to some extent. The supporting pole of Fig 4-3B is not a working part of the full sloper.

Sloper Adjustments

The customary method for adjusting the half sloper is to attach the feed line to points X then locate an SWR indicator between the feed line and the transmitter. Set the transmitter frequency for the center of the proposed antenna operating range. Feed power to the antenna and observe the reflected power reading on the SWR indicator. Experiment first with the enclosed angle of the sloper. Changing the pitch of the wire will affect the SWR. Find the position that yields the lowest reflected-power reading. If you are unable to obtain an SWR of 1:1, try shortening the sloper wire slightly. If the reflected power decreases, remove more wire from the antenna until no further decrease is noted. The SWR should be quite low at this time. You may now experiment further with the enclosed angle of the sloper to bring the SWR down to 1:1. You may not be able to get a perfect match to the transmitter, but anything from 1.5:1 or lower will be satisfactory.

Adjustment of the full sloper of Fig 4-3B is done in a similar manner. Experiment with the slope angle and the length of the dipole. Either antenna (depending upon the exact installation) may require slight shortening or lengthening to ensure a low SWR. The two formulas in Fig 4-3 provide starting points for dimension L.

The radiation angle of slopers is generally quite low. This makes the antennas rather desirable for DX communications. But, like other vertically polarized antennas, slopers tend to respond to nearby fields of man-made noise -- more so than is true of horizontal antennas. This can cause problems with reception in especially noisy neighborhoods (power lines, household appliances, etc.).

Slopers on Nonconductive Poles

You may be wondering if slopers can be used when you do not have a metal support structure. The answer is "yes," definitely. If you erect a half sloper (Fig 4-3A) while using a wooden mast or a tree for the support, you must run a piece of wire from the feed point to a ground system or collection of ground rods. The wire should come straight down from the feed point. It is then connected to a quality earth ground. The vertical drop wire replaces a metal mast or tower. Remember, we learned earlier that the metal supporting device is a working part of a half sloper. Buried radials provide the best ground for this antenna, but acceptable performance can often be had when using four 8-foot ground rods, spaced 4 feet apart, and bonded together with heavy-gauge wire of shield braid. In this situation you can aid the quality of the ground by connecting your cold-water pipe system to the group of rods. A chain-link fence, if available, can also be tied to the ground system.

The full sloper of Fig 4-3B does not require a drop wire. It may be erected as shown when using a nonconductive support. It will not have directivity off the slope of the wire, and radiation will be essentially omnidirectional.

The Effects of Nearby Conductors

Normally, sloper performance is not degraded by the presence of a beam antenna atop a mast of tower. Guy wires, on the other hand, can impair the performance and tuneup. If your support structure is guyed, break up the guy wires so that they are not resonant near the antenna frequency. You may install insulators in the guys to ensure nonresonant lengths.

Slopers for other bands, or additional slopers for the same band, can affect performance also. The interaction of the antennas may complicate the tuning adjustments for any one sloper. No two installations seem to respond identically to the presence of nearby antennas or random conductors. It may be necessary for you to experiment in order to obtain proper sloper performance if you have a lot of conductive clutter nearby.

Multiband Verticals

Thus far we have considered single-band vertical antennas. The exception is the full sloper of Fig 4-3B when balanced, tuned feeders are used with it. In that situation we have a multiband sloper when a Transmatch (antenna tuner) is used between the feeder and the transmitter.

You can make your own multiband vertical with wire. This amounts to the erection of two or more quarter-wave wires so that they are joined at the antenna feedpoint, but are fanned apart by several degrees upward. Each wire is cut for a different amateur band in accordance with L(feet) = 234/f(MHz). These wires may be worked against a system of buried radials, or you may use above-ground radials that are insulated at the outer ends. But, when you employ above-ground radials it becomes necessary to use two or more radials for each band. These wires are cut to length so that they are approximately 5% longer than 1/4 wavelength. This calls for quite a few radial wires when several amateur bands are covered by one antenna. If you use a buried or on-ground radial system, the wires should be cut for the lowest operating frequency of the antenna, and they may be 1/4 wavelength or somewhat shorter if necessary. Fig 4-4A shows how you can build a fanned multiband vertical antenna.

Another type of multiband vertical is the "trap" variety. Most of the commercially made multiband verticals fit this description. A trap is a device that consists of a capacitor and coil in parallel. A more appropriate name for it, at least in this application, would be a "barrier." A trap is a device that catches and holds something, whereas a barrier prevents something from passing beyond a certain point. In any event, traps are resonant at specific frequencies (by design), and they are used to block the passage of RF current beyond a certain point in an antenna. Several traps may be included along a radiator to block the flow of RF current at a number of frequencies. This is illustrated in Fig 4-4B. Each trap is designed for a different amateur band, and thus the multiband nature of the vertical antenna. In effect, a trap blocks the passage of RF energy at one frequency, while allowing RF energy to pass through it at other frequencies. A trap is a high-impedance device. Therefore, the higher the impedance the greater the trap resistivity to signal passage.

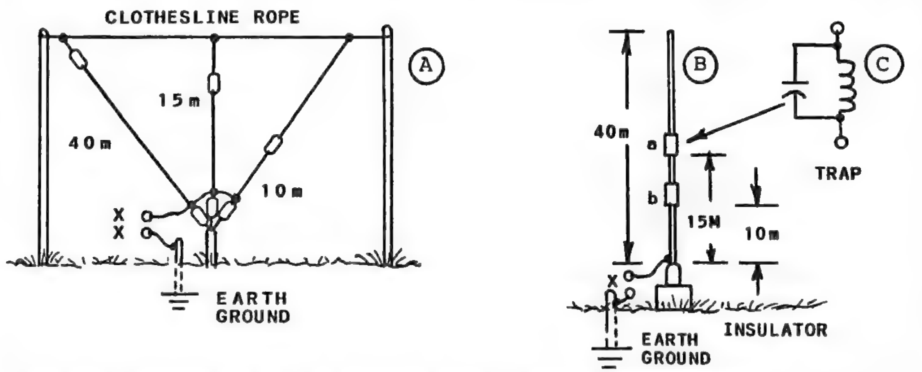


Fig 4-4 -- Examples of multiband vertical antennas. The model at A can be made from no. 12 or 14 wire. The bottom ends of the three wires are joined to provide a common feed terminal. Each wire is cut to length in accordance with L(ft) = 234/f(MHz). Each wire should be cut for the center of each Novice band. The antenna is fed with 50-ohm coaxial cable, with the shield braid soldered to the ground system. The 40-m wire is 32 feet, 10 inches long.The 15-m wire is 11 feet, 2 inches long. The 10-m element is 8 feet, 3-1/2 inches in length. The antenna at B is a three-band trap vertical, ground mounted. Traps a and b are structured as shown at C. They are high-Q parallel-resonant circuits. Trap "a" is resonant at 21.150 MHz, while trap "b" is resonant in the center or the 10-m Novice band. The portion of the vertical below trap "b" is the 10-m radiator.

Please refer to Fig 4-4B. Because the traps contain coils, they tend to load the antenna during operation on bands for which the traps are not used. In other words, when you operate 40 meters with this antenna, both traps become a part of the overall antenna. They act as small loading coils, and this results in the overall vertical length being somewhat shorter than would be the case with a single-radiator 40-m vertical. In a like manner, during 15-m operation the 10-m trap (b) acts as a loading coil.

The feed-point impedance of both antennas in Fig 4-4 is on the order of 30 ohms. This means that a slight mismatch will exist when you feed these systems with 50-ohm coaxial line. The SWR should not be cause problems, provided you keep the feeder length as short as practicable (75 feet or less). Most commercial trap verticals are designed for a 50-ohm impedance. A 30-ohm feed impedance and a 50-ohm feed line result in an SWR of 1.66:1. Most amateur transmitters will function satisfactorily when the SWR is less than 2:1.

There are various techniques for matching the feed line to the antenna terminals when unlike impedances exist. It is not my wish to get into the intricate workings of that task in this book. I suggest you read **W1FB's Antenna Notebook** (ARRL) and **The ARRL Antenna Book** for information about matching methods. The former book is written in plain language, whereas the latter volume is more rigid in the treatment of technical subjects. Both publications are an important part of an amateur's reference library.

Commercially made trap antennas generally operate on several ham bands. A typical product permits you to use the system from 80 through 10 meters. I recommend that you start with the simple antenna of Fig 4-4A. The cost is minimal and the system will be more efficient than that at B of Fig 4-4. This is because traps cause losses in the signal power. Furthermore, a trap style of antenna suffers from narrow bandwidth. For example, you may find a usable bandwidth of only 50 kHz between the 2:1 SWR points on 40 meters. Conversely, the antenna of Fig 4-4A should provide 100 kHz or greater bandwidth on 40 meters. The increased bandwidth enables you to move your operating frequency a greater distance within a ham band before the SWR becomes excessive. Most modern transmitters have a shut-down circuit that reduces the transmitter power increasingly as the SWR becomes higher. This is done to protect the solid-state final-amplifier from being damaged because of a prohibitive mismatch condition. It is interesting to note that for a given single-band antenna design, say, a half-wave dipole, the bandwidth doubles with each octave (upward) of frequency change. Translated to plain language, this means that if your 80-meter dipole provides 100 kHz of bandwidth between the 2:1 SWR points, a 40-meter dipole of the same design will yield a 200-kHz SWR bandwidth, and so on. This statement is based on the premise that the antenna Q is identical for both antennas. Antenna Q (quality factor) is determined by the diameter of the elements, for the most part. The larger the element diameter the lower the Q and the broader the response.

A Simple Multiband Vertical

You may want to keep things simple when you erect your first multiband vertical. Simplicity usually denotes reduced cost for materials, and this is an appealing factor to most of us! It is possible to use a single 30-foot piece of wire for the radiator in this simple arrangement (see Fig 4-5). A second 30-foot length of wire serves as the counterpoise (artificial ground). Two or more counterpoise wires, fanned equal distances apart, will aid the antenna performance. But, you can make plenty of contacts with only one counterpoise element. The ultimate design of your system must depend on available real estate.

The antenna in Fig 4-5 gives good performance from 40 through 10 meters if it is situated well away from nearby conductive objects, such as house wiring, phone lines and metal buildings. It may be used also on 80 meters, but the efficiency is lower than on the higher bands.

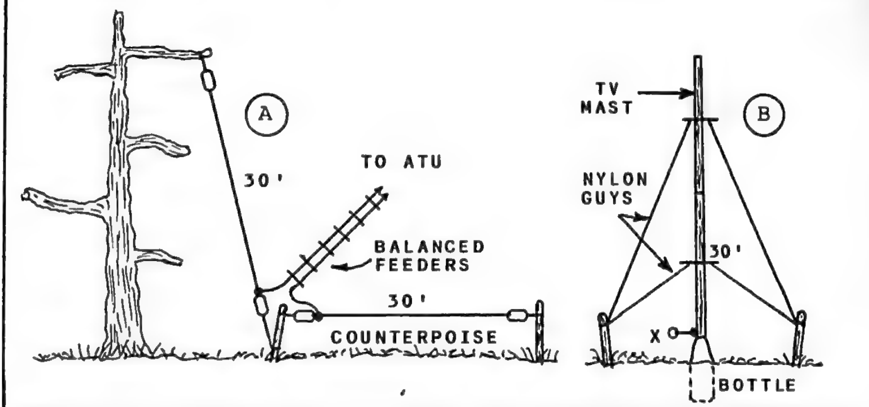


Fig 4-5 -- The drawing at A shows how simple a task it is to build a multiband vertical antenna. Two 30-foot lengths of wire are used to form the vertical radiator and counterpoise ground. Balanced feed line is used (any length) and is fed through an antenna tuning unit (ATU) to match the system to the transmitter. An alternative approach to the multiband vertical is shown at B. TV masting or metal downspout may be insulated from ground by means of a glass bottle as shown. A 30-foot counterpoise wire is used as shown at A. The vertical is fed with balanced line through an ATU.

The antenna of Fig 4-5A may be supported from any convenient object that is nonconductive. The feed line should be routed away from the system at a right angle to the vertical element, and well away from the counterpoise wire. You can construct your own balanced feeder as shown at D of Fig 2-7 (page 23). The wire size and the spacing between the parallel wires is not critical. I suggest no. 14 copper wire that is spaced three inches from the adjacent feeder wire. No. 14 wire is suitable also for the two antenna elements, but other wire gauges are satisfactory too. The ATU requires a 1:1 or 4:1 balun transformer at the tuner input. This converts the balanced feeder to an unbalanced condition, thereby providing the correct interface for the tuner. The counterpoise wire may be only a few inches above ground in regions where snow is not a problem, but the entire system may be elevated many feet above ground (roof installation, etc.).

An alternative vertical element is depicted in Fig 4-5B. You may use sections of TV mast, electrical conduit or metal down-spout as the 30-foot vertical conductor. It should be well guyed with nylon rope or guy wire that contains insulators. A glass bottle may be set in the ground to serve as a base insulator, as shown. The counterpoise wire is installed as shown at A of Fig 4-5. The arrangement at B is convenient when there are no trees or other nonconductive supports available.

A Broadside Vertical Antenna with Gain

Should you become really serious about working DX with a vertical type of antenna, you may want to consider the system shown in Fig 4-6. This antenna is known as the "Bobtail Array." It is used by a number of 40- and 80-meter DXers because it does not require especially high support poles.

The Bobtail Array (sometimes called Bobtail curtain) has what is known as broadside directivity. This means that maximum signal from the antenna is bidirectional (figure-8 pattern) from the broad side of the system. Most DXers orient the antenna for a NE/SW pattern for communicating with stations in Europe and far away places like Australia. This antenna has approximately 5 dB of gain in the favored directions. This is roughly equivalent to doubling your transmitter output power two times. You may design this antenna for any one of the HF Novice bands. Also, you can have two Bobtail Arrays if space permits. One can be used for N/S communications and the other for the E/W circuit.

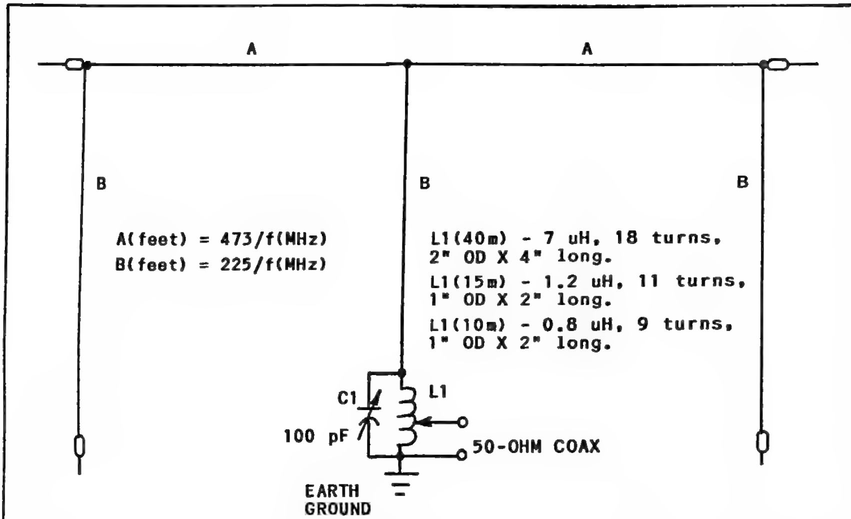


Fig 4-6 -- Details for the Bobtail Array, showing coil data for three Novice bands. L1 is tuned to resonance, then the tap on L1 is adjusted for an SWR of 1:1, after which C1 may require readjustment. Enclose C1 and L1 in a weatherproof box. No. 12 or 14 copper wire may be used for antenna elements A and B. The lower ends of the B wires may be close to ground, but must be protected from ice and snow. Good quality end insulators are required for this antenna. Glass, porcelain or Teflon materials are best.

L1 in Fig 4-6 can be a piece of commercial Miniductor stock from B&W Corp., or you may wind your own coil on polystyrene, phenolic or fiber-glass tubing (check with nearby commercial plastics dealers for scrap pieces). Surplus ceramic or steatite coil forms are also suitable. Do not use PVC tubing! It is a poor insulator for RF energy, and it may heat and melt when subjected to RF voltage.

The L1 coil turns are not close wound. Space them over the length dimension listed in Fig 4-6. This allows room for tapping the feed line on the coil without shorting the coil turns. No. 16 enamel wire may be used for L1. It will accommodate the maximum legal power from your Novice station. The plate spacing for C1 of Fig 4-6 must be at least 1/16 inch in order to prevent arcing between the rotor and stator plates, especially when the humidity is high. An elaboration of this design includes a 1-RPM motor that may be operated remotely to turn the shaft on C1. This scheme permits you to tune C1 from your ham shack, should you wish to cover a large part of a specified Novice band while maintaining an SWR of 1:1.

Short Vertical Antennas with Loading

It is not always practical to erect a full-size 1/4-wave vertical antenna, especially for 40 meters. At a small sacrifice in overall performance you can make the radiator 3/4 or less its normal length. When this is done it becomes necessary to ensure that the electrical length is 1/4 wave, even though the physical length is somewhat less. A loading coil can be placed in series with the radiator to compensate for the decreased radiator length.

The foregoing scheme is adopted frequently by amateurs who live in urban locations where tall verticals may not be welcomed by neighbors. Hams who operate in the 160- and 80-meter bands are especially fond of shortened verticals, since a full-size 160-meter radiator would be approximately 125 feet high, and an 80-meter one would be 63 feet high. Acceptable performance may be had with even a half-size vertical, provided a system of ground radials is used below the antenna. Thus, if you chose to erect a half-size 40-meter vertical, it would be only 16-1/2 feet high.

Needless to say, we must always trade performance for size when we shrink an antenna. In the case of a short, loaded radiator we will experience reduced antenna bandwidth between the 2:1 SWR points. The shorter the radiator, the greater the loading-coil inductance for establishing antenna resonance. In a like manner, the shorter the radiator the greater the reduction in antenna bandwidth. For example, a 40-meter full-size vertical may yield a 2:1 SWR bandwidth of 150 kHz. A resonant half-size 40-meter vertical may have a bandwidth of only 75 kHz.

Another minor shortfall that accompanies our use of shortened verticals is coil loss. Some signal loss must occur in the loading coil, owing to the inherent ac resistance of the winding. Normally, the loss is so small that it would be impossible to discern on an S meter (less than 1 dB for a high-Q loading coil). Fig 4-7 shows three methods for loading a short vertical. You can see that a loading coil may be placed at the base, center or top of the radiator. Base loading requires the smallest number of coil turns. Center loading calls for more turns (greater inductance) and top loading requires the greatest number of coil turns. However, the general belief is that top-loaded verticals provide the best performance, with center loading as second best. Base loading is thought to be the least desirable in terms of antenna efficiency. I have used all three methods, and I can't say that one was better than the others in terms of having my signal heard within the USA and abroad. Laboratory measurements may indicate otherwise.

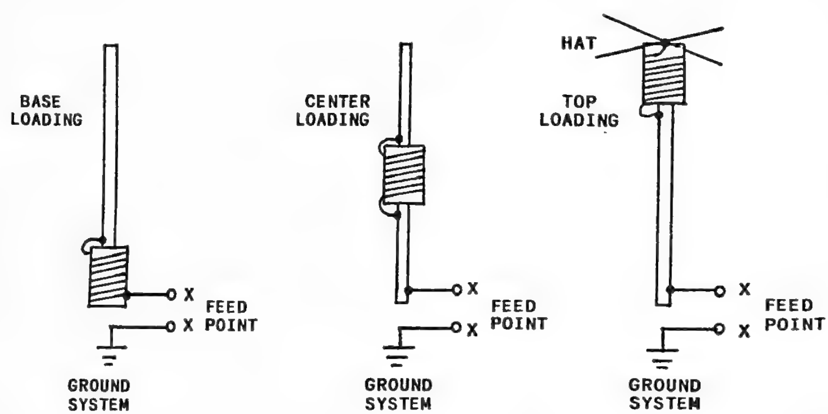


Fig 4-7 -- A short radiator may be changed to an electrical 1/4 wave by inserting a loading coil (inductive reactance) in series with the conductor. Base loading requires the smallest number of coil turns, while top loading has the greatest number of turns. A capacitance hat may be added to the center- and top-loaded antennas to reduce the number of coil turns.

The top-loaded vertical in Fig 4-7 has four rods above the loading coil. They are joined to one another and to the top of the coil winding. The longer the rods (capacitance hat) the fewer the coil turns needed to establish antenna resonance. Generally, the practical limit for rod length is three to four feet, overall. You may use more than four rods for increasing the effect of the hat.

The hat functions as a capacitor that is in parallel with the loading coil. There is distributed capacitance from the hat to the conductor below the coil. This increases the effective inductance of the coil, thereby allowing fewer coil turns. The larger the hat the greater the distributed capacitance. The hat may be used also with a center-loaded vertical for the purpose of reducing the loading coil inductance. The lower the coil inductance the greater the antenna bandwidth and efficiency.

I can't give you a magic formula for calculating how many coil turns are necessary for a loading coil. Most amateurs arrive at the solution to this problem by experimenting. The common practice is to wind many turns on the coil form, then check the overall antenna to learn where it is resonant. This may be done by probing the bottom end of the coil with a dip meter to find the frequency of resonance. The bottom end of the loading coil is temporarily connected to the earth-ground system for this test. A dip meter is an instrument that covers a wide frequency range by means of plug-in coils. It contains an oscillator and a meter. When it is tuned to the resonant frequency of a coil/capacitor combination the needle on the meter swings downward (to the left), and this is called the "dip." In other words, it is a dip in the meter reading. A dip meter may be built from scratch (see **The ARRL Handbook**), or you may purchase a factory-built unit. There are many uses for this instrument in your ham shack. Fig 4-8 shows how to couple a dip meter to a short vertical antenna that has a loading coil.

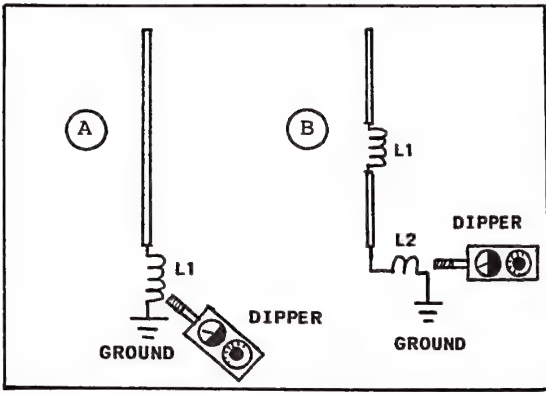


Fig 4-8 -- A dip meter can be used to determine the resonant frequency of the overall antenna. The method shown at A is suitable for base-loaded verticals. Shown at B is a technique for sampling the system with a 3-turn coil (L2) that is connected between the base of the antenna and the ground system (see text).

Method A permits probing the base-loading coil directly. If the frequency at which a dip occurs is too high, add turns to L1. If it is too low, remove turns from L1 until the dip is in the center of the proposed operating range within a given amateur band. Remove one turn at a time when the dip occurs close to the desired frequency.

The technique shown at B of Fig 4-8 is best suited for use when center or top loading is used. A two- to four-turn small coil (1 inch ID), L2, is inserted between the base of the antenna and the ground system. The dipper probe coil is inserted into L2.

An alternative method for adjusting loading coils is to place a field-strength meter several feet away from the test antenna. Apply sufficient transmitter power to obtain a half-scale reading on the field-strength meter. Add or subtract loading-coil turns until you obtain no further increase in field strength. This will occur when the antenna is resonant.

It is easy and fun to build your field strength meter. It does not have to be pleasing to the eye. The important consideration is that it works! A practical circuit is presented in Fig 4-9. The coil may be wound on a piece of PVC pipe or on a plastic pill bottle. You can use the tuning capacitor from a discarded AM pocket radio if you do not have a small receiving type of variable capacitor available.

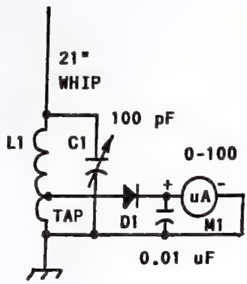


Fig 4-9 -- Circuit of a field-strength meter for 80, 40, 15 and 10 meters. D1 is a germanium detector diode (1N34A or equiv.). L1 for 80 m has 75 turns of no. 30 enam. wire, closewound 3/4" OD X 3 inches long. For 40 m, 34 turns of no. 22 enam. wire, 3/4" OD X 2" long. For 15 and 15 m, use 11 turns of no. 16 enam. wire, 1" OD X 1" long. Tap each coil 20% of the total turns. Make tap nearest to grounded end of L1. M1 can be a 50-, 100- or 200-uA dc meter.

When you make the tap on L1 of Fig 4-9, be sure to avoid shorting the tapped turn against the adjacent turns. This may be avoided by inserting a small U-shaped piece of meat-wrapping paper under the coil turn that is tapped. Another method is to pull the tapped turn out from the coil form, approximately 1/4 inch, twist the excess wire, then use the small end loop as the tap point.

The whip antenna receives RF energy, C1 tunes L1 to resonance, and D1 changes the RF voltage to dc. The microampere meter then responds to the dc current from D1. The stronger the signal being picked up the greater the dc current, and hence the higher the meter reading. You may use C1 to detune the circuit when the meter reads full scale. In other words, C1 can be used for a sensitivity control.

There are many inexpensive edgewise FM tuning meters available as surplus for less than $2.50. Most of the tuning meters I have checked have a 200-uA movement. The smaller the microampere rating of the meter the greater the field-strength meter sensitivity. Therefore, a 50-uA meter will yield the greatest sensitivity. A 0-1 mA meter may be used, but the instrument will be very insensitive with that type of unit.

The field-strength meter need not be built in a metal case. You can actually tack it together on a piece of wood or circuit board. In any event, keep the connecting leads short if you want good performance. The whip in Fig 4-9 should be vertical when checking vertical antennas (same polarization) and horizontal for antennas that are erected horizontally.

Loading Coil Considerations

A quality, strong coil form must be used for the antenna loading coil. Solid Delrin plastic rod is suitable, as is solid fiberglass rod material. This is the situation when we use center or top loading. The coil form must be able to withstand the stress of the antenna sections or capacitance hat above the coil. A base-loaded antenna rests on an insulator, which relieves the coil from undue stress. A piece of Miniductor stock or a tubing type of coil form will suffice for a base-loaded system.

After the loading coil is completed, and the antenna is tuned up, be sure to coat the coil with exterior polyurethane or spar varnish. This will help to protect it from dirt and moisture. You may wish to invert a plastic drinking glass over the coil to prevent a buildup of snow or ice on the coil.

If you use a capacitance hat with your short vertical, you may make final resonance adjustments by trimming one of the rods of the capacitance hat. Small changes in resonant frequency are more easily effected in this manner than when adding or removing part of a turn at the loading coil.

Feed-Point Impedance

The feed impedance of a short, loaded vertical is lower than with a full size quarter-wave vertical. The former antenna is roughly 30 ohms, whereas a shortened version may have a feed impedance as low as a few ohms. Generally speaking, a half-size vertical with coil loading will exhibit a feed-point impedance of 10-15 ohms, assuming we have a good ground system against which to operate it. A simple broadband matching transformer may be installed at the feed point to permit us to use 50-ohm coaxial cable. The transformer may be made with a ferrite toroid core and two enameled-wire windings (primary and secondary).The toroid core is an FT-140-61 (1-1/2" OD). It is available by mail from Amidon Assoc., Inc., 12033 Otsego St., N. Hollywood, CA 91607. The transformer turns ratio is 1.8:1. Use 12 turns of no. 18 enamel wire for the secondary (feed line side) and 7 turns for the primary (antenna side). Place the primary winding over the secondary after winding two layers of plumber's Teflon tape over the secondary winding.

Insert your SWR meter between the feed line and the toroidal transformer. Check the SWR. If it is not close to 1:1, remove a primary turn from the transformer and check the SWR again. If the SWR is lower (1.5:1 or less), make no further changes. On the other hand, if the SWR becomes higher when you remove a primary turn, add a turn and recheck the SWR. Use the number of primary turns that yields the lowest SWR, even though it may not be 1:1. Do not operate with more than legal Novice power with the toroid core I specified. Larger cores are necessary for higher power levels.

Homemade Loading Coils

It is not difficult to construct your own loading coils. Examples of two coil forms are presented in Fig 4-10. Both structures are suitable as foundations for high-Q inductors. The example at A of Fig 4-10 may be built from high-impact polystyrene rods and sheet stock. This is the milk-colored plastic that is resistant to shattering and cracking in cold weather. The clear polystyrene stock breaks easily when stressed, especially in cold weather.

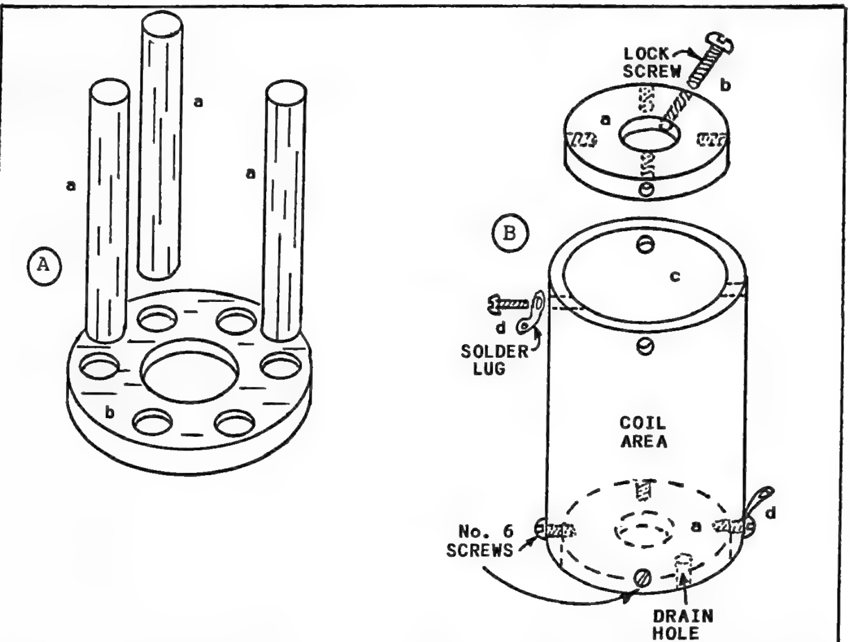


Fig 4-10 -- The coil form at A is simple to construct and provides a suitable foundation for a high-Q coil. Six pillars of high-impact polysytrene rod (part a) are required. The length and diameter of the rods is dependent upon the desired size of the form. For small coil forms, use 1/4-inch OD rods. Larger coils may require 3/8-inch OD rods. Base plate "b" (two required) may be cut from 3/8- or 1/2-inch polystyrene sheet. Wooden dowel rods and wooden end plates may be used if the parts are soaked for 24 hours in exterior polyurethane lacquer, then allowed to dry thoroughly. Alternatively, they may be boiled for 15 minutes in canning wax. The rods are cemented into the end plates. Coil form B has brass end plates. The coil form may be cut from Lexan or phenolic tubing. The coil winding is soldered at each end to lugs "d." The center hole for part "a" is sized for the tubing used in the vertical. A fiberglass rod may be passed through the holes in part "a" and inserted into the aluminum tubing sections above and below the coil.

Plastic materials for the coil forms in Fig 4-10 should be available from commercial industrial plastics dealers. Check the Yellow Pages of your phone directory for the location of your nearest dealer. Alternatively, you may wish to obtain a catalog of plastic materials from U.S. Plastic Corp., 1390 Neubrecht Rd., Lima, OH 45801. Their products are available by mail.

If you construct the coil form of Fig 4-10A from polystyrene material, it will be a simple matter to affix the rods to the end plates by means of polystyrene solvent/cement. It is available from the plastic supply house listed above. On the other hand, if you make the form from wood you will want to secure the dowel rods to the end plates with small nails or metal pins, driven in laterally at each rod-anchor point. You may use epoxy cement for wooden parts that have been treated with polyurethane varnish, but if the parts have been boiled in canning wax you will be unable to secure them with glue. Coil form A can be held in place on the lower section of vertical-antenna tubing by placing a hose clamp on the tubing below the bottom end plate of the coil form. A piece of fiberglass, Delrin or Lexan rod can be passed through the coil form to join the upper and lower tubing sections of the vertical. Slot the tubing with a hack saw, then use hose clamps to affix the tubing to the plastic rod. A similar mounting technique may be applied to the coil form of Fig 4-10B. The lock screw (part b) is threaded through the brass end cap to affix the coil form to the tubing sections. Use a lock screw at the top and bottom of the coil form. A no. 8 or 10 machine screw is good for this job. Additional mechanical integrity may be had by using two locking screws on each end plug.

If you use the coil forms for top loading (Fig 4-7), do not drill a center hole in the top end plate or plug. Rather, affix your capacitance-hat rods to the upper end plate and connect them to the top of the coil winding.

I discovered that clean, straight holes can be drilled in plastic sheeting by using the bits that are intended for boring holes in wood. Sheet-metal drills do not seem to make clean, straight-sided holes in plastic. Don't forget to make a drain hole in the bottom brass plug of coil form B, Fig 4-10. This will allow moisture to drain from the loading coil.

T- and L-Shaped Vertical Antennas

This chapter would be incomplete without descriptions of the popular "inverted L" and "flat-top T" antennas. They are easy to erect and are inexpensive to construct. Either antenna may be used for single or multiband operation. Generally, these antennas are single-band devices, but they may be used full size or as shortened, loaded radiators. The choice is dependent upon the space you have available on your property. Examples of these antennas are given in Fig 4-11.

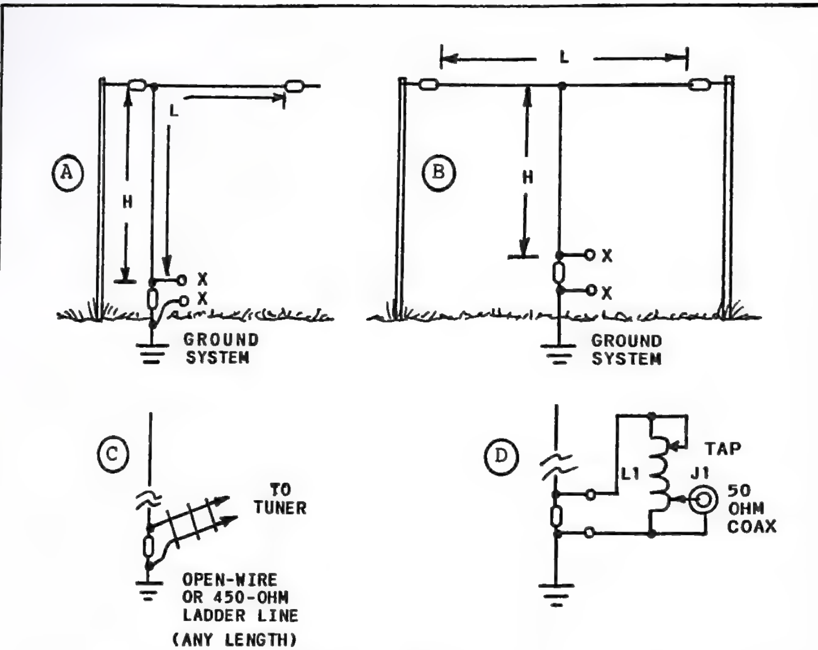


Fig 4-11 -- An inverted-L antenna is shown at A. Overall wire length is 1/4 wavelength for the multiband feed system shown at C. Section H should be as high as practicable for best results. The flat-top T antenna at B offers similar performance to the inverted L. It can be fed as shown at C if multiband use is planned. Antennas A and B can be cut shorter than 1/4 wavelength to permit single-band operation with the matching scheme shown at D. The upper tap on L1 is set for antenna resonance while using a dip meter or field-strength meter, as discussed earlier in the chapter. The bottom coil tap is then adjusted to obtain an SWR of 1:1 for 50-ohm coaxial feed line. Insert the SWR meter between J1 and the feed line.

The antennas in Fig 4-11 are excellent for DX operation. They offer a low radiation angle and vertical polarization. Multiband operation may be had by using tuned feeders, as shown at C. The impedance of the feed line is not important, nor is the length. Either antenna may be cut for 80 meters, then used from 80 through 10 meters. In a like manner, you may cut the system to length for 40 meters in order to provide a 40 through 10 meter antenna. Single-band operation with L1 (Fig 4-11D) eliminates the need for an antenna tuner. The more extensive the ground system the better the performance of either antenna. Buried or on-ground radials (1/4 wavelength long each) are best. Use as many as you can justify in your yard. Good results may be had also when you use four 8-foot ground rods, plus the cold-water pipe system in your home for the earth ground.

The inverted-L antenna is very popular among 160- and 80-meter operators who enjoy contacting DX stations. It may be supported by a tower or metal mast without significant impairment of the performance. If you support your inverted-L from a tower, try to keep the drop wire (H of Fig 4-11A) at least three feet away from the tower. You may increase the effective length of "H" by sloping it at up to 45 degrees. This may be helpful when you must use a relatively short support pole or tree. Similarly, the far end of the inverted L need not be perfectly parallel to earth. If the support pole at the far end of the wire is short, it's OK to slope the horizontal part of the antenna toward ground.

You may consider the horizontal (top) wire of Fig 4-11B as a large capacitance hat, since that is how it functions. Thus, the greater the length of H the shorter the length of L (Fig 4-11B) for 1/4-wavelength resonance of the system. The top wire of the T antenna may be shortened for a given height of H if you use two or more wires for the top of the T. This increases the capacitance-hat effect, which results in shorter top wires. This may be advantageous for you if you live on a small city lot.

The wire size for the antennas in Fig 4-11 is not critical. The primary consideration is that the wire is strong enough to stay aloft in the wind and when there is icing. No. 12 or 14 copper wire should have adequate strength for these antennas. Stranded copper antenna wire is less prone to breakage from flexing.

Ground Systems for Verticals

Thus far, our discussion about ground radials and other ground systems has been fairly vague. In chapter 1 we learned the importance of the ground system with regard to antenna performance Fig 4-1 in this chapter illustrates the need for a good ground screen with respect to the "image half" of many types of antennas.

I can't stress strongly enough the importance of a ground screen or above-ground radials when you use a 1/4-wavelength antenna, or one that consists of odd multiples of 1/4 wave -- such as a 3/4-wave antenna. The better the ground screen the greater the antenna efficiency, and hence the more effective you will be when it comes to being heard at the other end of the communications circuit. As the ground screen becomes more effective, the ground losses are reduced, and this aids antenna efficiency.

Laying a radial system under a vertical requires time and effort, so be prepared to invest a few hours in the project. Try not to worry about what this may do to your lawn, or what the neighbors might think. A lawn should suffer no harm if it is cared for in the correct manner (mowing, watering and fertilizing). A lawn-edging tool works nicely for creating slit trenches in which to place the radial wires. Make the slits in your lawn no more than 2-3 inches deep. Tuck the wires into the slits, then step firmly on the openings to close them. In a week or two the lawn will heal, and the lines will not be visible. It is best to do the trenching job in the fall or spring when the ground is soft and damp. Alternatively, you may give the lawn a good soaking with a hose before you start the project.

The radial wires are fanned out from the antenna feed point in as linear a manner as possible. At the hub of the wheel you have formed will be the convergence point of the radials. Solder them together at this junction, then connect them to an 8-foot ground rod that has been driven into the soil.

Don't be deeply concerned if your house or some trees are in the way of linear deployment of the wires. If the need arises, simply route the wires around the sides of the house or trees. I have found this practice necessary a number of times, but my antenna still performed well.

Wire Type and Length

Ideally, your radials will be 1/4 wavelength long. This is seldom possible at 160 or 80 meters when a ham lives on a small city lot. In such an event, use the greatest length that will fit within your property limits. Some radials may be only 20 feet long, while others for the same ground screen might be 60 feet in length (80 meter antenna). Although antenna engineers have determined that 120 radials represent the optimum number to use, they have also conceded that there is little increase in antenna efficiency when more than 120 radials are installed. I have had very good results with as few as 25 ground radials. My present system has only 20, but each is 1/4 wavelength long. Some hams have literally buried miles of wire in the ground in the hope that superb antenna efficiency would result. This is fine if you have the time and money for so grand a project, but you will fare nearly as well by using somewhat less wire in the ground. The best rule of thumb I can offer is to deploy as many radials as you feel economically and practically able to.

Soil acidity and alkalinity has an effect on the wire we bury in the ground. The greater the soil moisture the faster the wire will deteriorate. Aluminum wire is a poor choice for in-ground use. I used aluminum electric-fence wire for a radial system in CT: one year later the wire was gone! All I could find was white oxide in the ground where the wires had been. I prefer to use insulated wire, such as vinyl-covered no. 14 house wiring. The vinyl jacket helps to protect the wire if the open ends are sealed with epoxy cement before the wire is buried. If your soil is fairly dry, and the PH factor is normal, you should have long radial-wire life when using enamel-covered magnet wire.

The gauge of the radial wires is not significant. These wires carry miniscule amounts of RF current, so there is no difference in performance for no. 28 or no. 10 wire. The smaller wire sizes will break more readily, and they will be consumed more rapidly by soil chemicals than would be the case if no. 12 or 14 wire were used.

If you can't install a buried-radial system, consider the counterpoise wire (Fig 4-5) as an alternative. It can be used in place of a ground screen if it is 1/4 wavelength long at the lowest proposed operating frequency. A counterpoise will not work as well as a good radial system, but it will be better than a poor or questionable ground system, such as a rod driven into the soil.

It is always a good practice to connect the cold-water plumbing in your house to the ground system. Well casings may also be attached to the overall ground system. Copper plumbing is the best for this purpose, owing to the good electrical joints that result from soldering the pipes to their fittings. The older iron water pipes may not be suitable for the ground system. This is because pipe-joint compound may cause electrical isolation between the pipe sections. Jumpers may be placed across questionable pipe joints to ensure continuity. Metal hose clamps and shield braid from RG-8 or RG-58 coaxial cable may be used for this purpose. You can check the continuity across the joints in steel plumbing by means of an ohmmeter. A finite resistance indicates a suitable electrical joint.

Vertical Antennas for VHF and UHF

Vertical antennas for VHF and UHF are never mounted at ground level. The nearby conductive clutter would prevent the signal from being heard at normal ground-wave distances. These antennas need to be as high and in the clear as possible in order to be effective. Therefore, they are used with above-ground radials (normally four rods). The exception is when the 1/4- or 5/8-wave radiator is mounted on a vehicle. The car body serves as the ground plane for the antenna in this situation. Apart from these considerations, the same rules apply to VHF/UHF antennas as to those we have been discussing for the high-frequency bands.

The simplest, least expensive ground-plane vertical for VHF can be made from coat-hanger wire. Brazing rod is also suitable when constructing these little antennas. Commercially made VHF and UHF verticals are usually made from thin stainless-steel rod material, especially those antennas that are designed for mobile use. Commercial fixed-station ground planes are frequently made from aluminum tubing, which provides good longevity in regions where the air is not saturated with industrial pollutants or salt. Stainless-steel antennas are more suitable in areas where the air is dirty, or if one lives near the ocean.

Among the vertical antennas that you may construct for VHF and UHF are the 1/4-wave ground plane, 5/8-wave radiator, J antenna and half-wave dipole. These antennas are shown pictorially in Fig 4-12. If you droop the radials of the 1/4-wave ground plane, the antenna feed impedance will be approximately 50 ohms.

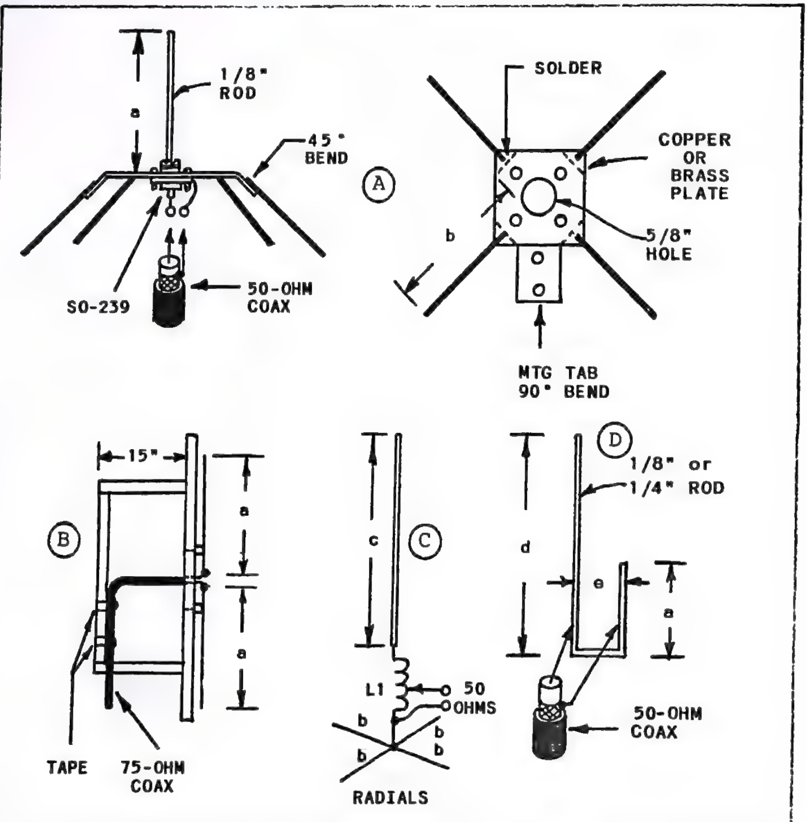


Fig 4-12 -- Practical vertical antennas for the Novice 220-MHz band. Antenna A is a vertical ground plane type. The system at B is a vertical dipole that is assembled on a wooden frame. The back piece (left) of the frame may be attached to a mast with U bolts. Two ceramic standoff insulators support the dipole near the feed point. A 5/8-wave vertical is shown at C. The tap on L1 is adjusted to obtain an SWR of 1:1 with 50-ohm feed line. Length "c" is 28-1/2 inches. L1 consists of 6-1/2 turns of no. 12 copper wire, close wound on a 1/2" OD plastic form. Approx. tap point is 1-3/4 turns above grounded end. A J antenna is shown at D. It needs no radials. Tap the 50-ohm feeder up the U section, as shown, to obtain an SWR of 1:1. For all antennas shown here, "a" is 12-3/4 inches, "b" is 13 inches and "d" is 38-1/4 inches. Dimension "e" is 1-1/2 inches All leads from the coaxial cable to the feed terminals of these antennas must be kept as short as practicable. The elements may be made from 1/8" brazing rod or 1/4" copper pipe.

Each of the antennas in Fig 4-12 provides omnidirectional radiation, and they have a low radiation angle (10 to 15 degrees, with respect to the horizon). Various materials may be used when building these antennas. Antennas C and D require conductors that are more rigid than those for the shorter antennas. Aluminum tubing with an OD of 3/8 inch or less may be used for each of the antennas shown. The 5/8-wave antenna may be used on a car for mobile operation. The radials are eliminated for vehicular use, since the car body acts as the ground plane. For outdoor installations you may mount the J antenna (Fig 4-12D) on a wooden mast by means of ceramic standoff insulators. The long portion of the J antenna would be attached to the insulators in that situation. These antennas may be built for use on 2 meters, 6 meters and 430 MHz by scaling them accordingly. Please refer to **The ARRL Antenna Book** for further information.

SWR Indicators in General

It is a simple matter to build an SWR instrument from scratch, and the cost is nominal. There are a number of commercial instruments available, but most of them are designed for below 30 MHz. Most commercial units have meter scales that are calibrated in watts and SWR. For antenna adjustments we do not need to have the watts scales. We are interested mainly in the reflected-power reading. This suggests building a homemade unit. You will find information about instruments you can construct if you check the measurements chapter of **The ARRL Handbook.** Circuit information is presented also in **The ARRL Antenna Book.**

A commercial SWR/wattmeter that is suitable for use on 220 MHz is fairly expensive. The Bird Thruline wattmeter is a top-grade instrument. It may be used from 1.8 MHz through the UHF region by means of plug-in detector units that are designed for various power levels and frequency ranges. Keep an eye out for used Bird instruments in the **QST** Ham Ads and at amateur flea markets. Be certain that any SWR meter you buy is designed for 50-ohm feed line, and that it will work at the frequency of interest.

As I mentioned earlier in this chapter, you may use a field-strength meter (Fig 4-9) in lieu of an SWR meter, at least for a rough indication that an antenna is matched to the feed line. The closer the match the greater the power transfer to the antenna, and hence an increase in field strength.

Chapter Summary

We have discussed a variety of vertical antennas that you can build easily and inexpensively. A great many additional types of vertical antenna exist. I have described the more common ones that are used by Amateur Radio enthusiasts. Each antenna in this chapter is capable of providing good results for long-distance communications. You must remember, however, that vertical antennas are more prone to man-made noise pickup than are horizontal antennas. This can cause a reception problem for you, should you reside in a noisy area.

Glossary of Chapter Terms

ATU - Abbreviation for antenna tuning unit (tuner, Transmatch).

Balun Transformer - A broadband RF transformer that has specific transformation ratios, such as 1:1, 4:1 and 9:1. Balun is a short term for "balanced to unbalanced." Used to transform an antenna impedance to that of a feed line, or to convert a balanced feed point to an unbalanced one to permit the use of coaxial cable.

Bandwidth (antenna) - The range of frequency over which an antenna exhibits an SWR that is less than 2:1. Useful bandwidth in general terms.

Beam Antenna - A directional antenna that provides signal gain in the direction of maximum radiation (major radiation lobe).

Broadside Radiation - A condition wherein maximum radiated signal is at right angles to the plane of the antenna. Usually a bi-directional pattern.

Counterpoise - An artificial ground consisting of one or more 1/4-wavelength wires that are supported slightly above the surface of the earth.

Cross Polarization - Horizontal polarization versus vertical polarization between two antennas in a communications circuit. This results in a line-of-sight path loss of 20 dB or greater.

Dip Meter - A multifrequency oscillator with plug-in coil probes and an indicating meter. Used to sample tuned circuits and antennas to determine the resonant frequency, as observed by a sharp dip in meter reading at resonance.

Field-Strength Meter - A portable instrument with a short antenna for use in measuring the relative intensity of the radiated energy from an antenna under test, as indicated by a meter that responds to rectified RF current.

Forward Power - With respect to an RF wattmeter/SWR indicator. An instrument reading that shows the power in watts being sent to an antenna via the feed line, or from the feed line to the antenna feed terminals.

Ground Plane - An artificial earth ground used in combination with 1/4- and 5/8-wave above-ground vertical antennas. Usually consists of four or more 1/4-wavelength conductors.

Ground Screen - Usually considered to be an on-ground or buried system of wires or other conductive material. Used with vertical antennas to increase the system efficiency.

Hat (capacitance) - One or more wires or rods placed immediately above an antenna loading coil to increase the antenna bandwidth and reduce the amount of coil inductance needed to provide antenna resonance. Used with center and top loading of verticals, or for end loading of shortened, loaded horizontal antennas.

Image Half - Invisible missing portion of an antenna, that occurs below the earth's surface. Enhanced by a ground screen.

Ladder Line - Balanced, parallel-conductor feed line that is contained in molded polethylene insulating material, usually with 300- or 450-ohm characteristic impedance. May be made with periodic plastic spacers as well.

Loading Coil - An inductor that is used in series with a conductor that is less than 1/4 or 3/4 wavelength to cancel the capacitive reactance and cause antenna resonance. May be used at the bottom, center or top of a short vertical antenna, or at the feed point, center or end of a horizontal antenna.

Mismatch - A condition when a source impedance is not the same as a load impedance (feed line to antenna, for example). A mismatch results in standing waves and reduced RF power transfer.

Multiband - The capability of an electrical circuit, such as an antenna, to work satisfactorily on several bands of frequency.

Q (antenna) - Antenna quality factor. Determines effective bandwidth of the antenna. High Q (small conductors) narrows the bandwidth, and low Q (large conductor diameter) increases the bandwidth.

Radials -- Conductors used to create an artificial ground below a vertical antenna. Conductors extending radially from the base of the antenna.

Radiation Angle -- Angle of maximum radiated energy (lobe) leaving the antenna, respective to the horizon.

Radiator - The portion of an antenna that radiates the RF energy.

Reflected Power -- Opposite of forward power, as observed on an RF SWR/wattmeter. RF power that is reflected back from the antenna toward the transmitter when a mismatch occurs at the antenna feed point.

SWR Bandwidth - See bandwidth.

Toroid Core - Donut-shaped ferromagnetic core (ferrite or powdered iron) such as those used in broadband transformers.

Transmatch - Network of coils and capacitors (tuner) for use in matching unlike impedances (transmitter to feed line).

Chapter 5

LOOPS AND STRAIGHT WIRE ANTENNAS

It is the temptation of most new amateurs to hang up a random length of wire and feed it at one end with a Transmatch. In a manner of speaking, this makes sense. After all, an end-fed piece of wire will radiate and receive signal energy. Also, it is inexpensive and can usually be erected quickly. Another attraction connected with this simple antenna is that it can often be strung between the chimney or some other high point on the house, and a nearby tree. But, how effective are these antennas? In some instances they may function quite well, whereas at other times they are dismal performers. We need to ask ourselves, "How does good performance compare to poor performance?" It's not an easy question to answer. Perhaps we can refer to good performance as a condition of being able to be heard far away, and to have answers from nearly all distant stations we might call. Flattering signal reports tend to make us feel that our antennas are performing well. On the other hand, if we seldom receive an answer to a "CQ," and if the majority of the stations we call fail to come back to us, we can assume that the antenna is not doing well for us. Only air time and Amateur Radio activity will reveal, over a period of days or weeks, whether or not we have a good antenna. Also, if we get unflattering signal reports from other stations consistently (RST 459, 539, etc.), while other amateurs in the general area get better reports from the same distant station, we can fairly conclude that our antenna is a dud.

There are a number of end-fed wire antennas that can be used with good results, but the same rules apply to them as do to dipoles, beam antennas and verticals: the antenna should be high above ground and as far from conductive objects as is within the realm of practicality. I do not recommend just any convenient (random) length of wire. Rather, it needs to be resonant at 1/4 or 1/2 wavelength, or multiples thereof (3/4 wave, full wave, etc.). Generally speaking, the longer and higher the wire, the better the performance. Antennas that are greater than one wavelength in dimension can produce gain. It follows that the greater the number of wavelengths for a given ham band, the greater the antenna gain and directivity. These very long wire antennas (properly called "long wires") produce a bidirectional pattern (lobes) off the ends of the wire rather than broadside to it. A physically long piece of wire does not qualify as a long wire. This term is applied to only those antennas that are 1 wavelength or greater, overall. Many amateurs tell people over the air that they are using long wires, when in reality they may have only a 1/4-wave end-fed wire. This is a misleading statement. The other amateur may think you have a 1000-foot 80-meter antenna!

Combinations of long wires may be used to increase the gain and directivity of the system. Two common antennas that follow this principle are the V beam and rhombic. Detailed information about these systems is presented in **The ARRL Antenna Book.** If you live on a farm, or otherwise large tract of land, you may want to consider these antennas.

Loop Antennas

A 1-wavelength long wire can be formed into a circular, square, rectangular or triangular form to create an effective antenna. This is known as a loop. The conductor is closed except at the feed point. Loops may be configured to provide polarization that is vertical or horizontal. For example, if you erect a square loop and feed it at the center of the top or bottom wires (horizontal sides), the polarization will be horizontal. If, on the other hand, you feed the center of either of the sides of the square (vertical parts), polarization will be vertical. This assumes that the loop is erected vertically rather than parallel to ground. The approximate dimensions of a full-wave loop may be obtained from L(feet) = 1005/f(MHz). This refers to the overall wire length, not one of the sides.

Loop antennas have a slight gain over a dipole, and they are quieter antennas than are dipoles and verticals for receiving. By "quieter" I mean that they are not as responsive to some forms of man-made noise as is the case with other types of ham antennas. This can be advantageous when you are trying to dig weak signals out of the background noise (QRN).

Loop antennas have a broader frequency response (2:1 SWR limits that we discussed earlier in this book) than dipoles and vertical radiators. This is because the Q of a loop is quite low, comparitively speaking. This characteristics makes them less subject to being detuned by nearby conductive objects and ground effects, compared to dipoles and other higher-Q systems.

You are perhaps wondering if there is an advantage in using vertical loop polarization rather than horizontal polarization. A vertically polarized loop has a lower radiation angle than a horizontally polarized one. This is good for DX work at the expense of strong coverage closer in. The loop that has horizontal polarization is fairly good for DX operation, and it is usually excellent for communications out to approximately 1000 miles at the lower end of the HF spectrum. The HF horizontally polarized loop will, on the other hand, provide good DX performance at 20, 15 and 10 meters, assuming it is high above ground and in the clear.

A loop may be used as a multiband radiator if it is fed with balanced feeders and a Transmatch. At its basic (fundamental) frequency the maximum radiation is broadside to the loop (bi-directional pattern). On the harmonic frequencies the maximum radiation is in the plane of the loop (off the ends), and this condition becomes more pronounced as the operating frequency is increased. Thus, a 40-meter loop has broadside radiation, but at 20, 15 and 10 meters its primary directivity is in the plane of the antenna. This is worth remembering when you erect a multiband loop, since you may wish to favor a particular DX direction on one or more of the bands.

A loop need not be one of the geometric forms mentioned earlier. A distorted or random shape will usually provide good performance too. The loop efficiency declines as the wires in any two parallel sides are brought closer together. The circular loop is said to have the greatest gain over a dipole, then comes the square shape, the triangle and, finally, the rectangle. The rectangular loop fares the worst because two of the sides are shorter than the remaining two, and this brings two of the parallel wires much closer to one another than if the loop were square.

A loop* may be erected parallel to ground, but it will not be a good DX antenna. This is because maximum signal energy will be directed skyward or straight up. This type of loop is often excellent for solid communications out to 600 miles on 80 and 40 meters. In this situation an antenna with <u>high-angle radiation</u> will generally outperform a dipole that is high above ground. The characteristic impedance of a round, square or triangular loop (at the design frequency) is approximately 115 ohms. Later, we will discuss methods for transforming this impedance to 50 ohms for use with RG-58 or RG-8 coaxial feed line.

A full-wave loop may be tilted from a mast or tower if there is insufficient height to erect it vertically. I have used delta (triangular) loops that tilted toward ground at 45 degrees, and the performance was excellent. The two lower corners (apex up) and bottom wire of the triangle were only 6 feet above ground.

Half-Wave Grounded Loops

Another loop we will discuss in this chapter is the half-wave, grounded loop. The missing portion of the full-wave loop occurs in the ground as the image half, as discussed earlier. This form of loop antenna has appeal for amateurs who lack sufficient property to accommodate a full-wave, conventional loop. We will examine the practical aspects of this antenna in the pages that follow. It requires a ground system that is not needed for a full-wave loop. I have used half-wave grounded loops of many

* single band

shapes, and have found them to be outstanding performers. In fact, they seem to perform as well as a full-wave loop, if a proper ground screen is used under them.

Practical End-Fed Wires

This section of chapter 5 is devoted to practical examples of the wires and loops we have been discussing. I can't stress strongly enough the value of erecting as big an antenna as you can manage. It is frivolous and anything but cost-effective to buy, say, $2500 worth of ham-station gear that will be used with a skimpy, close-to-ground antenna. RF power is not the common denominator for solving the DX problem. To the contrary: a modest 25-W station and a good antenna can often provide far greater DX capability than a high-cost layout with a make-do type of antenna. Your priorities should be directed toward the antenna department!

Fig 5-1 shows two versions of an end-fed multiband antenna. The system that has tuned feeders (end-fed Zepp) is the better of the two antennas, since it prevents the end of the antenna from entering the ham shack, which usually results in unwanted RF energy on the equipment cabinets and in the circuitry.

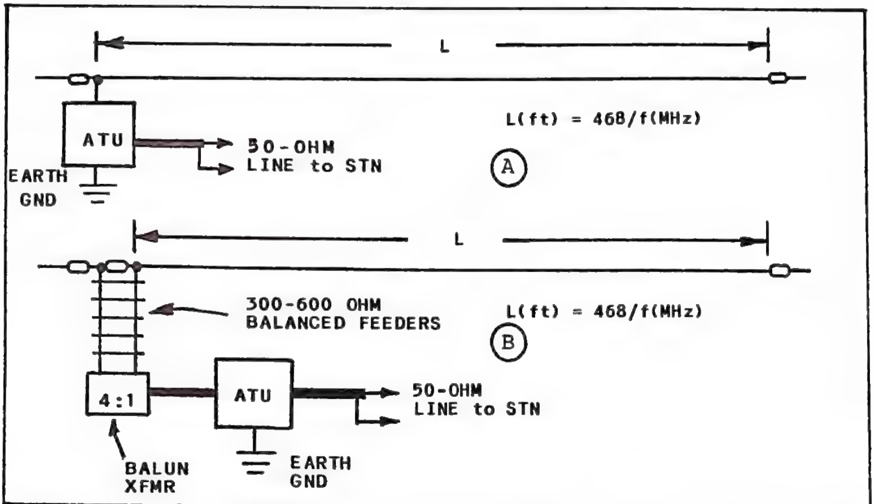


Fig 5-1 -- Two versions of half-wave, end-fed antennas. System A has the end of the wire coming directly to the antenna tuner. System B has balanced feeders from the antenna to the ham shack. Any length of feed line is satisfactory. A 4:1 balun transformer converts the balanced line to unbalanced 50-ohm coaxial cable.

There may be problems with stray RF energy when you use either antenna in Fig 5-1. Generally, the condition is more pronounced when using the example of Fig 5-1A. The exception is when the wire is 1/4 wavelength or odd multiples thereof at the operating frequency. A 1/4- or 3/4-wave wire, for example, has current at the fed end, and this alleviates the "wandering" RF problem in the station. A 1/2-wave wire, on the other hand, is voltage fed (high RF voltage at the fed end), and this is what causes the problem. This presents a strange paradox, however: although the 1/4- or 3/4-wave wire is easy to feed, it requires a ground screen under it in order to obtain good performance. The 1/2-wave (or multiple thereof) wire will deliver good performance without a ground screen! In any event, a good earth ground is needed with either of the antennas in Fig 5-1, primarily to help keep the RF energy off the station equipment. You may use the household cold-water pipe system, along with ground rods driven into the soil near the operating position. Use heavy conductors when running the ground connections, and keep them as short as you can. It is helpful also to lay one or two 1/4-wave wires on the ground (or bury them) for use as part of the ground system. You may also consider buying or building a "ground improver" network, such as the MFJ 930 Artificial Ground. This gadget is connected between the chassis of the transmitter and the lead that goes to your ground system. This little tuner is adjusted for maximum indication, as noted on the 930 internal meter. Under a condition of maximum meter deflection the reactance is tuned out of the ground lead, and there should be no RF voltage on the station equipment. The unit must be retuned each time you change bands, and in some situations you may find it necessary to readjust it when QSYing (moving frequency) from one part of a band to another.

The antennas of Fig 5-1 are suitable for multiband use from the fundamental frequency for which they are dimensioned, say, 80 meters, through 10, or even 6 meters. An antenna tuning unit makes this possible. The ATU is adjusted at the operating frequency for an SWR of 1:1. The example at B of Fig 5-1 can be fed with UHF TV ribbon (300 ohm tubular or foam-filled line), 450-ohm ladder line or homemade open-wire line. A 1:1 or 4:1 balun transformer is required in order to change the balanced line to an unbalanced condition, such as is presented by coaxial cable. Since some commercial Transmatches or tuners contain a balun transformer, you may not have to connect one in the line, as shown in Fig 5-1B. It is worth mentioning at this juncture that a balun transformer is in a somewhat hostile environment when used with an end-fed Zepp (Fig 5-1B). These transformers are designed to interface two impedances that are fairly low (600 ohms maximum). The balanced feeder for the Zepp example can, on some frequencies, present an impedance of 1000 ohms or greater to the balun transformer. It is possible that the balun may be damaged from heating or arcing under this condition when very high power is used. The point I want to make here is that balun transformers are by no means magical cure-alls for making an antenna work on several bands.

You can erect a long-wire antenna if you have ample real estate for a large wire antenna. These antennas are 1 wavelength or greater overall. As is true of the antennas in Fig 5-1, a long wire may be used on its harmonics for multiband operation. The greater the number of wavelengths of wire the higher the antenna gain. As the gain increases, so does the directivity of a long wire. Maximum radiation is in the plane of the wire (off the ends) rather than broadside to it. You need to keep this trait in mind in order to orient the wire for maximum signal intensity in a favored direction. Long wires may be fed as shown in Fig 5. They radiate a number of minor lobes in addition to the main ones. The primary lobes have a low radiation angle, and this is good for DX operation. However, numerous minor lobes at higher radiation angles are also present, and these are useful for short range contacts out to 1000 miles. You may want to try this type of antenna during your career as an amateur. Some hams have as many as four long wires that extend away from a common feed point like the spokes of a wheel. They are arranged for maximum signal E, W, SE, NW and NE, for example. A common feed line is used by means of a remote switcher that transfers the feeder from one long wire to another. This somewhat Utopian antenna system is fun to dream about, even though it may never be within the bounds of practicality for you.

Practical Loop Antennas

As we learned earlier, a loop may be used for single-band or multiband operation. Most amateurs arrange their loops for single-band use. This calls for a coaxial feed line and what is known as a 1/4-wave matching transformer. This transformer is made from 75-ohm coaxial cable (1/4-wave long), and it is installed between the antenna feed point and the 50-ohm coaxial cable that is routed to the station. The transformer changes the 115-ohm feed impedance to approximately 50 ohms. No ATU is needed when this is done. Similarly, you do not need a balun transformer. The 1/4-wave matching section is determined by the free-space dimension X the velocity factor of the coaxial cable you use. For example, let's imagine that you have built a full-wave loop for 7.1 MHz, the 40-meter Novice band. You want to feed the loop with 50-ohm (RG-8) coaxial cable. Your matching section is made from 75-ohm coaxial cable (RG-11). The proper length for this transformer is obtained from L(feet) = [246/f(MHz)] X 0.66. Thus, the equation becomes L = (246/7.1) X 0.66 = 22 feet, 10 inches. The coaxial connectors (if used) at each end of the 1/4-wave matching section must be included in the calculated length. Fig 5-2 illustrates a 40-meter loop with a 1/4-wave matching section. The geometry of the loop need not be square, as we learned earlier in this chapter.

For Novice power levels it is not mandatory that you use RG-8 and RG-11 coaxial line. The smaller RG-58 and RG-59 cables are entirely adequate for RF power amounts up to 300 watts. The smaller cables are more lossy per 100 feet than are RG-8 and RG-11. You will want to consider this factor if your feed line is quite long. The larger cable will reduce the signal loss to the antenna. The 50-ohm feed line in Fig 5-2 may be any convenient length.

BAND	L(ft)	T1(ft)
10m	35.7	5.76
15m	47.5	7.67
40m	141.5	22.86
80m	269.8	43.58

Decimal feet X 12 = inches

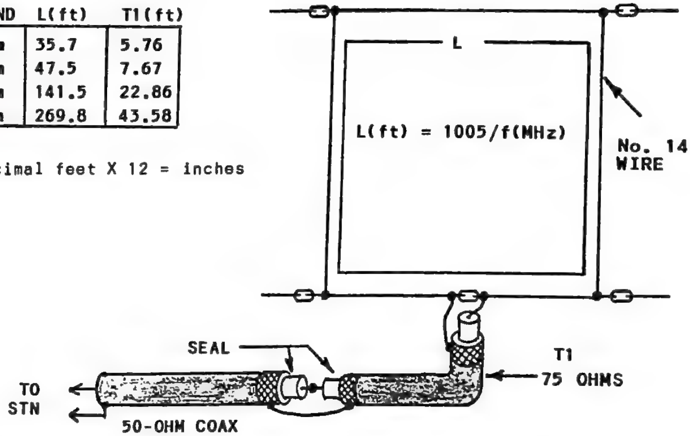


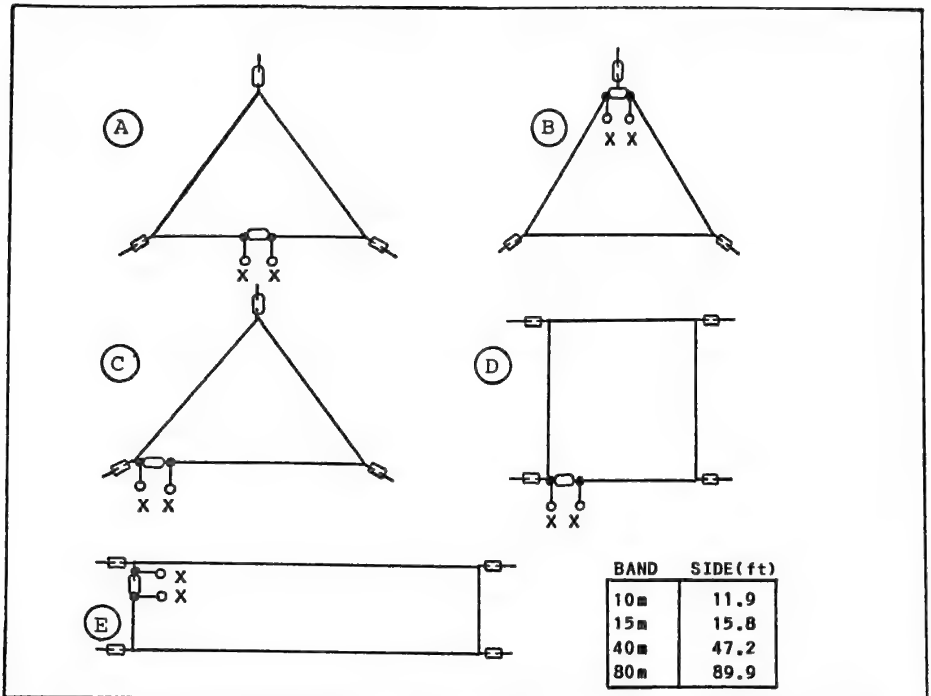
Fig 5-2 -- Example of a square loop for single-band operation. The data at the upper left indicates the dimensions for the loop and the matching transformer for various Novice HF bands. The wire size may be 12, 14 or 16 gauge, bare or enameled conductor. The feed method (center of lower side) shown here provides horizontal polarization.

The dimensions listed in Fig 5-2 are suitable also for circular or delta (triangular) full-wave loops. Rectangular loops with long sides do not conform exactly to the 1005/f(MHz) equation. You may find it necessary to shorten a rectangular loop somewhat in order to have it resonant at the desired frequency. For example, I had to remove 15 feet of wire from a long rectangular loop I built for 80 meters. It was cut initially by using the standard 1005/f(MHz) formula.

You may use standard coaxial-cable connectors at the point in Fig 5-2 where the 50- and 75-ohm coaxial lines are joined. Two male connectors and a barrel adaptor (union) are suitable. The connection should be sealed with tape or Coax Seal putty. This will help to retard oxidation. If you choose to splice the cables, as shown, keep the leads short. The junction should be sealed against dirt and moisture with epoxy cement, followed by a wrapping of vinyl electrical tape. The open end of T1 (at the antenna feed point) should also be sealed by means of epoxy cement. This will prevent moisture from migrating through the coaxial transformer, which would cause corrosion and eventual destruction of the cable.

Triangular Loops

You will find the triangular loop more practical than the example shown in Fig 5-2. Only one tall support is needed for the model portrayed in Fig 5-3A. In this apex-up version of the delta loop you may feed the antenna at the top (apex), center of the lower side, or at one of the lower corners (Fig 5-3C). Examples of loops and their feed methods are given in Fig 5-3.



BAND	SIDE(ft)
10m	11.9
15m	15.8
40m	47.2
80m	89.9

Fig 5-3 -- Examples of full-wave loops for the Novice HF bands. The table at the lower right provides dimensions for the sides of delta loops that are equilateral triangles. These dimensions are based on the standard formula total loop feet = 1005/f(MHz). Loops A and B provide horizontal polarization. Loops C, D and E have vertical polarization. Loop D has the greatest gain and loop E has the least gain. For single-band use see the T1 dimensions and feed method shown in Fig 5-2. Points X show where the feed line is attached to the loops. Top feed (B) is better than bottom feed (A) in terms of effective antenna height above ground.

The greater the loop height above ground the better the performance. However, you can still enjoy acceptable all-round performance when the bottom wire of a loop is only a few feet above ground. I have used 160- and 80-meter delta and rectangular loops that had their lower sides only 4 to 6 feet above ground. In fact, I once worked

42 countries on 40-meter CW (from CT) in one month of casual operating while using a 2-watt QRP transmitter and a 40-meter square loop. The lower leg, fed at the center, was only 4 feet above ground.

Amateurs (especially new hams) are frequently discouraged because they can't erect theoretically perfect or ideal antennas. Don't let this lofty objective prevent you from experimenting. If you want to build a loop, but lack the space to make it truly square or triangular (equilateral), don't give up. Loops with odd and distorted shapes work quite well. For example, your delta loop may have two short and one long sides.It will still perform nicely, but may have a fraction of a dB less gain than a loop that has perfect symmetry. It may be the ugliest loop in town, but it will work!

Supporting Your Loop

The antennas in Fig 5-2 and 5-3 are heavy, in terms of weight. Your support structures need to be capable of keeping the wires taught, even when high wind prevails. Trees are good supports for large loops, as are towers and guyed masts. The arrangement at A of Fig 5-3 is suitable for tower, metal and wooden masts. If you use a metal support structure, try to space the loop a few feet out from the tower or mast, and attempt to have the metal support structure at the physical center of the loop. This will help to preserve the electrical balance of your loop, which will minimize the effect of a metal object being within the field of the antenna.

If your tower or mast is not high enough to permit using an equilateral triangle, shorten the side legs of the loop and lengthen the bottom leg (Fig 5-3A, B and C) in order to have the overall loop-wire length meet the 1005/f(MHz) requirement.

Use insulators that can withstand the stress caused by antenna weight and wind loading. Don't use plastic materials that shatter easily, especially in areas where cold weather is seasonal. Polyethylene insulators, such as those sold at Radio Shack and through electric-fence suppliers, are excellent for use with loop antennas. Porcelain insulators are excellent also.

Multiband Loop Antennas

You may obtain suitable multiband performance with your loop by feeding it with balanced transmission line. Connect 300-ohm UHF TV ribbon line or 450-ohm molded ladder line to the feed terminals (**X**) of your loop. You may also use homemade open-wire feeders (300 to 600 ohm -- not critical). Use any convenient length of balanced feed line. If your Transmatch has a built-in balun transformer you may connect the balanced feed line directly to the balanced antenna terminals on your ATU. If you do not have a built-in balun, add a 4:1 balun just outside your ATU and connect it to the ATU via a short piece of 50-ohm coaxial cable. The balanced feeders connect to the remaining two terminals of the balun. The balun changes the balanced feed condition to an unbalanced one. It also steps down the impedance that is present at the transmitter end of the balanced feed line. This impedance will vary with the operating frequency and the length of the balanced feeders. I can't, for this reason, state the exact impedance that is presented to the balun transformer. Generally, it will be somewhat below 150 ohms on harmonically related bands.

The loop is dimensioned for the lowest desired operating frequency. Coverage may therefore be from 40 through 10 meters if your loop is designed for 40-meter use. There will be some added gain at 15 and 10 meters when you use this loop. Remember that maximum signal directivity will be broadside to the loop on 40 meters, but it will be in the plane of the loop (off the ends) on 15 and 10 meters. In any event, you will be able to work stations from all compass points, even during harmonic operation of the antenna. An 80-meter loop will provide multiband use from 80 through 10 meters.

I have found my loops to be equal to, and sometimes better than, my triband Yagi at 55 feet while talking to DX stations. On rare occasions the Yagi will exceed the performance of the loop by 3 to 6 dB. It depends on the time of day and propagation conditions at a given instant. My observations were made on 20 meters with a switching arrangement that allowed almost instantaneous antenna comparisons. These checks were made while using 80-meter loops that were delta or rectangular in shape, and with their bottom sides only 6 feet above ground.

Horizontal Loops

It is possible to erect a loop parallel to ground. If this type of antenna is high above ground it will give a good account of itself for local and DX work. The dimensions are the same as for the antennas in Figs 5-2 and 5-3, and the feed methods in those illustrations also apply.

Horizontal loops that are less than 1/2 wavelength above ground are not very effective for DX operation. This is because they tend to shoot the signal straight up toward the ionosphere. The earth acts as a reflector to enhance this condition. Short-haul contacts out to 1000 miles on 80 and 40 meters may be enhanced by using a horizontal loop at low height, so there is an advantage to be realized if you're not a DX chaser. You will still be able to work short skip on 15 and 10 meters with this type of loop, so don't be afraid to try it if you can't erect a vertical loop.

The Half-Wave Grounded Loop

You may wish to consider a space-saving variation of the full-wave loop antenna. We may take advantage of the image half of an antenna that occurs within the ground, which enables us to use a half wavelength of wire to approach the performance of a full wavelength of wire in a loop antenna. This method requires that we ground the far end of the half-wave loop. This is shown in Fig 5-4. Please note that a buried or on-ground wire connects the two lower legs of the loop (dashed line) between the far end and the feed point.

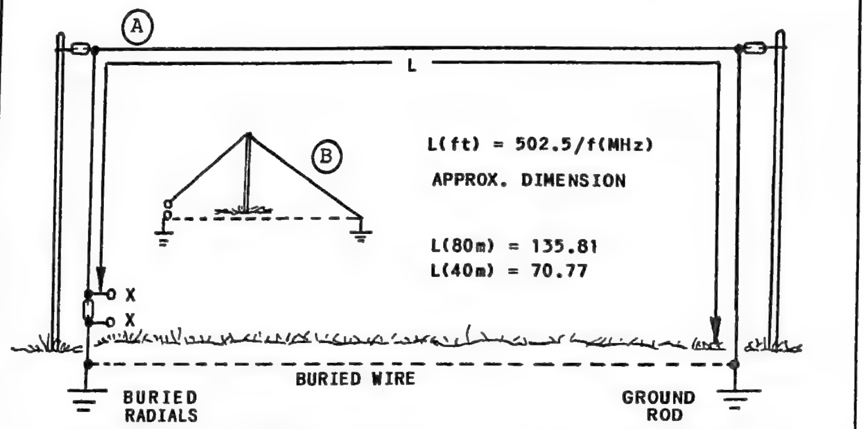


Fig 5-4 -- Example of an inverted-U half-wave grounded loop. The ground rod should be 8 feet long and the radials should be 1/4-wavelength long. Use as many radials as you can manage, as they will help to make the antenna perform in an optimum manner. No. 12 or 14 copper wire may be used for this antenna. No. 14 plastic covered house wiring is best for the buried wire that joins the feed point to the far end of the antenna. The insulation helps prevent deterioration of this wire as a result of soil acids. Solder all joints securely. The buried wire may be two or three inches below the earth surface. Alternatively, the wire may simply be laid on the ground. The feed line may be 50-ohm coaxial cable for single-band operation. Balanced feeders and a balun may be used for multiband operation. The higher the vertical legs of the loop the better the performance. Inset drawing B shows how to erect a grounded half-wave loop when only one support is available. The method at A offers better overall performance than the scheme at B.

The loop of Fig 5-4 should be resonant at 3.7 MHz for the 80-meter Novice band, and at 7.1 MHz for the 40-meter Novice band. If you have access to a dip meter you may use it to check resonance. Make a small 6-turn coil with a 1 inch ID. Connect it at points **X** of the loop. Insert the dipper coil into this loop and tune for a dip in meter reading. Check the dial reading of the dipper against your receiver by listening to the signal from the dipper. Make sure the dipper dial calibration is accurate. If the dip indicates too low an antenna frequency, remove some wire from the loop and check it again. Repeat this procedure until resonance is established. In a like manner, if the antenna resonance is too high in frequency, add sufficient wire to establish resonance. Half wave grounded loops may be used on their harmonics by employing balanced feeders and a balun transformer.

Chapter Summary

The choice between end-fed and loop antennas is yours to make. End-fed wires are capable of excellent performance, as are the loops we have discussed. Which system offers the best results for you is dependent upon your location and the exact configuration you decide to adopt. Experimentation will help you to select the antenna that meets your needs. The most important message I can pass on to you is that wire antennas are easy to construct and adjust. They are also fun to build, and they cost substantially less than their commercial counterparts. Be an experimenter and capture a part of Amateur Radio you might otherwise miss!

Glossary of Chapter Terms

Delta Loop - A triangular-shaped, full-wave closed loop.

End Feed - An antenna made from wire that is fed at one end by means of a matching device (not a dipole).

Fundamental Frequency - The design frequency of an antenna. An 80-m dipole that is used for multiband work through 10 meters has a fundamental frequency of 80 meters.

Harmonic Operation - Use of an antenna at frequencies that are exact multiples of the fundamental frequency, such as an 80-meter antenna being operated at 40 or 20 meters (2nd and 4th harmonics of 3.5 MHz, for example).

Long Wire - An antenna that is 1 wavelength or greater overall. Not simply a long piece of wire.

Matching Section - A device that usually contains capacitance and inductance, or a section of transmission line of a specific length. Used to match a feed line to the feed terminals of an antenna.

Rhombic Antenna - A large diamond-shaped antenna that consists of combined long wires. Used parallel to ground to obtain gain and a low angle of radiation.

Short Skip - Short- and medium-distance radio communication resulting from bouncing signals off the ionosphere and back to earth.

V Beam - A large V-shaped wire antenna that has conductors 1 or more wavelengths long. Provides gain and a bidirectional radiation pattern.

Zepp Antenna - A half-wavelength wire fed at one end with tuned, balanced feeders. Named after the type of antenna used on Zepplins.

Chapter 6

CHOOSING AND USING BEAM ANTENNAS

We have outlined in the foregoing chapters a variety of antennas you may construct for local and DX operation. Most of them are easy to build, and they are relatively inexpensive. Furthermore, towers and rotators are not required when using the wire antennas from the earlier chapters of this book. The same is not true of beam antennas for the HF bands. They are large, heavy and fairly expensive by comparison. This means that a well designed tower must be used to support the beam antenna, and you will need to employ a rotator for turning the Yagi or quad antenna.

A beam antenna should be a tool rather than a status symbol. In other words, you should not equip yourself with all of this extra gear, just to have a 1st class station in your part of town. This may seem like an unfriendly remark, but it is not meant to be abrasive. Beam antennas are worthwhile, but only if you have a dedicated outlook toward chasing DX a large part of the time. On the other hand, if you expect to operate in the 10- or 15-meter bands sporadically (perhaps you prefer the 80- and 40-meter Novice bands), the labor and cost of installing a tower and rotary beam antenna are not worth the rewards. I know a number of amateurs who have earned their DXCC awards with only 100 watts of power, and none of them has ever owned a beam antenna. Their success can be attributed to patience, operating skill and wire antennas that performed well.

Some amateurs like to ragchew locally on, for example, 10 meters. In this situation a beam antenna can be very useful. It maximizes your signal power by concentrating it in a given direction. A beam antenna has gain, and gain effectively increases the power of your transmitted signal. This is known as effective radiated power (ERP). By way of example, suppose you have a high-gain beam antenna that is rated at 10 dB of forward gain. If you feed your 100-watt signal to this antenna, the ERP is 1000 watts in the favored direction. Most amateur three-band (triband) beams do not have that much gain. Typically, the gain of these factory built antennas is 5 to 8 dB, depending on the design and how well they are adjusted.

Another useful feature of a beam antenna is its ability to reject unwanted signals off the sides and back of the antenna. This is helpful when QRM prevails on or near your operating frequency.

Homemade versus Commercial Yagis

The availability and convenience of commercially made Yagi beam antennas has made them popular. The majority of amateurs buy, rather than build, their HF beams. The choice is usually a triband system that permits operation on 20, 15 and 10 meters. The antenna elements contain traps (see earlier chapter) that enable the system to function on all three bands. These traps are bulky and heavy, which adds considerable weight to the antenna. This requires that heavy elements and a boom be used to handle the stress caused by weight and wind loading. A powerful rotator is needed in order to accommodate these large antennas. Small TV-antenna rotators are unsuitable, since their gears will break easily when the beam is turned, or when there is high-velocity wind.

Single-band beam antennas are lighter in weight, and can be built with elements of smaller diameter and weight than is true of the typical tribander. Furthermore, single-band Yagis are easy to build if you have access to a supplier of aluminum tubing. You will save money by building your own single-band Yagi.

Although it may seem strange to you, amateurs have fashioned single-band 10- and 15-meter Yagis from bamboo poles that were wrapped with aluminum foil! They were inexpensive and lightweight. More importantly, they worked as well as a commercial counterpart! This points to the innovation that I am trying to encourage in this book. In bygone days it was the practice among hams to construct their beam antennas with wood. Cone standoff insulators were used to support wire or small-diameter tubing, which was used as the element material. Booms for these antennas were often made from a ladder. This would be a viable scheme today, owing to the availability of aluminum ladders.

Telescoping sections of aluminum tubing are used in the construction of Yagi antennas. This helps to reduce the overall weight, since the element diameter decreases toward the outer ends. The larger tubing section is split in four places where it joins the smaller section. Stainless steel hose clamps are used to secure the telescoped sections.

Height Above Ground

The rules for wire antennas, respective to height above ground, apply also to beam antennas. Best tribander performance occurs when the antenna is 1/2 wavelength or greater above ground at the lowest operating frequency of the array. Thus, for a 20/15/10-meter tribander, the minumum recommended height is 35 feet (14 MHz). This is based on the free-space wavelength of L(feet) = 984/f(MHz). Therefore, the 1/2-wavelength dimension is based on 492/f(MHz).

Compromised performance is possible at heights which are less than 1/2 wavelength. I recall having 20-meter schedules with K8LZL/7 in Mesa, AZ. He lived where tower restrictions were in in force (none permitted). His tribander was supported atop his motor home on a short mast that placed the antenna only 15 feet above ground. Despite this handicap, his signal was always loud in NW lower Michigan at noon EST. His station was not effective for DX work, owing to the high radiation angle that resulted from having the antenna so close to ground.

Too great an antenna height can cause problems also. Beam antennas that are one or more wavelengths above ground are usually good performers for long-distance DX, but they can fail miserably during short-range contacts out to, say, 1000 miles. This is because the radiation angle is quite low when the beam antenna is located so high above ground. Some DX operators use two tribanders: one may be mounted 50-60 feet above ground, while the other one is 100-120 feet high. This provides an opportunity to select the antenna for which the height is optimum for a given distance or propagation condition. We must weigh cost versus need when considering an elaborate installation of this type.

How Beam Antennas Work

Most amateur HF beam antennas have three elements. They are called director, driven element and reflector. This applies to Yagis and cubical quads. Please refer to Fig 6-1.

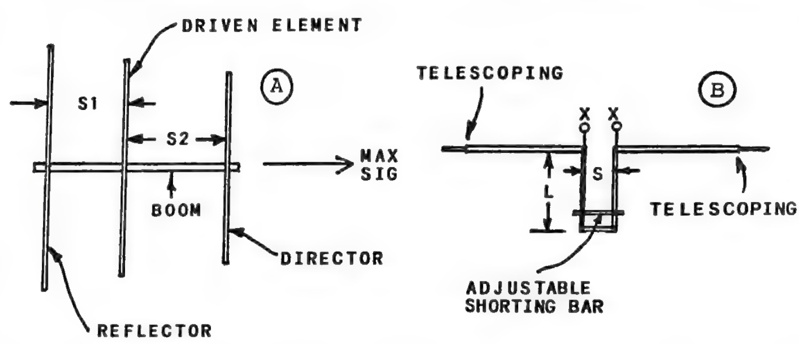


Fig 6-1 -- Illustration A shows a three-element, single-band Yagi beam antenna. It is named after the inventor, Dr. Yagi, who developed this design with another Japanese engineer, Mr. Uda. Practical spacing between the reflector and driven element (S1) is 0.15 wavelength. S2 may be 0.20 wavelength. The reflector is 5% longer than the driven element and the director is 5% shorter than the driven element. Shown at B is the driven element. It uses a hairpin match for 50-ohm coaxial cable. The U-shaped hairpin constitutes part of the driven-element length. The shorting bar and element length is adjusted for an SWR of 1:1.

You can think of the beam-antenna reflector as a mirror behind a light source. It is slightly longer than the driven element, and it helps to direct the signal energy forward, as does a mirror. The director can be equated to a lens that intensifies a light source by concentrating it in a forward direction. This overly simplified explanation of how the director and reflector work will help you to understand why maximum signal radiation is in the direction of the arrow in Fig 6-1A. The concentrated signal energy forms what is known as a major lobe. There are smaller lobes (minor lobes) radiated from the antenna also. They are present at the front and back of the Yagi. These minor lobes are of little consequence, since they represent a very small part of the radiated energy. The minor lobes have fairly high radiation angles compared to the major lobe.

Designers choose various spacings (S1 and S2 of Fig 6-1A) between the Yagi elements. The spacing affects the feed impedance and the front-to-back ratio of the antenna. The front-to-back ratio of a Yagi or other directive antenna is measured in dB. A typical 3-element Yagi has a front-to-back ratio of 16 to 20 dB, depending on the design. The front-to-side ratio of Yagis provides even greater rejection than is found off the back of the antenna.

Yagi-element spacing can be set for maximum forward gain at the expense of degraded front-to-back ratio. In other words, both of those characteristics can't be optimized with a given antenna design. The tradeoff is based on whether you prefer maximum signal rejection off the back of the antenna, or if you desire maximum radiated energy off the front of the Yagi. Large front-to-back ratios are desirable for reducing QRM from unwanted signals that originate in the opposite direction from the station you are communicating with. Some Yagis are set up for an S1 and S2 spacing of 1/4 wavelength. Other designs call for closer element spacing.

A popular method for matching 50-ohm coaxial cable to a Yagi is shown in Fig 6-1B. The U-shaped matching section is folded back over the boom and affixed to it by means of insulators. This matching scheme requires that the driven element be slightly shorter than 1/2 wavelength. This is because the hairpin section becomes a part of the driven element. The shorting bar and the element length are adjusted to provide an SWR of 1:1 in the part of the band of major interest (CW or phone segments). Adjustment is done with the reflector and director elements in place on the along with the driven element. When you obtain an SWR of 1:1 you can lock the shorting bar in place and tighten the clamps at the joints of the telescoping sections. The tubing or rod material used for the hairpin may be made from 3/8 inch OD aluminum. Tubing sizes for the antenna elements are typically 1-1/2 inch OD near the boom. They graduate to smaller OD sections toward the outer end of the elements. Generally, three telescoping sections are used for each half of each element.

Please refer again to Fig 6-1B. Approximate dimensions for the hairpin section are S = 0.00035 wavelength, and L = 0.003 wavelength. For example, the hairpin for a 10-meter Yagi will be dimensioned from L(feet) = 0.0427 [984/f(MHz)]. For 28.1 MHz we find L = 18 inches. Similarly, S = 0.005 [984/f(MHz)], which provides a center-to-center spacing of 2 inches for 28.1 MHz. Remember that these are approximate numbers.

In order to understand how this matching section works, imagine that the driven element is a straight 1/2-wavelength section of tubing. There is no U-shaped section at the center of the element. Now, envision fanning the center conductor and outer shield conductor of your coaxial cable. This fanned part of the feed line is clipped to the driven element equal distances from center until a 1:1 match is obtained. This form of feed is known as a delta match. The hairpin section is used because it makes adjustment easier, and the feed line will not flop about as it would if it were fanned for use as a delta match.

The driven element length (sections extended to maximum length) is obtained from 468/f(MHz). This allows leeway for shortening it during the matching adjustments. For 28.1 MHz it will be 16 feet, 8 inches long when fully extended. The director (Fig 6-1A) will be 5% shorter -- 15 feet, 10 inches, and the reflector will be 5% longer than the driven element -- 17 feet, 6 inches long. As you can see, we have just used simple math to design a 3-element 10-meter Yagi for the Novice band.

Two-Element Yagis

You can simplify the antenna design by using only two elements. A two-element beam antenna consists of (1) a driven element and a reflector, or (2) a driven element and a director. The former arrangement has maximum front-to-back ratio, while the latter scheme ensures maximum forward gain. The spacing between the elements may be on the order of 0.2 to 0.25 wavelength. A Yagi that has three elements can yield approximately 8 dB of gain, whereas a 2-element Yagi has a maximum gain of roughly 5.8 dB, when optimized. You may use the matching section shown in Fig 6-1B for 2- or 3-element Yagis. A 2-element Yagi is lighter in weight and less expensive to build than is the 3-element version.

Other matching methods may be used with Yagi antennas, such as the gamma and T matches. Detailed information about these systems is presented in **The ARRL Antenna Book.**

Triband Trap Yagis

Multiband Yagis are equipped with traps of the type that are shown on page 59. A Cushcraft A3 triband Yagi is designed to operate on 10, 15 and 20 meters. It is equipped with 3 elements as is the example shown in Fig 6-1A. A similar triband Yagi is the Hy-Gain TH3JRS. Discontinued similar beam antennas were built by the Mosley, Wilson and Heath companies. You may want to look for them as used gear at amateur flea markets.

Trap antennas are not as efficient as single-band antennas that have no traps. This is because slight losses always occur within the traps, however minor they may be. Also, the bandwidth of a trap antenna is somewhat less than that of a full-size model. Nonetheless, these small tradeoffs are acceptable in the interest of three-band convenience with a single antenna. The losses are usually so insignificant that you would be hard pressed to measure them with an S meter.

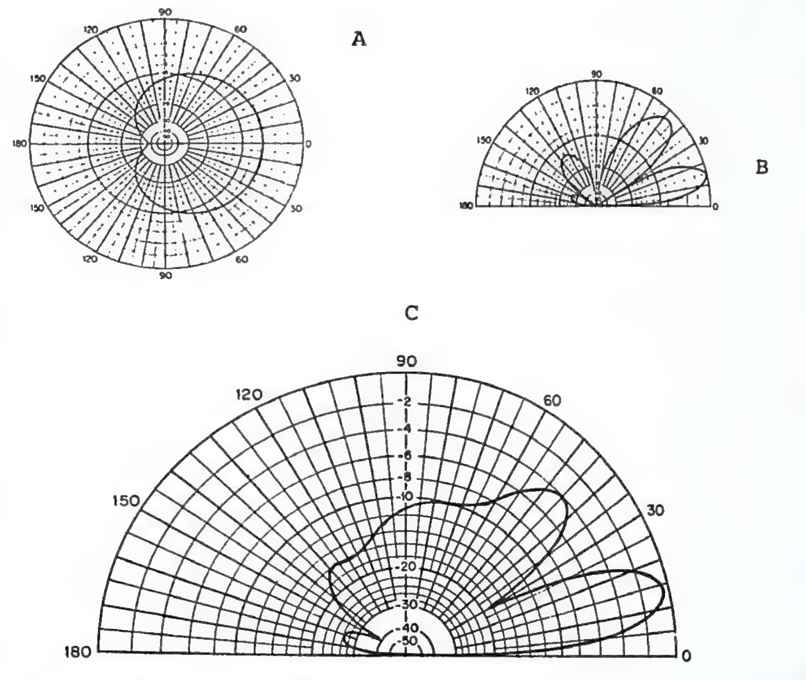


Fig 6-2 -- Yagi antenna radiation patterns. Illustration A is representative of what you would see if RF energy were visible and you were looking down on the antenna from the sky. The antenna major lobe is shown as a cardiod pattern. The pattern display at B shows the major (lower right) and minor lobes off the front and back of a triband Yagi that is 1 wavelength above a perfect ground. Imagine that you are standing at ground level and viewing the RF energy. Radiation angles for the lobes are shown in degrees. The pattern at C is a calculated one for a 15 or 20 meter Yagi that is one wavelength above ground.* Illustrations courtesy of **The ARRL Antenna Book.** (* typical ground)

Radiation Pattern

Fig 6-2 shows how the lobes from a Yagi antenna would appear if we could make the radiated RF energy visible. Fig 6-2A shows that the pattern (as though viewed from above the tribander) is quite wide. This indicates how non-critical the beam heading is when you aim the Yagi at the station you wish to work. Some amateurs worry about pointing their antennas precisely at the other station, within a few degrees. The broad pattern shows that you need not be that exacting when orienting your tribander. The situation is not the same when you use VHF and UHF Yagis that have a great many directors in front of the driven element. Antennas of this variety have very sharp patterns, and this calls for pinpoint orientation if maximum transmitted and received signal is to be obtained.

Fig 6-2B clearly defines the major and minor lobes of a triband Yagi. The major lobe has a radiation angle of some 15 degrees. This lobe is effective for DX contacts, whereas the next large lobe (45 degrees) is useful for communications over distances that are shorter. Keep in mind that the signal reflects off the ionospheric layers and returns to earth, somewhat like a pool-game shot when the ball is banked off the side cushions of the pool table. Thus, the sharper the angle the shorter the distance between the points where the ball starts and finishes. Lower radiation angles result in a broader enclosed angle, which causes the signal to return to earth at a much greater distance from the point of origin.

The very high back lobe from the Yagi (125 degrees) can be used for communicating over very short distances at times. Suppose you wanted to communicate on 15 meters with a station that was only 300 miles away from you. You might not hear his signal while your beam antenna is pointed at him. But, if both of you turned your antennas so they were back to back, the high-angle lobes would enable you to copy one another. This depends on band conditions at the time of your QSO. I have used this technique a number of times to talk to friends that were in neighboring states. This is but one "trick of the trade" I want to pass along to you in this book.

Other Yagi Characteristics

You will hear people refer to Yagis as parasitic arrays. The term "parasitic" means that the reflector and director elements (Fig 6-1) are not connected to a feed line via phasing lines. The two parasitic elements sit alone on the boom, and they are common to the boom at their electrical centers. They become part of the working antenna by means of mutual coupling. This is akin to the use of a tuned circuit (coil and capacitor) that employs link coupling. The centers of the reflector and director are at zero impedance, theoretically. Therefore, they are not affected significantly by being joined directly to the metal boom. You will hear amateurs call this style of antenna (Yagi) a "plumber's delight beam."

The opposite of a parasitic array is the <u>driven array</u>. Such an antenna may have several elements, but RF energy is applied to each of them by means of a phasing harness that connects to the transmission line. Several antennas fit this description. Among them are the collinear, ZL Special and W8JK arrays. Descriptions of driven arrays are given in **The ARRL Antenna Book.**

<u>Cubical Quad Beam Antennas</u>

A cubical quad antenna consists of a driven element and a reflector, or a driven element, director and reflector. Each element is a closed loop that is approximately a full wave at the operating frequency. The driven element size is obtained from the same formula we use when designing a single-loop antenna (chapter 5). Therefore, we use L(ft) = 1005/f(MHz). The loop director is 5% smaller than the driven element, and the reflector is 5% larger than the driven element. The director and reflector are parasitically coupled to the driven element, as is the case with Yagis.

The conductors for a cubical quad are made from no. 12 or 14 wire. X-shaped spreaders are used to support the wire, and the spreaders are made from non-conductive material, such as bamboo or fiber-glass poles.

Quad antennas are fragile, compared to Yagis. They are large and sometimes quite heavy, especially when they are designed for triband operation. Therefore, they become damaged or destroyed quickly when there is an ice build-up or a severe wind storm, or a combination of both. The desirable traits are (1) more broad band than a Yagi, and (2) they are not affected significantly by nearby conductive objects or the earth. Yagis, owing to their higher Q, are more likely to become detuned by nearby conductive objects.

I do not recommend that you construct a cubical quad beam antenna as your first home-brew effort. The materials for Yagis are less difficult to obtain, and construction is generally less complex. You can find detailed data about quads in **The ARRL Antenna Book,** should you care to research this subject further.

<u>Vertical versus Horizontal Polarization</u>

You may choose between vertical and horizontal polarization when you erect your beam antenna. Most HF-band Yagis are mounted so they are parallel to ground. This is the preferred format. If you install your Yagi so that it is perpendicular to earth (90 degree shift), the polarization will be vertical. Practically, there is nothing to be gained from doing this. Furthermore, your tower or mast will be located in the plane of the Yagi elements, and this will disturb the radiation pattern. If you use a vertically polarized Yagi, you will observe a severe signal reduction (cross polarization) during line-of-sight communications with amateurs who have horizontally polarized antennas.

At VHF and UHF you will find horizontal and vertical polarization in use. SSB and CW communications are carried out while using horizontally polarized antennas, whereas it is the practice to use vertical polarization for FM/repeater work. Why is this the situation? It is because repeaters must radiate the signal energy equally in all directions in order to provide a circular signal contour. A vertical antenna with gain is generally used at the repeater in order to achieve this goal. Therefore, in order to avoid signal loss from cross-polarization, we must use vertical antennas on our vehicles and at our homes. If you choose to have a rotary beam antenna at your home QTH for FM work, it should be erected also for vertical polarization.

Finally, a vertically polarized antenna is more responsive to local man-made noise than is a horizontal antenna. This causes a problem when we must deal with weak signals, if there is a substantial amount of QRN being generated nearby.

Stacking of Beam Antennas

You may increase the gain of your beam antenna system by using like antennas in combination. For example, if you have a 10-meter, 3-element Yagi on your tower, you can add an identical Yagi above the first one to increase your system gain by 3 dB. In order to garner another 3 dB of gain you must double the size of the array. Therefore, if you want to increase the system gain 6 dB, you will need to erect four identical Yagis. Some DX operators use stacked beams for the purpose of enhancing the transmitted and received signals, but it is costly and cumbersome to erect this type of system.

The stacked Yagis are fed with a phasing harness at the midpoint between the antennas. The spacing between the Yagis (vertically) is on the order of 1/2 wavelength, but spacings up to 1 wavelength are sometimes used.

Vertically polarized VHF and UHF Yagis are mounted side by side, rather than one above the other. If four Yagis are stacked they are mounted on the framework in a quadrature format (side by side (2) and above one another (another pair). Many amateurs prefer to use a single long Yagi rather than two or four shorter ones that are stacked. There are fewer mechanical problems to solve when using a single Yagi.

I do not recommend that you attempt construction of a stacked array until you have gained some practical experience with wire antennas of simpler design. When you are ready for these more elegant antennas you can consult **The ARRL Antenna Book.**

Your First Homemade Yagi

Let's examine a design you can duplicate. You will need to locate some aluminum tubing for the beam-antenna elements. Check the telephone directory Yellow Pages for tubing suppliers in your general region. You will also need some PVC tubing, wooden dowel rod, U bolts and machine screws. Stainless steel hose clamps are also required for securing the telescoping sections of the antenna elements.

We will make the project simple and inexpensive by adopting the 2-element Yagi design in Fig 6-3. The antenna gain and directivity will be beneficial for your work on 10 or 15 meters.

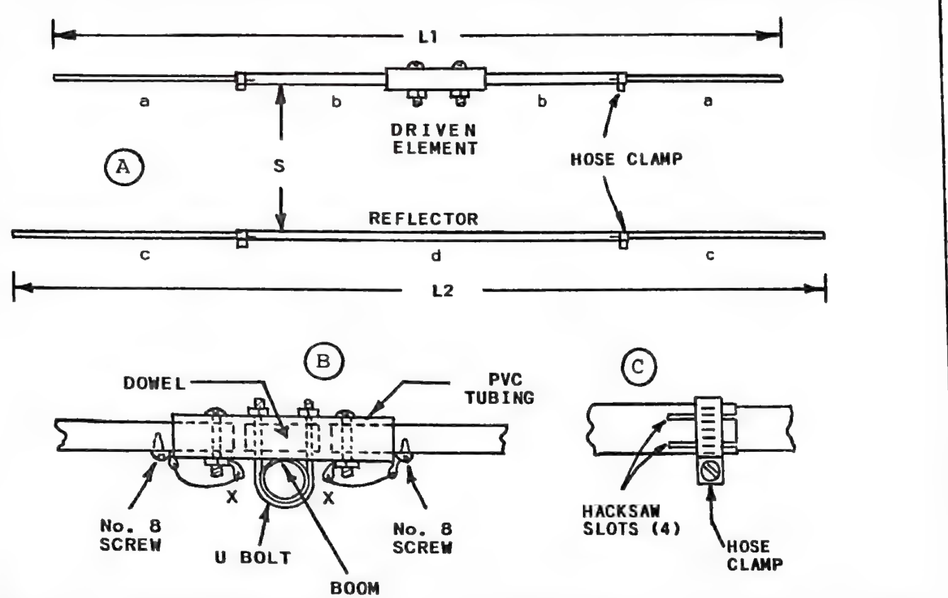


Fig 6-3 -- Mechanical details for a 2-element 10- or 15-meter Yagi. The boom is made from 2-inch OD X 0.058-inch thick 6061-T6 drawn aluminum tubing. Element sections "a" and "c" are made from 7/8-inch OD X 0.049-inch tubing. Sections "b" and "d" are 1-inch OD X 0.058-inch thick tubing. All element tubing is type 6061-T6 drawn aluminum or equiv. Detail B shows how the driven element center is isolated from the boom by virtue of PVC schedule 40 tubing being slipped over the 1-inch aluminum tubing. A wooden dowel is used inside the PVC stock to strengthen it where the U bolt is located. Solder lugs are used at the No. 8 sheet-metal screws and machine screws. A wire joins the lugs, as shown, to ensure continuity for the feed point (X). Data for slotting the 1-inch tubing and affixing it to the 7/8-inch tubing with a hose clamp is seen at C. The reflector is attached directly to the boom with a U bolt.

Our 2-element Yagi is designed to provide a feed impedance of 50 ohms, through a choice of element spacing (S of Fig 6-3A). The gain is on the order of 5 dB, which represents a respectable boost in signal strength. The spacing between driven element and the reflector is 0.22 wavelength for this design.

You may use RG-58 coaxial cable to feed this beam antenna if your transmitter power is under 300 watts, and if you use less than 100 feet of transmission line. When using RG-58 line, the losses become fairly high at 10 and 15 meters for long runs of this type of cable. RG-8 coaxial line is a better choice in terms of dB loss and power capability. I like to use foam RG-8/AU for feeding my HF Yagi antennas, even though it costs more than the smaller coaxial cable.

Mechanical details for constructing a gusset plate are provided in Fig 6-4. You may cut this piece from 1/4-inch aluminum plate. A saber saw is suitable for this job. The gusset plate is used for mounting the boom to the antenna mast by way of U bolts. Sheet steel may also be used, but the mating of dissimilar metals (steel and aluminum) leads to corrosion more rapidly than when like metals are joined.

Table 6-1 contains 10- and 15-meter dimensions for the 2-element Yagi of Fig 6-3. Final adjustment of the driven-element length is done while observing an SWR meter. Set the element length for an SWR or 1:1 or nearly so. Adjust the halves of the driven element by equal amounts during this process.

TABLE 6-1

Dimensions	10 meters	15 meters
a	7/8" X 4'6"	7/8" X 5'
b	1" X 5'	1" X 7'
c	7/8" X 4'6"	7/8" X 5'
d	1" X 10'	1" X 15'
L1	16'7"	22'2"
L2	17'5"	23'3-1/2"
S	7'8"	10'3"
Boom	2" X 9'	2" X 11'
PVC pipe	1" ID X 18"	1" ID X 18"
Dowel	1" OD X 5"	1" OD X 5"

The specifications in this table are for the 2-element Yagi described in Fig 6-3. L1 dimensions are approximate. The driven element must be adjusted for an SWR of 1:1 after the antenna is assembled.

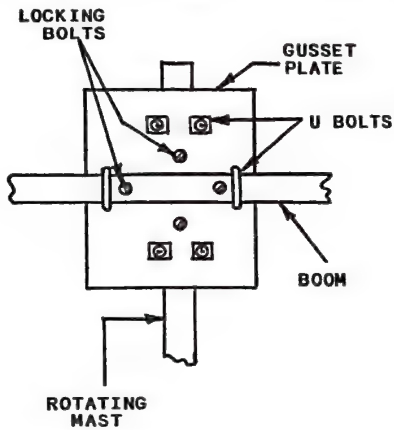


Fig 6-4 -- Mechanical details for a gusset plate that is used to join a Yagi-antenna boom to a rotating mast. A 6 X 6 inch aluminum or steel plate (see text) may be used. If aluminum is used, it should be 1/4 inch thick. A thickness of 1/8 inch is sufficient for a gusset made from steel. Locking bolts prevent the boom and mast from slipping under stress. A steel mast that is 1-1/2 inches OD is suitable for the 2-element Yagi in Fig 6-3. The locking bolts are 3/16 inch types.

Some Mechanical Considerations

Your mast should not protrude too far above the collet at the top of your tower. Excessive mast height can result in a bent mast during a wind storm. A good practice is to place your beam antenna 2 to 3 feet above the tower collet. This minimizes stress on the mast.

A well engineered rotator is essential to reliable performance. I use a Hy-Gain Ham-IV for my tribander. Avoid the temptation of using a light-duty rotator (such as those designed for TV and FM antennas). Chances are that your TV rotator will break during the first significant wind storm, so try to spend a bit more money at the beginning for a more rugged unit.

Mount your rotator inside the tower rather than above it on the mast. An inside installation calls for a mounting plate upon which to place the rotator mechanism. If you purchase a Rohn tower, for example, you may obtain the mounting plate from this manufacturer. Other tower manufacturers sell this accessory for their equipment also. The advantage connected with having your rotator inside the tower is that the collet at the top of the tower acts as a thrust bearing for the rotator, thereby relieving strain on the mechanism.

Your coaxial feed line needs to be looped between the beam antenna and the top of the tower. Be certain to provide sufficient slack in the line to allow 360-degree rotation of the antenna without placing stress on the feed line. Tape the feeder to the mast, just below the beam antenna. It should be taped at the top of tower as well. It is advisable to tape the rotator control cable and the coaxial feeder to one leg of the tower at 6-foot intervals. This will prevent the cables from flopping about in the breeze. Bring them to ground level, then route these conductors to the ham shack. You may want to bury the cables in the ground if there is substantial distance between your tower and house. Insert the cables in a suitable length of garden hose. This will protect the conductors from soil acids and moisture. Bring the ends of the hose out of the ground and seal them against dirt and moisture.

The bottom of your tower must be well grounded in the interest of safety. Drive an 8-foot ground rod into the soil at the base of the structure. Connect the ground rod to one leg of your tower by means of a wide copper or steel strap. The shield braid from a piece of RG-8 coaxial cable may be used in lieu of the strap.

Antennas for 220 MHz

You will probably want to explore the 220-MHz band after you get your HF station in operation. If you decide to engage in mobile operation, you will need to build or buy a 5/8-wave antenna for your vehicle. In fact, you may settle on this simple antenna for fixed-station use. The usual practice is, however, to employ a vertically polarized Yagi for home-station 220-MHz use. In this section we will learn how to build a 5/8-wave vertical and a 5-element Yagi. If you use the vertical for mobile operation it will not be necessary to include radials: the car body serves as the ground screen. But, if you use the vertical at your home QTH, four radials will be necessary under the radiator.

A Practical 5/8-Wave Vertical

We discussed earlier in this chapter the need for vertical polarization of our antennas when we use FM and operate via repeater stations. Vertical polarization is necessary also for working point to point on the FM frequencies, owing to the fact that most of the amateur stations have vertically polarized antennas.

A homemade 5/8-wave vertical is relatively easy to build, and the necessary materials can usually be found without too much difficulty. You will need a solid, small-diameter rod for the radiator (vertical element). Stainless steel stock is used for this part of the antennas that are of commercial origin. It is not easy to find 1/8-inch diameter stainless steel rod in my part of the USA, so I buy brazing rod from a welding shop for use as the radiator portion of my VHF and UHF verticals. Either material serves well for the purpose.

A 5/8-wave antenna requires a loading/matching coil at the base of the radiating element. This coil is tapped to provide a match to 50-ohm feed line. This is illustrated on page 74, Fig 4-12. The coil can be wound on a solid, low-loss plastic rod. Phenolic, high-impact polystyrene or Delrin rods are suitable. Consult your regional industrial plastics dealers for a source of these materials. Scrap lengths are often available at low cost.

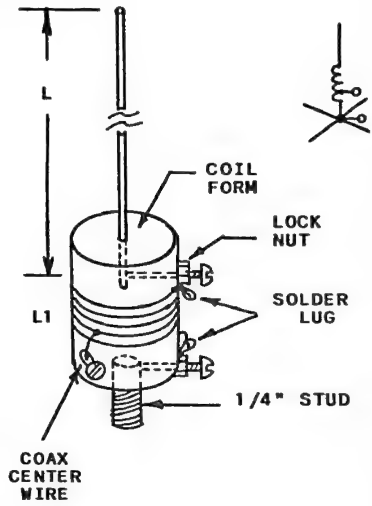


Fig 6-5 -- Mechanical details for a 220-MHz 5/8-wave vertical antenna. Radials (4) are needed for fixed-station use, as shown in the inset drawing. The coil form is drilled and tapped at the top and bottom to accommodate 8-32 locking screws. A solder lug is located under each locking nut. The ends of the coil are soldered to the two lugs. A third solder lug (lower left) is used for the coil tap and center conductor of the feed line. The feeder shield braid connects to the bottom of the coil winding, which is grounded to the car body or radials. L is 1/8 X 31-3/4 inches (see text). Coil L1 has a 5/8-inch ID and consists of 6 turns of no. 12 wire, spaced one wire diameter between turns. Tap at 1-1/2 turns from bottom end. The coil form is 5/8 X 3 inches (see text).

The shield braid of the 50-ohm feed line connects to the grounded, lower end of L1 in Fig 6-5. Keep this lead as short as you can. The center conductor of the coaxial cable is soldered to the coil-tap lug. The 1/4-inch threaded stud is used to affix the antenna to the car body. Make certain a good electrical connection is obtained between the stud and the car body. You may use a stud of smaller diameter, provided it is strong enough to withstand the strain of mobile operation. The locking screws must butt firmly against the whip antenna and stud before you tighten the locking nuts. Two coatings of exterior spar varnish or polyurethane varnish may be applied to L1 of Fig 6-5 after adjustment is completed. This will keep the coil turns in place and protect the winding from dirt and road chemicals.

If you plan to use this antenna for fixed station use, mount the antenna on a metal plate and attach four 1/8 X 13-3/8 inch radial rods, as shown in the inset drawing of Fig 6-5. An SO-239 female coaxial connetor can be mounted on the base plate (underside) near L1. The feed line, with its PL-259 male connector, can then be connected to the SO-239 fitting.

SWR Adjustments for the 220-MHz 5/8-Wave Vertical

Place a VHF/UHF SWR meter (such as a Bird Thruline) in the feed line to the antenna after it is mounted on your car or radial base plate. Trim the whip section 1/4 inch at a time and observe the decrease in reflected power reading. Continue trimming the radiator until the SWR is 1:1. Should the SWR not drop to 1:1, try moving the L1 coil tap (Fig 6-5) 1/4 or 1/2 turn either way. The SWR should become 1:1 with these two adjustments.

A Practical 5-Element Yagi for 220 MHz

You can build very large Yagi antennas for your 220-MHz work, but the high gain from a large Yagi is not normally needed for 220-MHz repeater operation. A modest 5-element model should serve well to ensure solid communications. Dimensions for multielement 220-MHz Yagis is presented in **The ARRL Antenna Book.**

Fig 6-6 shows the arrangement for your 5-element Yagi. The bill of materials for this antenna is modest. In fact, you can make the elements from coat-hanger wire if you want to save some money. The boom can be fashioned from a discarded broom handle -- still another cost-saver!

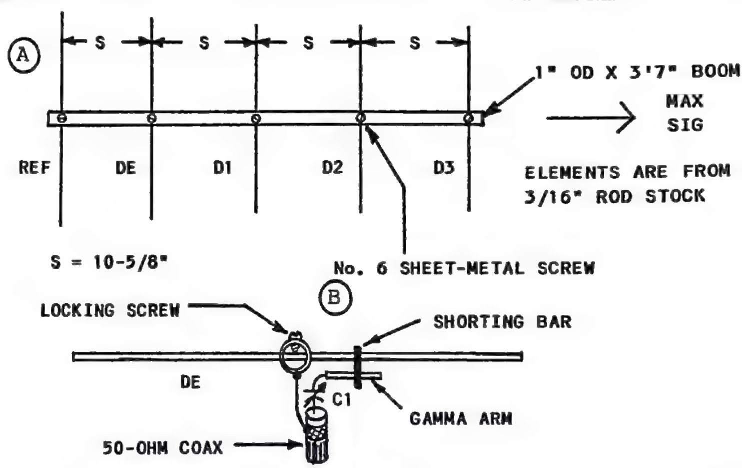


Fig 6-6 -- Details for the 220-MHz Yagi. No. 6 sheet-metal screws are used to affix the elements to the boom. The gamma arm at B is 3/16 X 4 inches. It is spaced 1-1/2 inches from the driven element. C1 is a 25-pF miniature air variable. REF = 26-3/4." DE = 25." D1 = 24-1/2." D2 = 24-3/8." D3 = 24-1/2." Adjust shorting bar and C1 at B for 1:1 SWR.

Wood or metal is suitable for the boom in Fig 6-6, although an aluminum boom will weigh less and probably last longer. Brass brazing rod is suitable for the Yagi elements and gamma arm.

C1 should be housed in a small weatherproof enclosure. You may find that a fixed-value silver-mica capacitor will suffice for C1. If you have a means for measuring capacitance, adjust C1 for a 1:1 SWR, then measure its capacitance. A standard value fixed capacitor can then be substituted for the variable one. If the value is not standard, place two or more capacitors in parallel to obtain the desired capacitance.

Seal the open end of the coaxial cable where it connects to the gamma-matching section. Adjustments of the gamma section require the use of a VHF/UHF SWR meter, such as a Bird. Point the Yagi toward the sky (reflector nearest to ground). Alternately adjust C1 and the gamma shorting bar until you obtain an SWR or 1:1. Lock the shorting bar in position after completing the adjustments.

The mast for your 220-MHz Yagi should be L-shaped at the upper end. You can make the mast from 1-inch iron water pipe. Use a 90-degree elbow at the top, then screw a 12" length of 1-inch water pipe into the elbow to form an inverted L. A pipe flange may used at the outer end of the horizontal section of pipe. This will provide a surface against which you can secure the boom of your Yagi (keep the elements vertical). U bolts are suitable for affixing the boom to the pipe flange. This arrangement keeps the vertical part of the mast away from the Yagi elements. In other words, you don't want to have the mast interlaced with the Yagi elements.

The gain of the antenna in Fig 6-6 is on the order of 9.2 dB, according to the National Bureau of Standards (NBS). The boom and element dimensions were developed by the NBS for optimum performance. The feed system in Fig 6-6B was not suggested by the NBS.

Chapter Summary

I'm sure you have become aware that I have tried to encourage you toward building your own beam antennas. Not only is it more economical to build rather than buy, it is fun, and fun is what Amateur Radio is supposed to be all about! You can point with pride to a homemade antenna, and you will feel like you have achieved something meaningful as you work distant stations with your hand-made radiator.

I have presented simple antennas that offer good performance. I hope you will try them before you reach the point where you feel you need something bigger and better.

Glossary of Chapter Terms

Array - An attenna that contains a number of similar radiating elements that combine to cause a directional radiation pattern. Two or more Yagis, for example, may be combined to form an array of Yagis.

Boom - A square or circular (conductive or nonconductive) device that is used to support the elements of a directional gain antenna. Yagi directors, driven element and reflector are affixed to a boom, by way of example.

Collet - When associated with a tower, the necked-down top part of a tower top section through which the mast is routed. A piece of steel pipe that is welded to the top of the tower.

Cubical Quad - A type of directional gain antenna that consists of two or more full-wave wire loops to form a reflector, driven element and one or more directors.

ERP - Effective radiated power from a radio station. ERP includes the transmitter output power, minus feed-line losses, plus the gain of the antenna in dB, as expressed in watts.

Gamma Match - A system for matching a coaxial feed line to the feed point of a radiator. Permits grounding the center of a driven element and exciting it by a gamma arm and series capacitor. The capacitor tunes out inductive reactance that is present at the feed point.

Lobe - The radiated energy from an antenna that has boundries on either side that are formed by nulls in the radiation pattern.

Matching Coil - An inductor that is used at an antenna feed point to provide a match between the characteristic impedance of the antenna and a coaxial feed line. This coil generally serves also to resonate the antenna (loading coil).

Mutual Coupling - Induced currents in conductors that occur when the conductors are sufficiently close to one another for this form of energy transfer. One conductor within the immediate field of another conductor that is supplied with ac energy. A coil and its link is one example.

Parasitic Array - An antenna for which the elements other than the driven element receive their energy through mutual coupling rather than direct connection to the feed line. A Yagi antenna is one example of a parasitic array.

Phasing Harness - A network of transmission-line sections that is used in combination to feed RF energy to the various driven elements of an array. The harness ensures that the RF currents are fed to each driven element in the correct phase.

Rotator - An electrically operated mechanical device that is used to turn directional antennas. This device is frequently referred to incorrectly as a "rotor," which is a moving part within a rotator.

Stacking -- Side by side or one above the other format used when identical beam antennas are combined into an array. For example, four Yagis may be used in a quad arrangement when stacked.

Yagi - A directional gain antenna that has parasitic elements. Invented by Japanese scientists Yagi and Uda.

Chapter 7

SUPPORT STRUCTURES FOR YOUR ANTENNAS

Not everyone is lucky enough to have tall trees on his property. As fate seems to arrange things for us, even if we do have tall trees, they are seldom in the right place to serve as supports for our antennas. This situation calls for the erection of a mast or tower, more often than not.

We have the option of buying a mast or building one. My experience with antenna supports suggests that it is more economical to build a mast. Store-bought masts are high priced, to my way of thinking! Later in this chapter we will discuss the details of some homemade masts that are easy to construct.

Homemade towers are few in number. It is difficult to construct a tower that is inexpensive and strong. Professional welders or construction workers can probably design and build a fine tower, but it's not an undertaking for laymen, and I consider myself one: a commercial tower stands majestically in the field next to my home!

It is a common temptation to string an antenna wire from the house to a telephone or power pole nearby. I strongly recommend that you avoid this practice. Utility poles are privately owned, and we have no right to attach our antennas to them. Furthermore, an antenna that's hooked to a power-company pole constitutes a safety hazard. Should the high-voltage lines break, they can fall on your antenna, thereby routing lethal voltages to your ham shack! Still another reason for avoiding utility poles is associated with TVI, RFI and QRN. By having our antennas so close to the electrical wiring, we can induce RF energy into the lines, and then into the homes of neighbors that are nearby. This may disturb reception for TV and FM radios, and it can disrupt the function of VCRs, tape players, electronic organs and other entertainment devices. The RFI (radio frequency interference) can backfire: computer hash, TV birdies and all manner of radio crud can come from neighbor's homes via the power line. If your antenna is near these lines you will hear this RF junk in your receiver.

Commercial Steel Towers

You are probably wondering about the type of steel tower that is best for you, consistent with cost. Your choice is dependent upon local zoning ordinances or neighborhood covenants, at least in part. Be sure to check with your city engineer about zoning ordinances that concern towers. It is possible that there is a height restriction or specific regulations that concern placement of the tower on your property, guying and the number of yards of concrete that must serve as the tower foundation. These matters need to be investigated before you invest money for a tower!

Let's assume that you've been given the "green light" to proceed with the installation of your tower. Should you buy a tower that requires guy wires? Would it be better to erect a self-supporting (unguyed) tower? Or, how about a crank-up or tilt-over tower as opposed to one that must be climbed? It goes without saying that the fewer the features the lower the cost. It's hard to beat Rohn no. 25 tower for strength and moderate cost. But, this type of tower can't be lowered by cranking. Therefore, all antenna work requires that you or a friend climb the tower for antenna installation and repairs. Guy wires are also required for this style of tower. Generally speaking, a secure installation that relates to Rohn 25 tower calls for guying every 20 feet, starting 20 feet above ground. The tower should be set in no less that 3-1/2 cubic yards of concrete for heights up to 60 feet. Towers of greater height need additional concrete at the base (check with the tower manufacturer about guying and base requirements).

As a new amateur you may wish to start in a modest manner when buying that first tower. A height of 40 or 50 feet is adequate for most of your communications needs. Rohn makes three types of towers that require guying. The lightest grade is no. 25G. It, and the two other grades of Rohn tower can be erected to a height of 120 feet. Rohn 45G is a huskier, more costly guyed tower. The strongest Rohn tower* is no. 55G. Current prices for Rohn 10-foot (standard) tower sections may be obtained from the ads in **QST**.

Rohn also makes a fold-over tower. It is available in heights from 48 to 64 feet. The 48-foot model is no. FK2548 and the tallest one is no. FK4564. This style of tower has a winch at the base, plus a leverage arm that locks against the tower when it is upright. My FK2548 is hinged and guyed at 20 feet above ground. It sits in 4 cubic yards of concrete. Only one set of guys is used. The top 28 feet of tower folds over when it is winched down. The tip of the tower touches ground only a few feet from the tower base when it is folded over (minus antenna). This makes it very convenient to install or repair my triband Yagi or 2-meter array.

There are towers that crank up and down, rather than fold over. The tower sections recess into one another, and a winch is used

* (in use by amateurs)

to adjust them. Hy-Gain Corp. sells crank-up towers from 37 to 70 feet. These towers need no guy wires. U.S. Tower Corp. also sells crank-up towers from 40 to 72 feet. No guys are needed with these towers either.

WARNING! All towers are dangerous if caution is not exercised during installation and adjustments. You should never work around your tower without wearing a hard hat and safety belt. The hard hat is especially important if you are on the ground or roof while a friend is working above you on the tower. Beware of falling objects! A safety belt of high quality and good condition is a must when you are working aloft.

Never work on your tower unless someone is near at hand to assist you in the event you injure yourself. An observer can save your life, should an accident occur.

Caring for Your Tower

Maintenance for towers is as important as it is for your car. Periodic inspections should be made to ensure that the bolts which hold the tower sections together are present and in good condition. Vibration does, on occasion, cause bolts to fall out. Bolts and nuts that are not made from stainless steel can become rusty and worn with time. They should be replaced when their quality is questionable. You may want to consider buying stainless-steel bolts and nuts at the beginning. They should last for the life time of the tower.

Frequent inspection of the steel cable on the winch of a tilt-over or crank-up tower needs to be carried out. Frayed cable should be replaced. Never lower your tower when the cable is frayed and rusty. Also, the moving parts of the winch should be oiled at regular intervals.

Guy anchors and turnbuckles also need inspection at least twice a year. A few drops of oil on the threads of the turnbuckle rods will help to prevent damage from rust. Check the guy wires for deterioration at each inspection. Replace any guy wire that appears rusty or frayed.

Guy-wire tension should not be so great that the wires are under stress. In other words, don't tighten the turnbuckles until the guy wires are like guitar strings. They should be snug, but without apparent slack. This allows leeway for tower movement during periods of high wind velocity.

Guy Anchors

The security of your tower is dependent to a large extent upon the integrity of the guy anchors. It is not sufficient to drive pipe into the ground for anchoring. Likewise with wooden stakes.

I use 4-foot long screw anchors for my Rohn fold-over tower. These anchors have an auger bit on one end, and there is an eye at the opposite end. The anchors are screwed into the earth at a 45-degree angle by inserting a short length of pipe through the eye of the anchor, then walking in a circle until only 6 inches of the guy anchor remains above ground. I purchased my guy anchors from Texas Towers in Plano, TX (see QST ads).

Homemade guy anchors can be fashioned from buried concrete and 3/8-inch OD steel rod that has an eye formed at one end. The opposite end of the rod is centered in the concrete, with the lower end threaded and fitted with a metal plate and nut at the lower, outside area of the concrete block. Approximately one cubic yard of concrete is suitable. It should be buried three feet below the surface of the earth.

Homemade Wooden Antenna Supports

It is relatively simple and inexpensive to construct a wooden mast for heights up to 40 feet. Fig 7-1 shows the details for a mast that I constructed from 2 X 4 inch lumber.

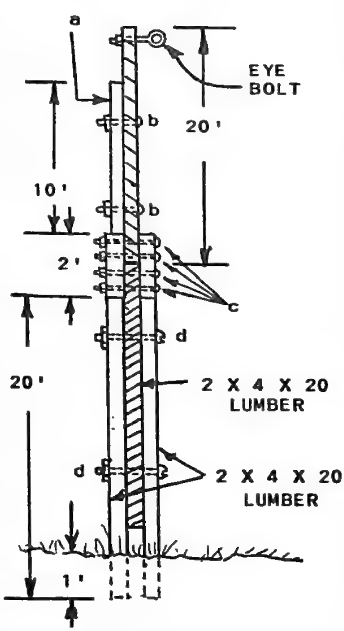


Fig 7-1 -- Details for 40-foot mast made from 2 X 4-inch lumber. Four 20-foot lengths of 2 X 4 lumber are used. Section "a" is a 15-foot piece of 2 X 2 inch lumber. It serves as a stiffener for the top 2 X 4 piece. Bolts "b" are 3/8 X 6-inch carriage types with washers under the bolt head and nut. Item "c" is a 3/8 X 8-inch carriage bolt, nut and two washers. Part "d" is a 1/2 X 8-inch carriage bolt, nut and two washers. Two 2-foot pieces of 2 X 4 lumber serve as joiners for the 20-foot sections. They are secured with four bolts ("c"). Weatherproof pressure-treated lumber is best for longevity. Untreated lumber may be used if it is well painted or varnished. The portion in the ground needs to be treated against dry rot and termite damage. Compounds such as Cuprinol may be used for this purpose.

The mast in Fig 7-1 is illustrated without guy lines. It can't stand alone. It should be guyed at the 20- or 25-foot level above ground. Use four nylon or steel guy lines. Eye screws (large) may be used to affix the guys to the mast.

The guy wires may be eliminated if you wish to bracket the wooden mast to your two-story home. My mast was secured at the peak of the roof above a second-story window. I used a homemade steel clamp (U shaped with two lips for lag bolting the bracket to the trim strip just below the edge of the roof) for anchoring the top of the mast. I piled some large rocks around the base of the mast where it entered the ground. This helped to ensure stability.

Fig 7-1 shows an eye bolt at the top of the mast. You may attach a pulley and halyard at that point. This is a convenient scheme for raising and lowering antennas during experiments or repairs. Use a good grade of nylon rope for the halyard. Polypropelene clothesline rope is unsatisfactory: it deteriorates rapidly when exposed to sunlight.

The 10-foot piece of 2 X 2-inch wood that serves as a stiffener at the top of the mast may not be necessary. I used it to prevent the top 2 X 4 section from warping. Needless to say, a good grade of lumber is important if you want your mast to be straight. Make certain there are no defects, such as large knot holes, in the sections. Most lumber yards can provide 20-foot 2 X 4s, so if your dealer does not stock them, ask him to order them for you.

Examination of the drawing in Fig 7-1 reveals that the mast can be built so that the top section tilts over by removing the lower "d" carriage bolt. You will need to allow some clearance between the two lower 20-foot 2 X 4s and the two short pieces of 2 X 4 lumber that serve as joiners.

The mast in Fig 7-1 is unsuitable for large beam antennas. It is strong enough, however, to support a VHF Yagi and TV rotator, or a 5/8-wave VHF or UHF antenna. My mast was used primarily for supporting an 80-meter inverted-V antenna.

Trees as Antenna Supports

Many amateur wire antennas are held aloft by one or two trees. There is no reason why you should not take advantage of these natural objects, if they are tall enough to be useful. There is, however, a shortcoming associated with tree-supported antennas. They sway in the wind, and this places a strain on your antenna wire. Breakage often results from this unwanted stress.

An old-time solution to the foregoing problem is to use a pulley and halyard at the far end of the wire antenna. The antenna end insulator is attached to the halyard, well away from the tree limbs and foliage. The pulley is located near the trunk of the tree, so that part of the halyard extends horizontally out to the antenna insulator. The lower end of the halyard is equipped with a counterweight, such as a coffee can filled with sand or concrete. It should be situated no more than three feet above ground. This will eliminate the possibility of it falling on a person, should the halyard break. As the tree sways in the wind, the counterweight raises and lowers accordingly. This keeps the antenna taut, but relieves stress when the tree bends away from the antenna. Use a pulley of good quality. Make certain it has no rough edges on the wheel, as this will fray the halyard and cause it to break.

An extension ladder is required in order to attach the pulley near the top of the tree. If you wish to use a tree as a temporary antenna support, you may shoot a line over the tree with a spin-casting fishing rod that is equipped with a 1/4- or 1/2-ounce lead weight. The monofilament fish line is used to pull a larger line up and over the tree. Alternatively, you may use a bow and arrow or slingshot for hurling the monofilament line over a tree. Try to shoot the line over a fairly large limb near the trunk of the tree.

Chimneys and Steel Masts

It is practical to install a steel pipe mast on the roof of a house for use as an antenna support. If your home has a well built chimney that has no loose bricks, it can serve as the anchor point for a mast. TV antenna chimney-mount straps and brackets are satisfactory for affixing a relatively short 1-1/4 or 1-1/2 inch OD TV mast to the chimney. The mast should be no longer than 10 feet. Greater lengths place undue stress on the mounting hardware, especially during periods of strong wind. A pulley can be attached to the top of the mast for accommodating a halyard. **Safety First:** This type of installation must be grounded for lightning. Use aluminum TV antenna ground wire. Attach it to the mast, then bring it down the roof and side of the house to an 8-foot ground rod. Towers and telescoping steel masts should be similarly grounded in the interest of safety.

Roof Tripods

Short, three-legged roof towers are sometimes used as antenna supports. They are made for TV antenna installations, but they are sturdy enough to support a rotator and VHF beam antenna. A mast is installed in the center of the tripod tower, then locked in place by means of machine screws and securing nuts.

The unfortunate aspect of roof-tripod installations is that three lag bolts must be screwed into the roof. The tripod is aligned so that the bolts screw into the roof rafters. This ensures a sturdy foundation for the tower. Roof patching compound is placed over the three spots where the lag bolts enter the roof.

I have used roof tripods successfully a number of times. I once had an array of 2-meter Yagis (four antennas) on a roof tripod. The array was rotated with a standard TV-antenna rotator. At no time have I experienced water leaking into the attic after affixing a tripod to the roof with lag bolts and roof sealer. If you can overcome the trauma of making holes in your roof, a tripod may be the answer to your antenna needs. Certainly, a tripod on a two-story house is far more economical than a 50-foot tower in the back yard!

How to Build an A-Frame Mast

Perhaps the oldest style of homemade wooden antenna support is the A frame. This is a relatively inexpensive mast to build. The height of an A frame may be as great as 40 feet if it is constructed from 2 X 2-inch square lumber sections. The wood should be straight-grained pine (known as hemlock) or fir. It should be free of cracks and large knot holes. You will want to make certain that the pieces are not warped. Kiln-dried lumber is best. Avoid purchasing "green" (uncured) lumber, since it will warp as it dries in the sunlight.

You will need four 20-foot pieces of 2 X 2-inch lumber for your 40-foot A-frame mast. Three of these sections are used for the upright portion of the mast. The fourth piece is cut for use as the five cross braces between the legs of the lower part of the A frame.

The cross braces are held in position (see Fig 7-2) by means of 1/4 X 4-inch lag bolts. You will need to drill 1/4-inch holes in the two lower members of the A frame to accommodate the lag bolts. Drill a 1/8-inch hole in each end of each cross brace (center it). This will allow the lag bolts to be screwed into the braces without causing them to split. Also, a 3/4-inch steel washer should be placed under the head of each lag bolt.

The top ends of the two lower 20-foot sections are bolted to the lower end of the single 20-foot section that serves as the top member of the A frame. This requires three carriage bolts that are 1/4 inch diameter by 5-1/2 inches long. Fig 7-2 shows the location of these bolts. Be sure to put a 3/4-inch steel washer under the head and nut of each bolt. The washers prevent the bolt heads and nuts from sinking into the lumber when they are tightened.

Try to purchase pressure-treated lumber for your A frame. This will retard weathering and dry rot. If this type of material is not available in your area, paint the mast sections (before assembly) with exterior primer paint. Follow this with two coats of exterior enamel paint. If you want to retain the natural look of the wood, stain the pieces and apply two coatings of exterior polyurethane varnish after the stain has thoroughly dried.

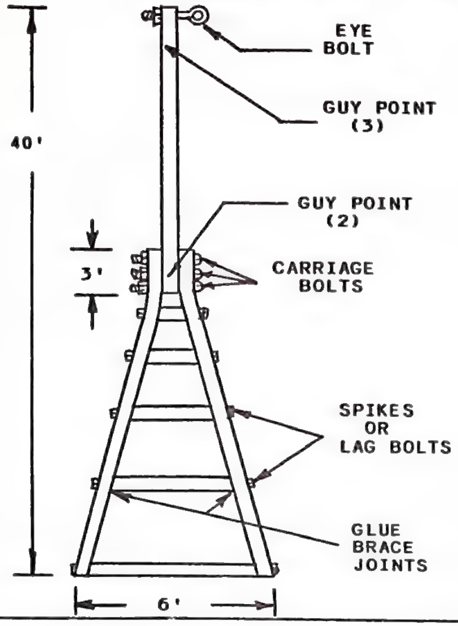


Fig 7-2 -- Layout for a homemade A-frame mast. The assembly is made from 20-foot sections of 2 X 2-inch lumber (see text). Carriage bolts hold the upper section to the lower part of the mast. Long spikes or lag bolts are used to secure the cross braces to the vertical legs of the frame. The joints between the braces and legs should be secured with a good grade of exterior glue. The eye bolt at the top of the mast is used to hold a pulley for a halyard. Two guy lines are needed at the junction of the upper and lower mast sections. Three guy lines are required at the top of the mast.

Large eye screws are suitable for the guy-line anchor points on the A frame. The two lower guys extend from the front and back sides of the mast. There are three guy lines attached near the top of the mast. The lower guys are not required if you affix the A frame to the peak of the roof at one end of your home. This may be done by using a U-shaped metal bracket to secure the mast to the house.

If you use guy cable for your installation, be sure to break the guy wires into nonresonant lengths by means of strong insulators. A nonresonant length is one that is neither a quarter or half wave (or multiple thereof) long at any of the proposed operating frequencies. You need not be concerned with this chore if you use nylon guy line.

Two A frames may be used in an open area to support an end- or center-fed wire antenna. This arrangement is often necessary when there are no trees or towers available. The A frame may be used also to support a vertical type of antenna -- wire or tubing as the conductor. The radiator in this situation needs to be isolated from the mast by means of stand-off insulators, such as those that are employed for electric fences.

The cross braces in Fig 7-2 must be mitered at the ends. It is important that the mating surfaces of the braces and mast legs are flush before you apply the glue.

Chapter Summary

Everyone loves a bargain: in this chapter we have considered a number of cost-reduction measures for those of you who are willing to use a saw, hammer and wrench. It is not essential that we buy and erect expensive steel towers for supporting wire antennas or VHF/UHF beam antennas. A homemade wooden mast is rugged, and it should last for many years if it is weatherproofed and constructed properly. Furthermore, the wooden supports described in the foregoing pages are less conspicuous in your yard than is a large steel tower. Many amateurs who live in urban settings prefer to keep a "low profile," as it were, and this may be one of your objectives. Perhaps you will elect to start out with a wooden antenna support. There will be plenty of time later on to ponder the cost and erection difficulties of a tall metal tower.

Glossary of Chapter Terms

A Frame - A structure that is shaped like the alphabetical letter A. A wooden assembly used by amateurs to support antennas.

Birdies - Spurious signal energy from various electronics devices, as heard in a receiver. A TV birdie, for example, appears approximately each 15.75 kHz in an amateur band. It comes from the TV receiver horizontal oscillator and causes a loud buzzing noise in a receiver. A birdie is generally an unwanted signal that appears in an amateur short-wave band.

Guy - To strengthen and help support an object or structure than would otherwise fall from stress or gravitational pull.

Guy Line - A metal or nonconductive cable or rope that is used to guy a structure.

Halyard - A cable or rope that is routed through a pulley at the top of a tower or mast. Use to raise and lower an antenna.

Hard Hat - A plastic or metal hat that protects one's head from injury. Such as the type worn by construction workers.

Chapter 8

ANTENNA HINTS & KINKS

If I may use a truism, there are right and wrong ways to do any job. This applies to antenna work, and in this chapter we will discuss a number of tricks that you can use to make your antenna projects easier to complete. For example, the seemingly simple task of splicing two pieces of antenna wire must be done properly if we want the joint to be strong and electrically reliable. Also, you must decide how to bring your antenna feed lines, ground wire and rotator cables into your station from out of doors. This is a matter that confounds plenty of amateurs. We shall learn in this chapter a variety of methods for dealing with this common problem. Solutions for other day-to-day problems are also presented here.

Wire Splices

A poor antenna-wire splice will cause the overall system to be weak. Furthermore, is the electrical integrity of the joint is poor, unwanted rectification can occur at the joint during transmissions and reception. How can this happen? Well, the faulty joint may become oxidized, and this creates a semiconductor diode junction. RF current that passes through the defective joint is rectified. During the rectification process the unwanted diode generates a square wave that is rich in harmonic energy. The resultant harmonics can interfere with TV and FM reception in your area. This may occur intermittently, depending upon the moisture in the air, or the velocity of the wind that blows against your ailing antenna.

Reverse interference is also possible when there is a rectifying antenna joint: you may hear all manner of hash, music and unwanted signals as you tune your receiver. If you live near a commercial broadcast station, the problem will be greater. The poor joint rectifies incoming RF signal energy, and this generates harmonics that appear in your receiver. Fig 8-1 shows the proper way to make a wire splice.

The soldering iron should be a 100-watt or larger type. Use only resin-core (sometimes called rosin-core) solder, and make certain that the wires to be joined are free of oxidation before you apply the solder.

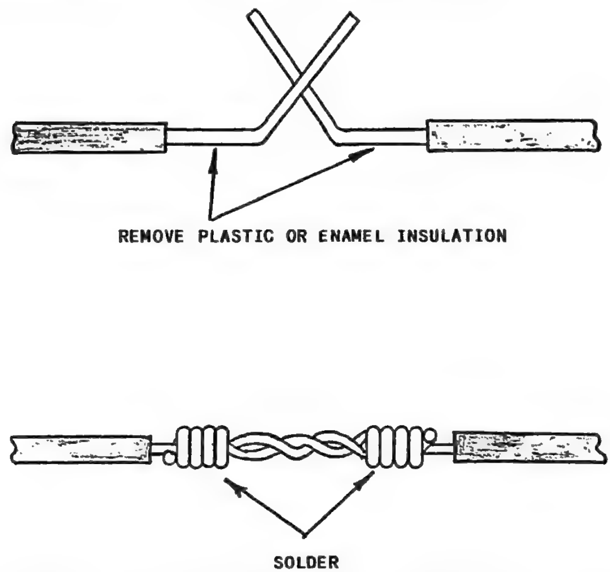


Fig 8-1 -- Example of the correct way to splice antenna wires. This method ensures strength of the joint. Soldering is recommended to prevent a poor electrical joint, which can cause rectification and harmonic generation.

Feed Line Strain Reduction

Center-fed antennas, in particular, must bear considerable weight when they are fed with coaxial cable. The larger cables, such as RG-8/U, can impose substantial stress on an antenna when they are allowed to dangle and blow about in the wind. Also, the weight of the feeder causes antenna sag, and this reduces the height of the radiator above ground. Fig 8-2 shows how a short pole can be used below the antenna feed point to relieve stress on a dipole.

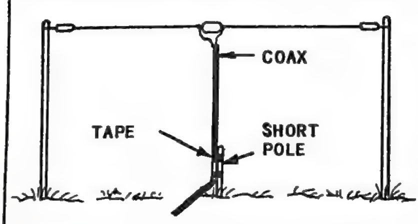


Fig 8-2 -- A coaxial feed line places substantial strain on a dipole antenna unless a support pole is located below the feed point, as shown. The feeder is taped to the small pole. Allow some slack in the feeder.

You may employ the method in Fig 8-2 for supporting open-wire or ladder-line feeders. These two feed lines are especially vulnerable to breakage at the antenna feed point when there is stress on the line. Two standoff insulators are required at the top of the short stabilizing post. The balanced feeder is attached to these insulators, rather than being taped to the post.

In the event you must have a long span of coaxial cable that is parallel to the ground, strain relief may be provided with a guy line from which the cable is hung. A messenger cable of this type can be made from TV guy wire or aircraft steel cable. The messenger cable is drawn taught between two anchor points. The coaxial feed line is pretaped to the steel cable at frequent intervals. Nylon cord may be used as an alternative to the tape.

Bringing Wires Into the House

One of the more perplexing challenges we face as amateurs is that of routing feed lines, earth-ground wires and rotator cables into the house from outside. Most amateurs are reluctant to bore holes through the wall of a house for the purpose of accommodating these conductors. The act may be compared to that of cutting a hole in a new vehicle for the purpose of installing a mobile antenna. Few hams are willing to do that! On the other hand, if you plan to live in the same house the rest of your life, it is worth considering a clean, permanent ingress to the shack via an outside wall. Foresight is valuable when you are having a new house built: you can have the builder provide a spot for bringing wires into the house. One technique that has been adopted by some amateurs (for homes being built) is to have a section of PVC plumbing pipe (3-inch diameter) attached to an outer wall near the ham shack. It is routed into the basement or some other room in the house. Two PVC elbows and a union are used outside the house to provide a U-shaped termination for the pipe. This allows the cables to enter the PVC duct while keeping rain and dirt from entering the pipe. A PVC pipe cap is used inside the house. This prevents rodents and insects from entering the house through the conduit. Holes may be drilled in the pipe cap to permit the cables to exit. Caulking compound may then be applied around each cable or wire to create a seal.

A method that I have used successfully on a number of occasions is replacing a basement or ground-floor window pane with Plexiglass. Holes are easily cut in the plastic window pane. Coaxial feed line may be brought through the window by means of a PL-258 coaxial bulkhead connector, such as an Amphenol 83-1J. This unit is a feed-through device that has two female ends which accommodate standard PL-259 UHF cable-end connectors. A 1/4-inch bolt is suitable for bringing the ground lead into the shack via the plastic window pane. Similar bolts are practical for routing balanced feeders into the house. The longevity of the plastic material will be greater if you choose a type that is ultraviolet resistant.

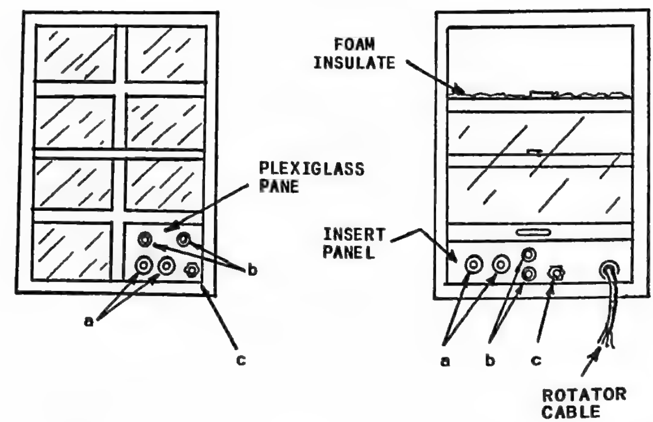


Fig 8-3 -- Examples of window panels that may be used to bring cables and wires into a house from out of doors. The types and numbers of feed-through fittings are a matter of personal choice. In these examples "a" is a ceramic feedthrough bushing for balanced feeders. Item "b" is a coaxial feedthrough connector, type PL-258. A bolt is used for the through ground terminal ("c"). In the right-hand example the lower half of the window is raised to allow the insert panel to be held in place by the weight of the window. Foam insulation is packed between the window panes near the top. This prevents insects and cold air from entering the house at the window offset point. A rubber grommet can be used at the point where a rotator cable passes through the panel.

Fig 8-3 shows two methods I have used for bringing wires into the ham shack. The panel in the right-hand illustration may be made from aluminum or wood. The window should be secured at the offset point for security reasons. A small metal L bracket may be used to lock the raised window in position. Place an L bracket at the left and right of the raised portion. Wood screws can be used to affix the brackets to the top of the lower window, and to the frame of the window at the left and right.

The items marked "a" in Fig 8-3 are ceramic feed-through bushings. If you use a Plexiglass window pane for your panel, you may replace the feed-through bushings with ordinary machine screws and nuts. No. 10-32 hardware is suitable. Use a lock washer to assure a tight fit. A solder lug can be slipped over the machine screw on each side of the panel. This will provide the terminals to which you may solder the balanced feeders.

If you route a rotator cable through your window panel, it is wise to clamp the cable to the wall inside and outside the window. This will prevent the cable from moving within the grommet, and it will help to prevent the cable from breaking the seal, should you elect to use RTV compound or a similar material on both sides of the grommet.

A Through-Wall Patch Panel

A more severe method for bringing cables into your home is shown in Fig 8-4. I used this technique in the family room of my home in CT. It involves cutting a hole in the outer and inner walls of the room. I prefer this method over all others for permanent installations.

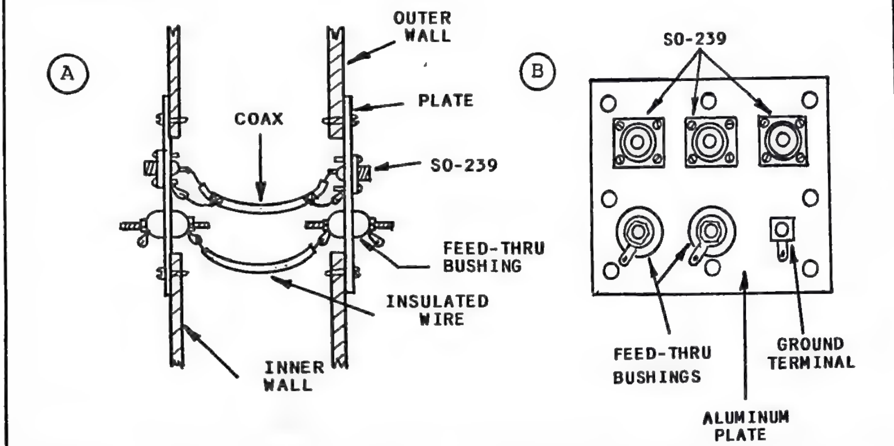


Fig 8-4 -- Method for bringing cables and wires into the ham shack. Holes are cut in the inner and outer walls of the house to allow installation of identical aluminum plates (2) opposite one another, as shown at A. The illustration at B shows a typical wall plate. It will accommodate three coaxial cables, two single-wire antennas, or balanced feeders. A bolt is used at the lower right for bringing the ground system into the ham shack. Caulking compound should be placed under the outer-wall plate to serve as a weather seal.

The wires and cables that pass through the wall must have some slack in them. This allows you to solder the conductors to the fittings on the outer plate before you attach it to the outer wall. The conductors need to have sufficient slack to permit tilting the inner-wall plate toward you when you solder the conductors to the inner-plate fittings. Clear RTV sealant may be used between the inner plate and the wall. This will prevent cold air from entering the room from behind the plate.

You may want to consider having only one SO-239 connector on the wall. An RF switch can be installed on the inner panel in place of the two SO-239s that are eliminated. This will allow you to have a single cable connected between your rig and the panel. The switch can then be used to select one of three (or more) coaxial-fed antennas. A high-quality ceramic switch should be used for this purpose.

Sources of Antenna Wire

Although no. 14 stranded copper wire is a popular choice when we construct antennas, it is fairly expensive. Since it does not have insulation, it corrodes and eventually becomes brittle and frayed. This is especially true for those of you who live in urban areas, where air pollution is sometimes high in level.

I like to use insulated wire for antennas that are meant for long-term use. Hard-drawn copper (single conductor) that has enamel, Formvar or Nyclad insulation is my preference. Soft-drawn copper wire will stretch with time and stress, and this shifts the antenna resonance lower in frequency. No. 14 is a suitable gauge for most amateur antennas (80 through 10 meters). You can often purchase this type of wire from a shop that rewinds electrical motors. Since the shop owner generally buys his magnet wire in large quantities, the price he charges you can be modest. I know of some hams who obtained reasonable amounts of wire from these sources for free I suspect that this is the exception rather than the rule!

No. 14 stranded electrical wire is also good for antenna work. This wire is available in 500-foot rolls at most of the larger variety stores. The vinyl jacket not only protects the copper from corrosion, but strengthens the antenna. Used wire of this kind can often be obtained at low cost from wrecking yards.

An inexpensive source of no. 18 Copperweld wire is your local farm-supply store. It comes in 1/4-mile spools, and is used as electric-fence wire. A roll of this wire is relatively inexpensive, and the material is strong (but springy to handle). Try to avoid sharp bends when handling Copperweld wire, as this can fracture the outer layer of copper. This exposes the steel core, and eventually the core will rust and break.

Another inexpensive type of antenna wire is the two-conductor line that is sold as "speaker wire." Clear plastic insulation is used for this material. One wire is copper colored and the other is tin colored. I have used 18 gauge speaker wire many times for my antennas. It is easy to pull the conductors apart, along with their insulation. This provides twice as many feet of wire per unit price. The insulation strengthens the wire and prevents it from corroding. I have used speaker wire as balanced, tuned feed line during portable operation. It has a characteristic impedance of roughly 75 ohms. I do not recommend this wire for VHF and UHF use (too lossy). This wire is not suitable for use in antennas that are longer than, say, 130 feet. I have found the plastic insulation on speaker wire to be long-lived when exposed to sun, heat and rain for long periods.

Some Tips on Metal Antenna Hardware

Ordinary steel screws and nuts are prone to rusting quickly when used out of doors. Cadmium-plated steel hardware lasts longer than the unplated variety, but plated brass screws and nuts are best. If you're in doubt about the nuts and bolts you have on hand, you can use a magnet to determine their composition: the magnet will not attract brass screws. Stainless-steel hardware is best for long-term use, but it is hard to locate and it is costly.

Screws, nuts and solder lugs that are used out of doors may be protected against corrosion by coating them with exterior polyurethane or marine spar varnish. I apply this material with an artist's brush after the antenna joints have been secured. A dab of Coax-Seal putty is suitable also for protecting antenna hardware.

Insulating Materials

Standard porcelain antenna insulators are expensive. You should try to make your own center and end insulators. This will save you time and money. For example, variety stores carry a wide assortment of plastic hair curlers. These make excellent end insulators for lightweight antennas. Similarly, plastic coat hangers may be cut into short lengths for use as insulators or feed-line spreaders.

Pieces of 1/2- or 3/4-inch PVC pipe (schedule 40) serve nicely as antenna end insulators. I have resorted to the use of some odd materials when I needed an end insulator while camping: I have used the vinyl-plastic retainer from a six pack of soda pop or beer. It is strong and of good dielectric quality!

I have made temporary antenna loading coils by placing the winding on a small plastic soda-pop bottle. These bottles are useful also as permanent covers for loading coils that are used out of doors. Simply cut off the top of the bottle where it widens to the overall diameter of the bottle. Drill a hole in the flat end of the bottle to accommodate the antenna wire, and invert the modified bottle over the coil. This protects the coil from rain, snow and dirt. You can use large plastic drinking glasses and refrigerator containers as coil covers. They are more durable than pop bottles, which makes them ideal for long-term use.

Do not overlook your area industrial plastics outlet. Most of these organizations have odd-lot pieces of plastic tubing, rod and sheeting for sale at bargain prices. I buy most of my antenna insulating material from these dealers. If you are located a long distance from such an outlet, you may want to obtain a copy of the catalog that is available from U.S. Plastic Corp., 1390 Neubrecht Rd., Lima, OH 45801. This company will ship via UPS, but there is a minimum order of $5. U.S. Plastic Corp. sells tubing, rods and sheets. The plastics available are PVC, nylon, Delrin, polystyrene, Plexiglass, Lexan, phenolic, Teflon and more.

Chapter Summary

You will learn more about Amateur Radio by becoming involved in antenna construction. Furthermore, working other stations will will be more fun when you construct your antenna, rather than buy a commercial one. Nothing compares with the pride of doing something on your own when it comes to equipping your station. Antennas represent one of the few remaining frontiers of home-brew activity among amateurs. Anybody that is physically able should make an effort to build his own wire or tubing type of antenna. If nothing more, the antenna will take shape quickly, and the cost will be less than for a comparable commercial antenna.

US AMATEUR SUBBAND ALLOCATIONS, 1.8 to 1300 MHz

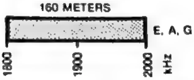
Power Limits: All US amateurs are limited to 200 watts PEP output in the Novice segments below 28,100 kHz and in the 30-meter band. On all other segments, 1500 watts PEP output is permitted. In addition, there are ERP limitations for stations in repeater operation. (See 97.67, FCC rules.) At all times the power level should be kept down to that necessary to maintain communications.

KEY

- ☐ = CW AND RTTY
- ☐ = CW, VOICE, SSTV, FAX AND RTTY
- ■ = CW, VOICE, SSTV AND FAX
- ▨ = CW AND SSB

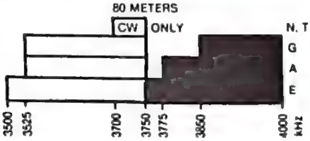
- E = EXTRA
- A = ADVANCED
- G = GENERAL
- T = TECHNICIAN
- N = NOVICE

160 METERS



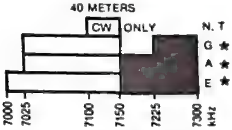
Amateur stations operating at 1900-2000 kHz must not cause harmful interference to the radiolocation service and are afforded no protection from radiolocation operations, see January 1986 Happenings for details.

80 METERS



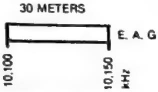
5167.5 kHz Alaska emergency use only (SSB only)

40 METERS



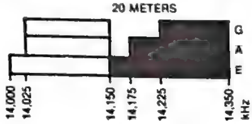
* Phone operation is allowed on 7075-7100 kHz in Puerto Rico, US Virgin Islands and areas of the Caribbean south of 20 degrees north latitude, and in Hawaii and areas near ITU Region 3, including Alaska.

30 METERS

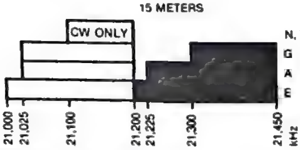


Maximum power limit on 30 meters is 200 watts PEP output. Amateurs must avoid interference to the fixed service outside the US.

20 METERS



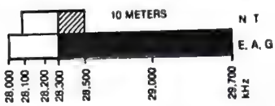
15 METERS



Consult *The ARRL Repeater Directory* for information on recommended operating frequencies and band plans for the bands above 50 MHz.

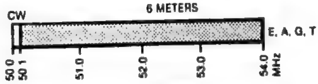
12 METERS

Amateurs must avoid interference to the fixed service outside the US.

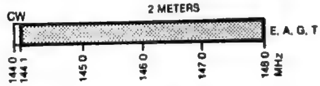


Novices and Technicians are limited to 200 watts on 10 meters.

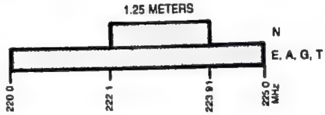
6 METERS



2 METERS



1.25 METERS

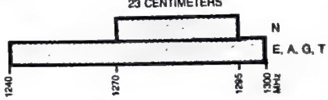


Novices are limited to 25 watts PEP on 222.1 to 223.91 MHz

70 CENTIMETERS

33 CENTIMETERS

23 CENTIMETERS



Novices are limited to 5 watts PEP on 1270 to 1295 MHz.

U.S. Customary — Metric Conversion Factors

International System of Units (SI) — Metric Units

Prefix	Symbol			Multiplication Factor
exa	E	10^{18}	=	1,000,000,000,000,000,000
peta	P	10^{15}	=	1,000,000,000,000,000
tera	T	10^{12}	=	1,000,000,000,000
giga	G	10^{9}	=	1,000,000,000
mega	M	10^{6}	=	1,000,000
kilo	k	10^{3}	=	1,000
hecto	h	10^{2}	=	100
deca	da	10^{1}	=	10
(unit)		10^{0}	=	1
deci	d	10^{-1}	=	0.1
centi	c	10^{-2}	=	0.01
milli	m	10^{-3}	=	0.001
micro	μ	10^{-6}	=	0.000001
nano	n	10^{-9}	=	0.000000001
pico	p	10^{-12}	=	0.000000000001
femto	f	10^{-15}	=	0.000000000000001
atto	a	10^{-18}	=	0.000000000000000001

Linear

1 meter (m) = 100 centimeters (cm) = 1000 millimeters (mm)

Area

1 m^2 = 1 × 10^4 cm^2 = 1 × 10^6 mm^2

Volume

1 m^3 = 1 × 10^6 cm^3 = 1 × 10^9 mm^3
1 liter (l) = 1000 cm^3 = 1 × 10^6 mm^3

Mass

1 kilogram (kg) = 1000 grams (g)
(Approximately the mass of 1 liter of water)

1 metric ton (or tonne) = 1000 kg

U.S. Customary Units

Linear Units

12 inches (in) = 1 foot (ft)
36 inches = 3 feet = 1 yard (yd)
1 rod = 5½ yards = 16½ feet
1 statute mile = 1760 yards = 5280 feet
1 nautical mile = 6076.11549 feet

Area

1 ft^2 = 144 in^2
1 yd^2 = 9 ft^2 = 1296 in^2
1 rod^2 = 30¼ yd^2
1 acre = 4840 yd^2 = 43,560 ft^2
1 acre = 160 rod^2
1 $mile^2$ = 640 acres

Volume

1 ft^3 = 1728 in^3
1 yd^3 = 27 ft^3

Liquid Volume Measure

1 fluid ounce (fl oz) = 8 fluidrams = 1.804 in^3
1 pint (pt) = 16 fl oz
1 quart (qt) = 2 pt = 32 fl oz = 57¾ in^3
1 gallon (gal) = 4 qt = 231 in^3
1 barrel = 31½ gal

Dry Volume Measure

1 quart (qt) = 2 pints (pt) = 67.2 in^3
1 peck = 8 qt

1 bushel = 4 pecks = 2150.42 in^3

Avoirdupois Weight

1 dram (dr) = 27.343 grains (gr) or (gr a)
1 ounce (oz) = 437.5 gr
1 pound (lb) = 16 oz = 7000 gr
1 short ton = 2000 lb, 1 long ton = 2240 lb

Troy Weight

1 grain troy (gr t) = 1 grain avoirdupois
1 pennyweight (dwt) or (pwt) = 24 gr t
1 ounce troy (oz t) = 480 grains
1 lb t = 12 oz t = 5760 grains

Apothecaries' Weight

1 grain apothecaries' (gr ap) = 1 gr t = 1 gr a
1 dram ap (dr ap) = 60 gr
1 oz ap = 1 oz t = 8 dr ap = 480 gr
1 lb ap = 1 lb t = 12 oz ap = 5760 gr

Multiply →

Metric Unit = Conversion Factor × U.S. Customary Unit

← **Divide**

Metric Unit ÷ Conversion Factor = U.S. Customary Unit

Metric Unit =	Conversion Factor ×	U.S. Unit
(Length)		
mm	25.4	inch
cm	2.54	inch
cm	30.48	foot
m	0.3048	foot
m	0.9144	yard
km	1.609	mile
km	1.852	nautical mile
(Area)		
mm^2	645.16	$inch^2$
cm^2	6.4516	in^2
cm^2	929.03	ft^2
m^2	0.0929	ft^2
cm^2	8361.3	yd^2
m^2	0.83613	yd^2
m^2	4047	acre
km^2	2.59	mi^2
(Mass)	(Avoirdupois Weight)	
grams	0.0648	grains
g	28.349	oz
g	453.59	lb
kg	0.45359	lb
tonne	0.907	short ton
tonne	1.016	long ton

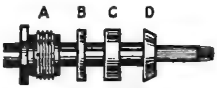
Metric Unit =	Conversion Factor ×	U.S. Unit
(Volume)		
mm^3	16387.064	in^3
cm^3	16.387	in^3
m^3	0.028316	ft^3
m^3	0.764555	yd^3
ml	16.387	in^3
ml	29.57	fl oz
ml	473	pint
ml	946.333	quart
l	28.32	ft^3
l	0.9463	quart
l	3.785	gallon
l	1.101	dry quart
l	8.809	peck
l	35.238	bushel
(Mass)	(Troy Weight)	
g	31.103	oz t
g	373.248	lb t
(Mass)	(Apothecaries' Weight)	
g	3.387	dr ap
g	31.103	oz ap
g	373.248	lb ap

BNC (UG-88/U) CONNECTORS

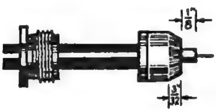
Connectors bearing suffix letters (UG-88C/U, etc.) differ slightly in internal construction; assembly and dimensions must be varied accordingly.

1) Cut end square and trim jacket 5/16" for RG-58/U.

2) Fray shield and strip inner dielectric 1/8" Tin center conductor.

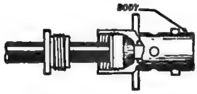


3) Taper braid and slide nut (A), washer (B), gasket (C), and clamp (D), over braid. Clamp is inserted so that its inner shoulder fits squarely against end of cable jacket.

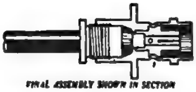


4) With clamp in place, comb out braid, fold back smooth as shown, and trim 3/32" from end.

5) Tin center conductor of cable. Slip female contact in place and solder. Remove excess solder. Be sure cable dielectric is not heated excessively and swollen so as to prevent dielectric entering body.



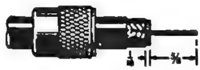
6) Push into body as far as it will go. Slide nut into body and screw into place with wrench until tight. Hold cable and shell rigidly and rotate nut.



7) This assembly procedure applies to BNC jacks. The assembly for plugs is the same except for the use of male contacts and a plug body.

83-1SP (PL-259) PLUG

1) Cut end of cable even. Remove vinyl jacket 1-1/8" — don't nick braid.



2) Bare 5/8" of center conductor — don't nick conductor. Trim braided shield to 9/16" and tin. Slide coupling ring on cable.

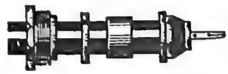
3) Screw the plug assembly on cable. Solder plug assembly to braid through solder holes. Solder conductor to contact sleeve. Screw coupling ring on assembly.

N (UG-21/U) CONNECTORS

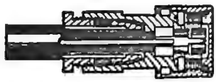
1) Remove 9/16" of vinyl jacket. When using double-shielded cable remove 5/8".

2) Comb out copper braid as shown. Cut off dielectric 7/32" from end. Tin center conductor.

3) Taper braid as shown. Slide nut, washer and gasket over vinyl jacket. Slide clamp over braid with internal shoulder of clamp flush against end of vinyl jacket. When assembling connectors with gland, be sure knife-edge is toward end of cable and groove in gasket is toward the gland.



4) Smooth braid back over clamp and trim. Soft-solder contact to center conductor. Avoid use of excessive heat and solder. See that end of dielectric is clean. Contact must be flush against dielectric. Outside of contact must be free of solder. Female contact is shown; procedure is similar for male contact.



5) Slide body into place carefully so that contact enters hole in insulator (male contact shown). Face of dielectric must be flush against insulator. Slide completed assembly into body by pushing nut. When nut is in place, tighten with wrenches. In connectors with gland, knife edge should cut gasket in half by tightening sufficiently.

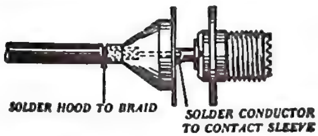
From Armed Services Index of R.F. Transmission Lines and Fittings, ASESA 49-2B.

83 SERIES (SO-239) WITH HOODS

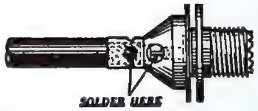
1) Cut end of cable even. Remove vinyl jacket to dimension appropriate for type of hood. Tin exposed braid.

2) Remove braid and dielectric to expose center conductor. Do not nick conductor.

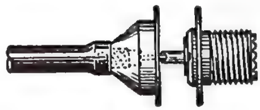
3) Remove braid to expose dielectric to appropriate dimension. Tin center conductor. Soldering assembly depends on the hood used, as illustrated.



4) Slide hood over braid. Solder conductor to contact. Slide hood flush against receptacle and bolt both to chassis. Solder hood to braid as illustrated. Tape this junction if necessary. (For UG-177/U.)



5) Slide hood over braid. Bring receptacle flush against hood. Solder hood to braid and conductor to contact sleeve through solder holes as illustrated. Tape junction if necessary. (For UG-372/U.)



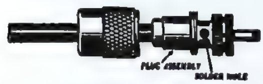
6) Slide hood over braid and force under vinyl. Place inner conductor in contact sleeve and solder. Push hood flush against receptacle. Solder hood to braid through solder holes. Tape junction if necessary. (For UG-106/U.)

83-1SP (PL-259) PLUG WITH ADAPTERS (UG-176/U OR UG-175/U)

1) Cut end of cable even. Remove vinyl jacket 3/4" — don't nick braid. Slide coupling ring and adapter on cable.

2) Fan braid slightly and fold back over cable.

3) Position adapter to dimension shown. Press braid down over body of adapter and trim to 3/8". Bare 5/8" of conductor. Tin exposed center conductor.



4) Screw the plug assembly on adapter. Solder braid to shell through solder holes. Solder conductor to contact sleeve.

5) Screw coupling ring on plug assembly.

Conversion, Decimal Feet to Inches (Nearest 16th)

Decimal Increments

	0.00	*0.01*	*0.02*	*0.03*	*0.04*	*0.05*	*0.06*	*0.07*	*0.08*	*0.09*
0.0	0-0	0-1/8	0-1/4	0-3/8	0-1/2	0-5/8	0-3/4	0-13/16	0-15/16	1-1/16
0.1	1-3/16	1-5/16	1-7/16	1-9/16	1-11/16	1-13/16	1-15/16	2-1/16	2-3/16	2-1/4
0.2	2-3/8	2-1/2	2-5/8	2-3/4	2-7/8	3-0	3-1/8	3-1/4	3-3/8	3-1/2
0.3	3-5/8	3-3/4	3-13/16	3-15/16	4-1/16	4-3/16	4-5/16	4-7/16	4-9/16	4-11/16
0.4	4-13/16	4-15/16	5-1/16	5-3/16	5-1/4	5-3/8	5-1/2	5-5/8	5-3/4	5-7/8
0.5	6-0	6-1/8	6-1/4	6-3/8	6-1/2	6-5/8	6-3/4	6-13/16	6-15/16	7-1/16
0.6	7-3/16	7-5/16	7-7/16	7-9/16	7-11/16	7-13/16	7-15/16	8-1/16	8-3/16	8-1/4
0.7	8-3/8	8-1/2	8-5/8	8-3/4	8-7/8	9-0	9-1/8	9-1/4	9-3/8	9-1/2
0.8	9-5/8	9-3/4	9-13/16	9-15/16	10-1/16	10-3/16	10-5/16	10-7/16	10-9/16	10-11/16
0.9	10-13/16	10-15/16	11-1/16	11-3/16	11-1/4	11-3/8	11-1/2	11-5/8	11-3/4	11-7/8

Conversion, Inches and Fractions to Decimal Feet

Fractional Increments

	0	*1/8*	*1/4*	*3/8*	*1/2*	*5/8*	*3/4*	*7/8*
0-	0.000	0.010	0.021	0.031	0.042	0.052	0.063	0.073
1-	0.083	0.094	0.104	0.115	0.125	0.135	0.146	0.156
2-	0.167	0.177	0.188	0.198	0.208	0.219	0.229	0.240
3-	0.250	0.260	0.271	0.281	0.292	0.302	0.313	0.323
4-	0.333	0.344	0.354	0.365	0.375	0.385	0.396	0.406
5-	0.417	0.427	0.438	0.448	0.458	0.469	0.479	0.490
6-	0.500	0.510	0.521	0.531	0.542	0.552	0.563	0.573
7-	0.583	0.594	0.604	0.615	0.625	0.635	0.646	0.656
8-	0.667	0.677	0.688	0.698	0.708	0.719	0.729	0.740
9-	0.750	0.760	0.771	0.781	0.792	0.802	0.813	0.823
10-	0.833	0.844	0.854	0.865	0.875	0.885	0.896	0.906
11-	0.917	0.927	0.938	0.948	0.958	0.969	0.979	0.990

The Amateur's Code

ONE

The Amateur is Considerate. . . He never knowingly uses the air in such a way as to lessen the pleasure of others.

TWO

The Amateur is Loyal. . . He offers his loyalty, encouragement and support to his fellow radio amateurs, his local club and to the American Radio Relay League, through which Amateur Radio is represented.

THREE

The Amateur is Progressive. . . He keeps his station abreast of science. It is well-built and efficient. His operating practice is above reproach.

FOUR

The Amateur is Friendly. . . Slow and patient sending when requested, friendly advice and counsel to the beginner, kindly assistance, cooperation and consideration for the interests of others; these are marks of the amateur spirit.

FIVE

The Amateur is Balanced. . . Radio is his hobby. He never allows it to interfere with any of the duties he owes to his home, his job, his school, or his community.

SIX

The Amateur is Patriotic. . . His knowledge and his station are always ready for the service of his country and his community.

— PAUL M. SEGAL
ex-W3EEA, W9EEA

NOVICE ANTENNA NOTEBOOK

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About the Author

M. F. "Doug" DeMaw, W1FB, was licensed in 1950 as W8HHS while he worked as an R&D engineer for the University of Michigan Willow Run Research Center. Later, he worked as an R&D engineer for Ryan Aeronautical Research Laboratories in San Diego. He served also as a TV broadcast engineer at WWTV, channel 9, and as chief engineer/DJ for WATT radio in Cadillac, Michigan.

Doug founded Avtronics, Inc in 1960 at Traverse City, Michigan, where his firm manufactured low-frequency radio-beacon transmitters and alarm receivers for civilian airports. Upon selling Avtronics in 1963 he established Comaire Electronics in Ellsworth, Michigan, where the firm manufactured VHF and UHF amateur equipment, plus low-frequency radio-beacon transmitters and VHF Unicom transceivers. While operating Avtronics, he established ***VHFer*** magazine, which he turned over to Loren Parks, K7AAD, in 1965 when he joined the ARRL HQ staff as an assistant technical editor.

In 1968 he was promoted to ***Handbook*** Editor/Lab Supervisor, and in 1970 he succeeded the late George Grammer, W1DF, as Technical Department Manager/Senior Technical Editor.

While employed by the ARRL, he coauthored ***Solid State Design for the Radio Amateur*** with famous QRPer Wes Hayward, W7ZOI. W1FB also wrote two books for Prentice-Hall, Inc and one book for Howard Sams.

W1FB retired early from the ARRL staff in 1983 to return to his native state of Michigan, where he formed a new business (Oak Hills Research) in partnership with his son, Dave, N8HLE. Since retiring, he has written articles for ***QST*** and has done article and book editing for the ARRL.

Doug is a Life Member of the ARRL, a Senior Member of the IEEE and past president of the Michigan QCWA, Chapter 10. He holds a Radiotelephone First Class license and an Amateur Extra Class license. He is presently Chairman of the Lake County Board of Commissioners in Michigan, and is a member of the Michigan Association of Counties.