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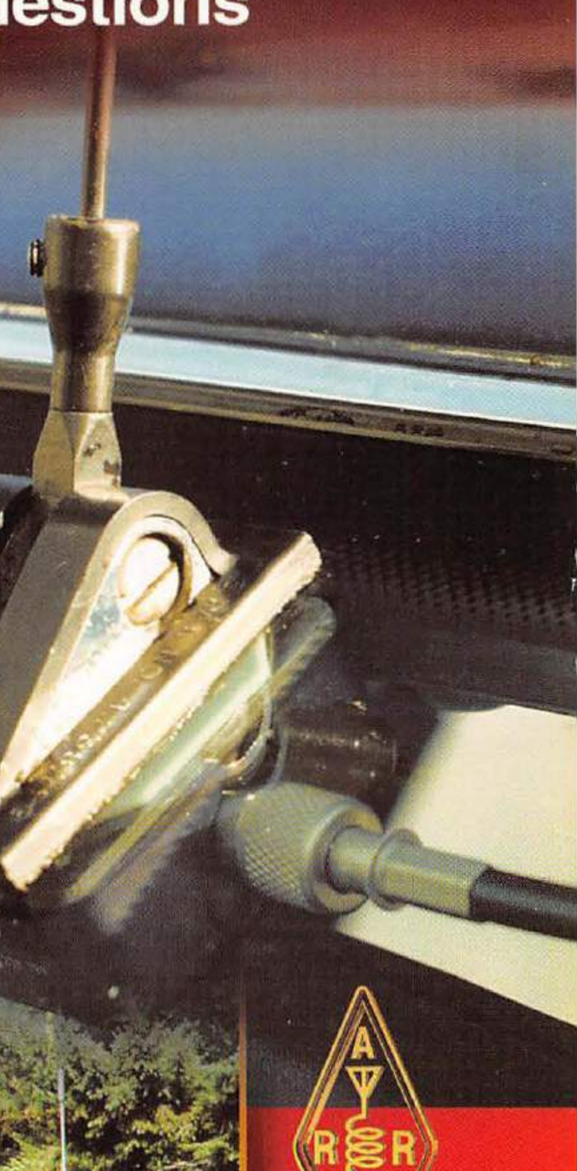
Ham Radio FAQ

The ARRL Lab and "The Doctor" answer your

Frequently
Asked
Questions



Compiled By: Al Alvareztorres, AA1DO, and Ed Hare, W1RFI

ARRL The national association for AMATEUR RADIO

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Frequently Asked Questions

Compiled by

Al Alvareztorrez, AA1DO

With assistance from:

Steve Ford, WB8IMY
Ed Hare, W1RFI
Zack Lau, W1VT
Michael Tracy, KC1SX
Joe Carcia, NJ1Q

Composition and layout:

Michelle Bloom, WB1ENT
Paul Lappen

Graphics:

Cover—Sue Fagan
Drawings—Mike Daniels
Digital photography—Joe Bottiglieri

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Contents

Foreword

If you're like most Amateur Radio operators, you have questions. Your questions may be relatively straightforward, or complex. Regardless, now that you've identified a question or two (or 20), you'll need a source that will provide the information. Where should you turn?

You could start with your Elmer, if you're fortunate enough to have one. Or you could search for the information you need on the Web — but this might leave you sifting through contradictory information from unknown sources. One Web site we heartily recommend is **www.arrl.org/tis/**. TIS stands for the ARRL Technical Information Service, an ARRL membership service that has been assisting hams with ham-related questions since the early days of Amateur Radio. This Web search could well turn out to be fruitful, assuming you have a computer handy. What if you don't, or you don't quite know what to ask?

That's where *Ham Radio FAQ* (for Frequently Asked Questions) comes in.

Ham Radio FAQ has been compiled to help Amateur Radio operators do what they enjoy doing best —operate Amateur Radio — efficiently, comfortably and safely. If you've ever had a question relating to:

- your station—setting it up and operating it,
- your antenna system,
- operating mobile or portable,
- getting the most from your batteries, or
- installing a proper ground and efficient lightning protection,

you'll find this book will have the answers you've been looking for.

Just in case, we've included a comprehensive References chapter that provides sources you can tap for answers to any remaining questions you may have.

Need still more help? Contact our Technical Information Service at **tis@arrl.org** or by mail c/o ARRL Headquarters, 225 Main St, Newington, CT 06111-1494.

I hope you'll let us know how you liked this book. There's a handy Feedback form at the back, or you can send an e-mail message to **pubsfdbk@arrl.org**.

David Sumner, K1ZZ
Executive Vice President
May 2001

Preface

The working title for this book started out as *101 Frequently Asked Questions about Amateur Radio*. It soon became apparent that 101 questions were not enough, so the title was changed.

This is intended as a technical book for the beginning to intermediate ham. The questions are, for the most part, actual questions, virtually unedited, as received by the ARRL Technical Information Service and The Doctor through the years. I've found that, except for minor details, hams tend to ask questions on the same subjects again and again.

Hams are concerned about their antennas: how well they work, and how to fit them on their property or inside their homes. They want to know about their grounding system and how to install a radio or antenna on a vehicle. They want to know how to take care of their batteries and how to best use their equipment. . . and of course, "How *do* I figure UTC?"

Although this is a technical book, I would be remiss if along with, "What is the best antenna?" and "Which radio should I buy?" which, by the way, are answered inside, I were not to answer *the* most frequently asked question: "Where did the name HAM come from?"

There is an urban legend that simply will not die about three fellows at the Harvard Radio Club named Albert S. Hyman, Bob Almy and Poogie Murray. At first they called their station "HYMAN-ALMY-MURRAY." Tapping out such a long name in code soon became tiresome and called for a revision. They changed it to "HYALMU," using the first two letters of each of their names. Early in 1910 some confusion resulted between signals from the amateur wireless station "HYALMU" and a Mexican ship named "HYALMO." They decided to use only the first letter of each name, and the station call became HAM.

There are several variations on the theme, including one that involves the *Congressional Record*. This story, however, has never been proven and the alleged *Congressional Record*, although searched for, has never been found. I think a more plausible story is the simplest—like most words in a language, "ham" just evolved and acquired new meaning over the years.

Before television, radio and the movies, almost all dramatic entertainment was via the live performance of a theater group. Along with the logistical problems of the constantly traveling troupes of actors there was the inevitable need to press into service local talent—amateurs. Some of these inexperienced actors had a tendency to "over act" and I'm sure that in many cases their antics were very annoying to the seasoned veteran actors. These "actors" were called hams—to this day, improvising to the extent of being almost absurd is called "hamming it up."

Enter radio at the turn of the Twentieth Century. In the early days of Spark, everyone was operating on virtually the same frequency—or more accurately everyone was operating on *all* frequencies! On more than one occasion when a ship-to-shore operator was trying to pass traffic, his receiver would be swamped by a local Amateur Radio operator's powerful signal (there were no regulations on power level in those days). The professional operator, borrowing a term with which he would have been very familiar at the time, would complain to his shipmate, "THOSE @#&! HAMS ARE BLOCKING YOUR SIGNAL!" Amateurs, in a typical Yankee response, took the name as a badge of honor.

But now let's get to the good stuff. What *is* the best antenna? What radio *should* I buy? . . .

Al Alvareztorres, AA1DO
Technical Information Services Coordinator

About the ARRL

The seed for Amateur Radio was planted in the 1890s, when Guglielmo Marconi began his experiments in wireless telegraphy. Soon he was joined by dozens, then hundreds, of others who were enthusiastic about sending and receiving messages through the air—some with a commercial interest, but others solely out of a love for this new communications medium. The United States government began licensing Amateur Radio operators in 1912.

By 1914, there were thousands of Amateur Radio operators—hams—in the United States. Hiram Percy Maxim, a leading Hartford, Connecticut, inventor and industrialist saw the need for an organization to band together this fledgling group of radio experimenters. In May 1914 he founded the American Radio Relay League (ARRL) to meet that need.

Today ARRL, with approximately 170,000 members, is the largest organization of radio amateurs in the United States. The ARRL is a not-for-profit organization that:

- promotes interest in Amateur Radio communications and experimentation
- represents US radio amateurs in legislative matters, and
- maintains fraternalism and a high standard of conduct among Amateur Radio operators.

At ARRL headquarters in the Hartford suburb of Newington, the staff helps serve the needs of members. ARRL is also International Secretariat for the International Amateur Radio Union, which is made up of similar societies in 150 countries around the world.

ARRL publishes the monthly journal *QST*, as well as newsletters and many publications covering all aspects of Amateur Radio. Its headquarters station, W1AW, transmits bulletins of interest to radio amateurs and Morse code practice sessions. The ARRL also coordinates an extensive field organization, which includes volunteers who provide technical information for radio amateurs and public-service activities. In addition, ARRL represents US amateurs with the Federal Communications Commission and other government agencies in the US and abroad.

Membership in ARRL means much more than receiving *QST* each month. In addition to the services already described, ARRL offers membership services on a personal level, such as the ARRL Volunteer Examiner Coordinator Program and a QSL bureau.

Full ARRL membership (available only to licensed radio amateurs) gives you a voice in how the affairs of the organization are governed. ARRL policy is set by a Board of Directors (one from each of 15 Divisions). Each year, one-third of the ARRL Board of Directors stands for election by the full members they represent. The day-to-day operation of ARRL HQ is managed by an Executive Vice President and his staff.

No matter what aspect of Amateur Radio attracts you, ARRL membership is relevant and important. There would be no Amateur Radio as we know it today were it not for the ARRL. We would be happy to welcome you as a member! (An Amateur Radio license is not required for Associate Membership.) For more information about ARRL and answers to any questions you may have about Amateur Radio, write or call:

ARRL—The national association for Amateur Radio
225 Main Street
Newington CT 06111-1494
Voice: 860-594-0200
Fax: 860-594-0259
E-mail: **hq@arrl.org**
Internet: **www.arrl.org/**
Prospective new amateurs call (toll-free):
800-32-NEW HAM (800-326-3942)
You can also contact us via e-mail at **newham@arrl.org** or check out *ARRLWeb* at **http://www.arrl.org/**

1 Antennas, Transmission Lines and Propagation

Most amateurs are searching for that "death-ray" antenna that will make their signal heard around the world. While this chapter doesn't tell you exactly what that antenna must be, it should help you choose from among the many antenna types available to hams today.

Let's start off with a question relating to safety.

Q Could someone be injured by touching the ground side of a coaxial-fed dipole antenna when I am transmitting at 100 W?

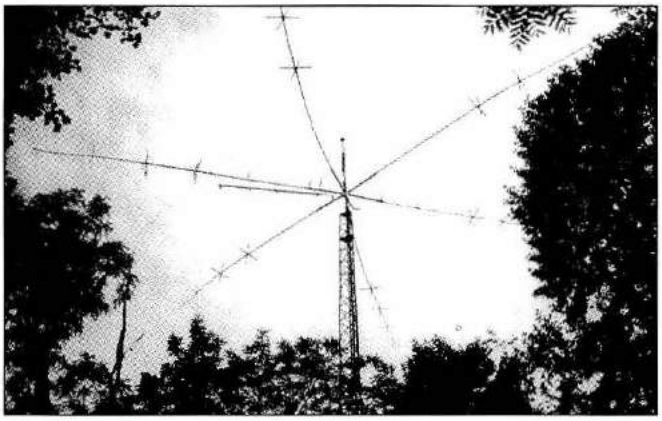
A Most definitely! There really is no such thing as a "ground" side to a dipole. Although one side of your dipole is connected to the shield that goes to ground at the shack end, this is a "ground" for dc only. There is plenty of RF voltage present on that side of the dipole—enough to get your attention with a painful burn. Always be safe in everything you do. Make sure your antennas are installed so that nobody can come in contact with them inadvertently.

ANTENNAS

Q I want to put up an antenna. What is the best antenna I can make or buy?

A Although this is possibly the number one question received by the ARRL Technical Information Service, it is probably the hardest to answer. Choosing an antenna is much like choosing whom to marry. They all have their good points; they all have their bad points and the best choice is often dictated by external factors. The major factors that you may need to consider are:

- What frequency band or bands you intend to operate?
- How much room do you have available?
- Can you put up a tower?
- Do you have tall trees?
- How much money do you want to spend?
- Will you have any zoning problems to deal with?
- Will there be any neighborhood (or family) aesthetics to deal with?
- What are the local weather conditions (high wind, icing, etc)?
- Do you want an antenna that works in all directions, or an antenna that has gain in one or more directions?



This list is just a start. The rest of this chapter answers the question of what antenna is best for different applications and needs. Much like choosing a husband or wife, you will have to weigh the pros and cons—and live with the result. Unlike choosing a mate, though, you probably don't expect that you are choosing your *last* antenna. You are choosing your *next* antenna. Building and experimenting with antennas is a life-long endeavor for most hams.

The ultimate answer to your question is that the best HF antenna is probably separate monoband Yagi antennas mounted high and in the clear. For VHF and UHF use either stacked Yagis or a large parabolic dish. But few hams can do that, so most hams select a compromise antenna based on the above criteria.

Q I am not sure what kind of operating I want to do. What is a good first antenna for me to try on HF?

A The rest of this book will talk about many of the different antennas you can try over your decades of hamming, but first antennas should be easy to build and use. The easiest first antenna is a half-wave dipole, mounted up as high as you can reasonably get it. Generally, if the dipole is up at least 30 feet, it will work out pretty well. If you can't put it up high and straight, it is okay to put it in the form of a V, an inverted V, an L or even bend the ends around a bit. All you need are three insulators (one is used as your center connector) and some wire. Strong, multi-stranded copper wire will withstand the elements best, but nearly any wire, from speaker wire to ac-line cords, can be used with great success!

The only trick to making a dipole is cutting it to the right length. A conventional dipole antenna is made of two equal lengths of wire with the total length adding up to a half wavelength at the desired frequency. The length of a half-wave dipole is a bit less than a half-wave in free space. End effects, conductor diameter and wire insulation tend to lower the resonant frequency a bit. Eq 1 can be used as a real close starting point, although you may need to do a bit of trimming. Adding a little bit to the end of each wire will give you a bit of trimming room—it is easier to trim wire off than to add it back.

Length (feet) = 468 / f (MHz) Eq 1

where f (MHz) is the frequency in MHz.

Here are the required dipole lengths for each of the Novice/Technician HF subbands:
80 meters: 126′ 6″
40 meters: 65′ 7″
15 meters: 22′ 1″
10 meters: 16′ 6″

For example, if you're making a dipole for the 10-meter band, you'll need two lengths of wire 8′ 3″ long (8′ 3″ × 2 = 16′ 6″) plus enough extra so the wire can be looped through the insulator and secured tightly. Attach the wires to the insulators and center connector as shown in **Fig 1-1**. Attach your coax feed line at the center connector. Solder the shield braid of the coax to one side of your dipole. Solder the center conductor of the coax to the other side. Be careful not to melt the coax while you're soldering it to the antenna. You can also purchase center connectors that feature built-in SO-239 jacks. With a matching PL-259 plug on your feed line, you can easily disconnect your feed line from your antenna whenever necessary for portable operation, for example. Whatever way you connect the coax to the antenna, be sure to waterproof the connection if it will be outdoors. If water gets inside the cable its loss will increase in a hurry!

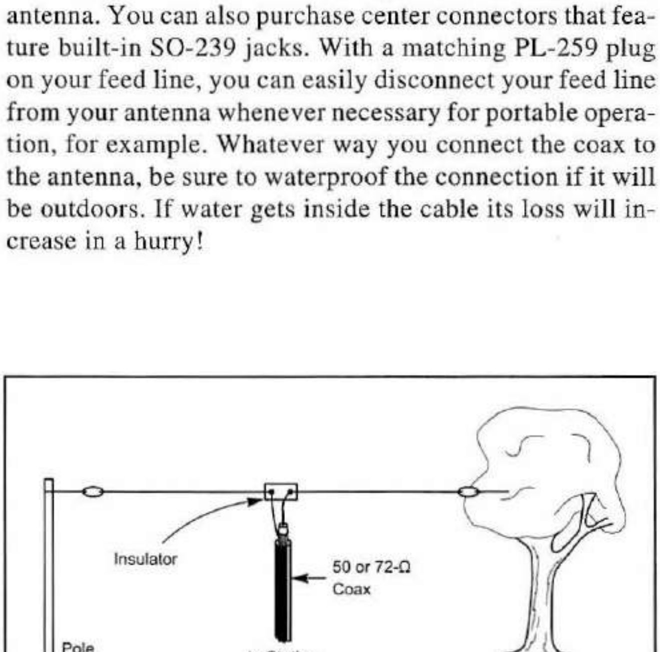


Fig 1-1—Dipole antennas for the HF bands are easy to make... and they perform well, too!

So, what type of coaxial cable should you use? At up to a few hundred watts, if the distance from your transceiver to your dipole is less than 50 feet or so, RG-58 is fine. For longer runs or higher power, you should use a low-loss cable such as RG-8, RG-213 or Belden 8214. If you own an antenna tuner, you can try feeding your dipole with 450-Ω ladder line. This type of open-wire feed line exhibits very low loss at HF. The only disadvantage of using ladder line is that you must keep it away from metal objects.

Choose your antenna supports: trees, flagpoles, chimneys or whatever stirs your imagination. You can even install your dipole in an attic. If you decide to mount it outdoors, invest in enough high-strength rope or cord to do the job. You want to be sure your antenna will survive storms, ice loading and so on. Mount your dipole as high off the ground as possible. How high is "high"? Conventional wisdom states that your dipole should be mounted at least a quarter wavelength above the earth at the frequency you choose to operate. Getting an 80-meter dipole 60 feet off the ground could present a challenge! If you can't raise your dipole to this altitude, don't worry about it! Your performance may suffer a bit, but the antenna will work. Watch out for nearby gutters, pipes, aluminum siding, window screens and other large pieces of metal. They'll detune your dipole and increase the SWR if they're too close. And, of course, never place your antenna near power lines!

If you've cut your dipole to the proper length, your SWR should be reasonably low (less than 2:1). Don't worry if the SWR seems to rise as you move in frequency toward the band edges—this is normal.

Q That sounds easy enough. Now, what can I use for my first 2-meter antenna?

A The simplest antenna to make is a 2-meter ground plane. Most VHF FM operation is vertically polarized, so you want to use a vertically polarized antenna. The rubber ducky antennas common on handheld VHF and UHF transceivers work fine in many situations. That's no surprise, considering that repeaters generally reside high and in the clear so you and your handheld don't have to meet that requirement.

Sometimes, though, you need a more efficient antenna that's just as portable as a handheld. Here's one: A simple *groundplane* antenna you can build for 146, 223 or 440 MHz in no time flat. It features wire end loops for safety (sharp, straight wires are hazardous) and convenience (its top loop lets you hang it from high objects for better performance).

What You Need to Build One

All you'll need are wire (single conductor, #12 THHN), solder and a female coax jack (SO-239) for the connector series of your choice. Many hardware stores sell THHN wire, which is thermal-insulation, solid-copper house wire, and they sell it by the foot. You'll need 7 feet of wire for a 146-MHz antenna, 5 feet of wire for a 223-MHz antenna, or 3 feet of wire for a 440-MHz antenna.

The only tools you need are a 100-W soldering iron or gun; a yardstick, long ruler or tape measure; a pair of wire cutters; a 1/2-inch-diameter form for bending the wire loops (a section of hardwood dowel or metal tubing works fine), and a file (for smoothing rough cut wire edges and filing the coax jack for soldering). You may also find a sharp knife useful for removing the THHN insulation.

Building It

To build a 146-MHz antenna, cut three 24 5/8-inch pieces from the wire you bought. To build a 223-MHz antenna, cut three 17 5/8-inch pieces. To build a 440-MHz antenna, cut three 10 5/8-inch pieces.

The photos show how to build the antenna, but they may not communicate why the cut lengths I prescribe are somewhat longer than the finished antenna's wires. Here's why: The extra wire allows you to bend and shape the loops by hand. The half-inch-diameter loop form helps you form the loops easily.

Make the End Loops First

Form an end loop on each wire as shown in **Fig 1-2**. Strip exactly 4 inches of insulation from the wire. Using your 1/2-inch-diameter form, bend the loop and close it right up against the wire insulation with a two-turn twist as shown in the bottom most example in Fig 1-2. Cut off the excess wire (about 1/2 inch). Solder the two-turn twist. Do this for each of the antenna's three wires.

Attach the Vertical Wire to the Coax-Jack Center Pin

Strip exactly 3 inches of insulation from the unlooped end of one of your wires and follow the steps shown in **Fig 1-3**. Solder the wire to the connector center conductor. (Soldering the wire to a coaxial jack's center pin takes considerable heat. A 700 to 750° F iron with a large tip, used in a draft-free room, works best. Don't try to do the job with an iron that draws less than 100 W.) Cut off the extra wire (about 1/2 inch).

Attaching the Lower Wires to the Connector Flange

Strip exactly 3 inches of insulation from the unlooped ends of the remaining two wires. Loop their stripped ends-right up to the insulation-through opposing mounting holes on the connector flange. Solder them to the connector. (You may need to file the connector flange to get it to take solder better.) Cut off the excess wire (about 2 1/4 inches per wire). This completes construction.

Adjusting the Antenna for Best Performance

Bend the antenna's two lower wires to form 120° angles with the vertical wire. (No, you don't need a protractor: Just position the wires so they just about trisect a circle.) If you have no means of measuring SWR at your antenna's operating frequency, stop adjustment here and start enjoying your antenna! Most hand-held radios should produce ample RF output into the impedance represented by the antenna and its feed line.

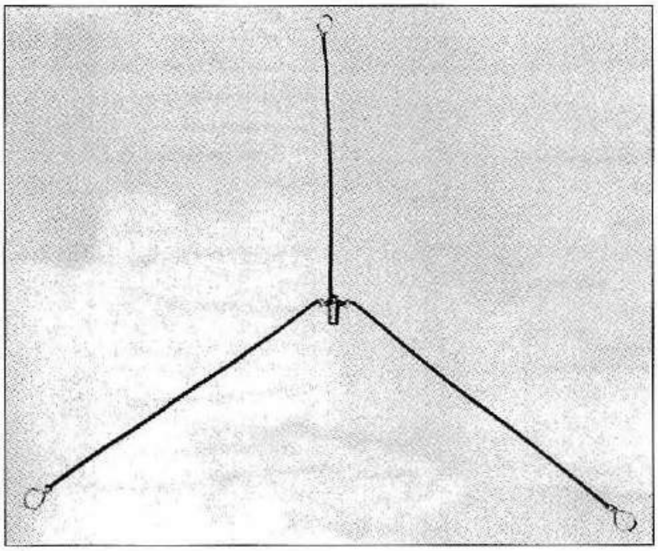


Fig 1-2—This ground-plane antenna can be mounted in a number of different ways.

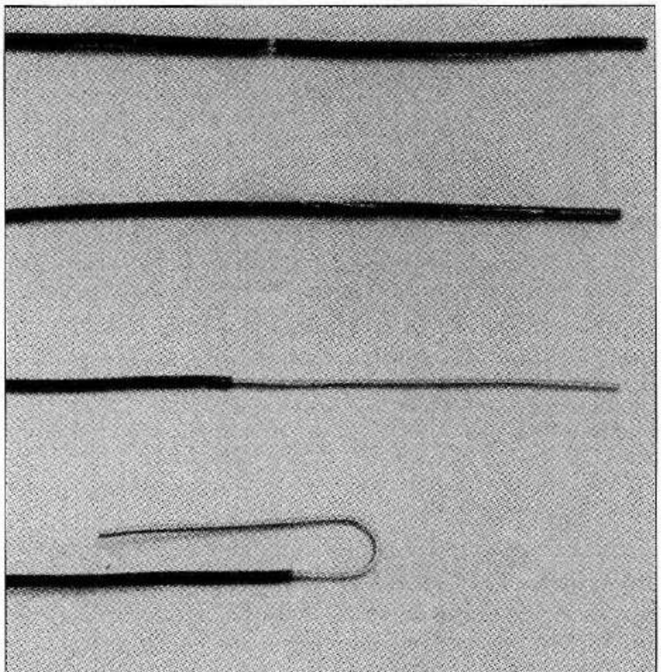


Fig 1-3—Making loops on the antenna wire requires that you remove exactly 4 inches of insulation from each. Stripping THHN insulation is easier if you remove its clear plastic jacket first.

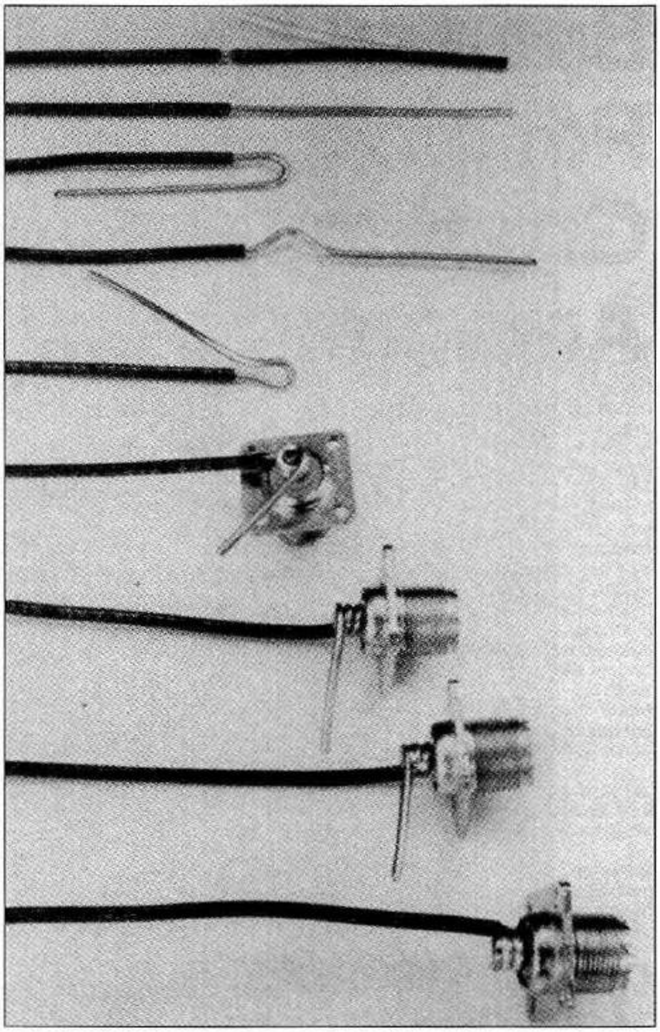


Fig 1-4—Remove exactly 3 inches of insulation to attach the vertical wire to the coax connector center pin. This photo shows an SO-239 (UHF-series) jack; the title photo shows a BNC jack. Use whatever your application requires.

Adjusting the antenna for minimum SWR is worth doing if you have an SWR meter or reflected-power indicator that works at your frequency of interest. Connect the meter inline between your handheld and the antenna. Between short, identified test transmissions—on a clear simplex frequency—to check the SWR, adjust the angle between the lower wires and the vertical wire for minimum SWR (or reflected power). (You can also adjust the antenna by changing the length of its wires, but you shouldn't have to do this to obtain an acceptable SWR.) Before considering the job done, test the antenna in the clear to be sure your adjustments still play. (Nearby objects can detune an antenna.)

Plug and Play

As you use the groundplane, keep in mind that its coax connector's center pin wasn't made to bear weight and may break if stressed too much. Barring that, your groundplane should require no maintenance at all.

There you go: You may not have built a monument to radio science, but you've home-constructed a portable antenna that'll get much more mileage from your handheld than its stock rubber ducky. Who said useful ham gear has to be hard or expensive to build?

Gain and Patterns

Q What is gain?

I am a new ham, so I don't know much about antennas. You will have to start from the beginning with me. Some of the antennas you described mentioned gain. Would gain make an antenna louder? That sounds like it would always be better.

A Yes, gain will make an antenna louder, but gain is not a free ride. Gain always implies that the antenna will produce a stronger signal in one direction, but less signal in others. Some antennas, like those Yagi antennas that most people envision when they think of ham antennas, can be rotated, thus giving gain in any desired direction. Other antennas give gain by directing energy toward the horizon in all directions (omnidirectional gain), while others give gain in a particular direction, but can't be rotated. While gain may be good, it often comes with a price either in antenna complexity or in lack of flexibility.

Gain can be visualized easily. Blow up a balloon, as though you were doing a demonstration before an audience. Note that it is roughly circular in shape. This is the radiation pattern from what is called an *isotropic radiator*—an imaginary antenna that radiates equally well in all directions. See **Fig 1-5A**. Now, squeeze the balloon in the center. The balloon bulges out in two directions. This is like the pattern from a dipole antenna (much more about the dipole later). It bulges more in some directions, and less in others—it has gain, in other words. This is shown in Fig 1-5B.

If you squeeze the balloon on one end, it bulges in one direction only. It is like a beam, such as a Yagi or other directional antenna. See Fig 1-5C. Another analogy for gain is found in a flashlight. It creates a strong light in one direction, and almost no light in other directions. See **Fig 1-6**.

There are a number of different ways to get gain. Gain can either be referenced to an isotropic radiator or to a half-wave dipole in free space. Antenna gain is usually expressed in dB, either dBi relative to isotropic, or dBd relative to a half-wave dipole. A half-wave dipole in free space has about 2.15 dBi gain. This means that gain in dBi will be 2.15 dB higher than gain expressed in dBd. (So a gain of 3 dBd would be a gain if 5.15 dBi—both say the same thing.)

As an interesting aside, anything that concentrates energy in one direction gives gain. This means that putting an antenna over ground can give gain, too! Ground is a pretty good conductor, so a signal that is sent downward from the antenna toward ground will be reflected skyward, adding up in phase with the direct signals from the antenna at some angles. This results in gain—up to 6 dB over perfect ground, and typically 4 dB over average ground. This is shown in **Fig 1-7**.

This means that a half-wave dipole that has 0 dBd gain in free space could have as much as 6 dBd gain when mounted

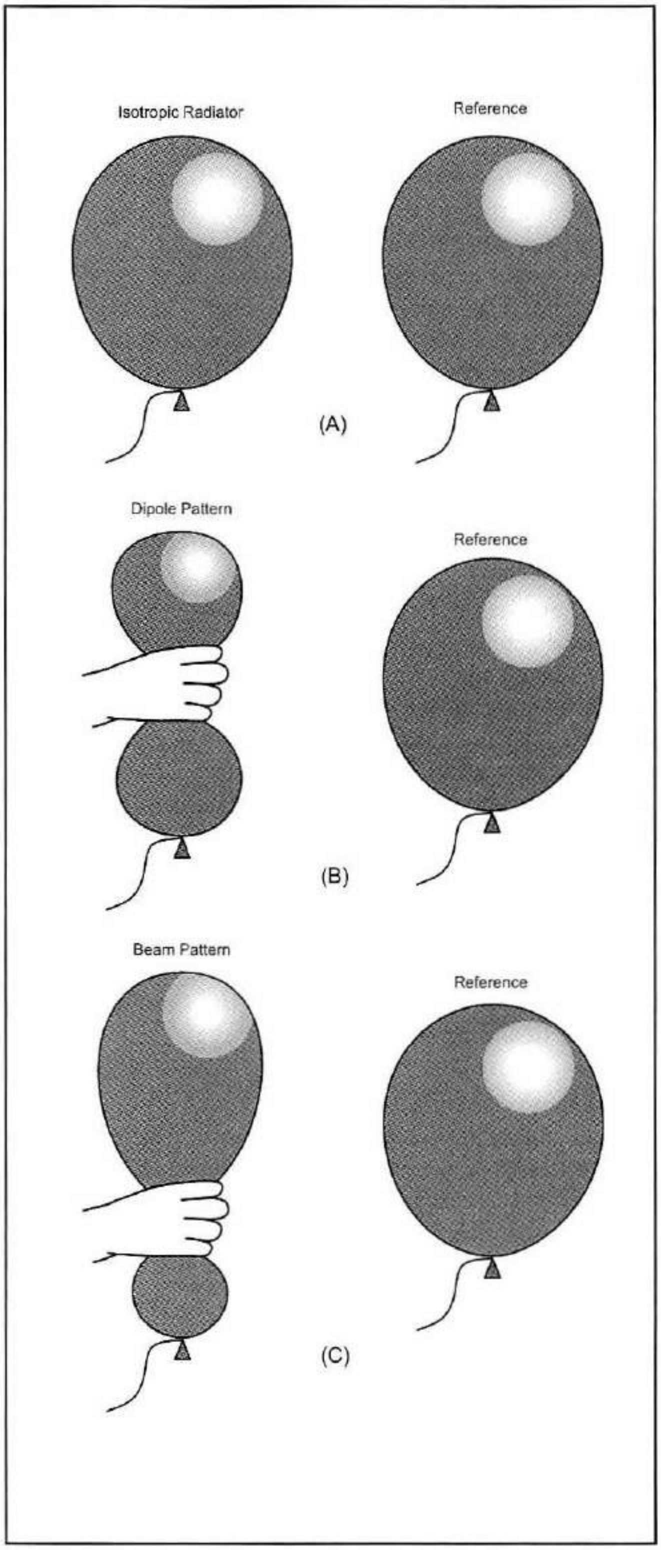


Fig 1-5—Demonstrating antenna pattern gain with balloons. Take a balloon, blow it up so that it is roughly circular in shape and then declare that this is a radiation pattern from an isotropic radiator. Next, blow up another balloon to the same size and shape and tell the audience that this will be the "reference" antenna (A). Then, squeeze the first balloon in the middle to form a sort of figure-8 shape and declare that this is a dipole and compare the maximum size to that of the "reference" antenna (B). The dipole can be seen to have some "gain" over the reference isotropic. Next, squeeze the end of the first balloon to come up with a sausage-like shape to demonstrate the sort of pattern a beam antenna creates (C).

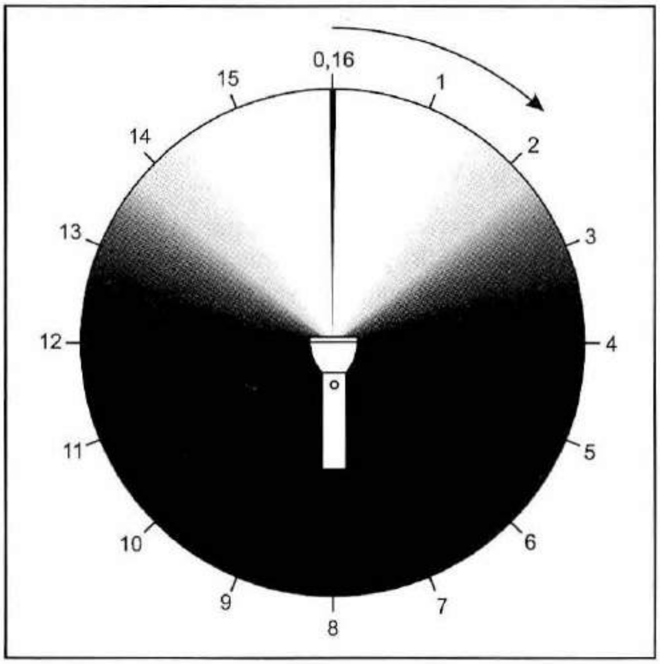


Fig 1-6—The beam from a flashlight is concentrated in one direction, at the expense of other directions. Again, this demonstrates gain.

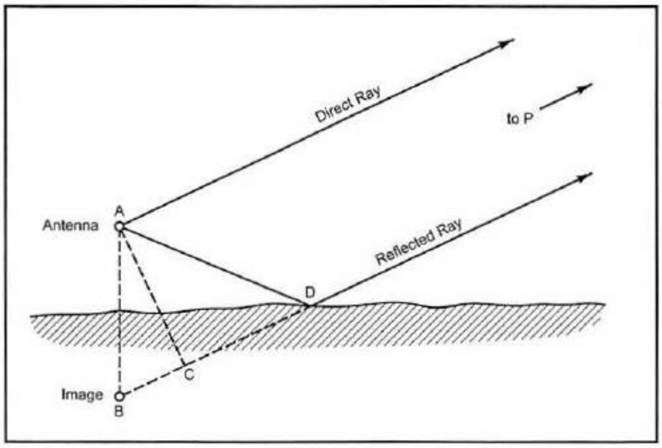


Fig 1-7—At any distant point, the strength of the signal will be the result of the vector sum of the direct ray from the antenna and the ray reflected from earth ground.

over ground. It is hard to imagine that a dipole has gain over a dipole, but because the term dBd references a half-wave dipole *in free space,* that does indeed occur. Many of your antenna choices will be determined by both the antenna gain and by its vertical radiation pattern.

Q Could you explain in more detail how decibels are used for gain comparisons?

A I will presume that you are somewhat familiar with the decibel. If not, at least a few numbers will put it into perspective. Decibel is a term used to compare two power or voltage levels. The formulas are:

$dB = 10 \times \log (P1/P2)$, where P1 and P2 are two power levels

It can also be used to compare voltages, if the voltages are at the same impedance. The formula for this is: $dB = 20 \times \log (V1/V2)$, where V1 and V2 are the two voltage levels. If the impedances are not equal, you can use the formula:

$$dB = 10 \times \log ((V1^2/R)/(V2^2/R)).$$

A beam can have considerable gain. Typical HF Yagi beams can have 8 dBi gain or more; a large VHF or UHF beam can have 20 dBi gain, or even more. Some easy numbers to remember are:

1 dBi = 1.25 × power
2 dBi = 1.6 × power
3 dBi = 2 × power
10 dBi = 10 × power

So, a 20 dBi gain antenna would have 10 × 10, or 100 × the power gain of an isotropic radiator. One watt fed into that antenna would be as loud as 100 W fed into an isotropic source, but only in the direction the antenna is beaming.

Decibels also work in the other direction, too. An antenna with –3 dBi gain actually has a loss of 3 dB; it will lose half of the power applied to it. An antenna that is –10 dBi is operating at 10% efficiency; one that is –20 dBi is 1% efficient, etc. That –20 dBi gain antenna with 1 W fed into it would sound as loud as an isotropic antenna being fed with 10 milliwatts.

Most H-Ts have antennas that are not very efficient. A gain of –10 dBi (10% efficient) would be about typical. This can work very well if you are near a repeater, but if you are right at the edge of a repeater's range, or operating simplex over a few miles, this will not give a very good signal; it will sound scratchy into the repeater.

As mentioned above, another reference point is dBd, referring the gain to a half-wave dipole in free space. The half-wave dipole in free space has a gain of 2.15 dBi, so gain expressed in dBd is always 2.15 dB less than gain expressed in dBi. Don't worry, the gain of the antenna is the same in both cases, only the reference has changed. If you want to compare an antenna whose gain is in dBd to one whose gain is in dBi, add 2.15 to the gain of the antenna in dBd and you now have dBi and can compare the antennas.

Not to make it too complicated, but you should know that most antenna gain figures tell you what the antenna would be if it were in free space—infinitely far away from the earth. In the real world, the ground affects the antenna performance by reflecting signals upward. This actually adds up to about 4 dB to the gain of an antenna. So a half-wave dipole over ground can actually have about 4 dBd of gain! Slick, eh? The half-wave dipole over ground has 4 dB gain over a half-wave dipole in free space.

For more info on gain, see **www.arrl.org/tis/info/antgain.html**. For info on antenna ground, see **www.arrl.org/tis/info/antgrnd.html** and for info on antenna theory, see **www.arrl.org/tis/info/antheory.html**.

Q Why should I care about the vertical radiation pattern? Isn't gain just a compass-direction thing?

A Not at all. To be useable for any particular communication, gain needs to be directed toward the distant radio station. Of course, the gain needs to be pointed at the radio station, but it also needs to be at the correct vertical angle to get to that station, either by being directed toward the horizon for VHF signals (and local HF communication) or skyward, toward the ionosphere for HF long-distance propagation. On HF, the angle that is needed can vary over quite a range, depending on the frequency, the distance involved and the state of the ionosphere. In very general terms, for close-in communication, you need to select an antenna that directs energy upward at relatively high angles. For DX communication, you generally need low angles. This is covered in more detail in the Propagation section of *The ARRL Antenna Book*.

Q Do different antennas have different elevation patterns?

A They sure do. In general terms, most vertically polarized antennas radiate energy at low angles, good for DX communication. Vertical antennas are usually omnidirectional, radiating energy equally in all directions. **Fig 1-8** shows the radiation pattern you can expect from a quarter-wave vertical. The pattern for a half-wave vertical would be similar, but would show a bit more gain toward the horizon. If a vertical antenna is over a very good ground, it can be an excellent DX antenna. If over poor ground, it may seem more like a dummy load. The Vertical Antenna section of this chapter answers some common questions about verticals.

Q Do horizontal antennas have the same pattern as vertical antennas?

A No, they don't. The elevation pattern of a horizontal antenna depends on its height above ground. At low heights, horizontal antennas radiate most of their energy at high angles, good for close-in communications. Most of the time, however, at higher frequencies, the ionosphere will not reflect those high angles back towards earth. The ionosphere will usually support such higher-angle communications on

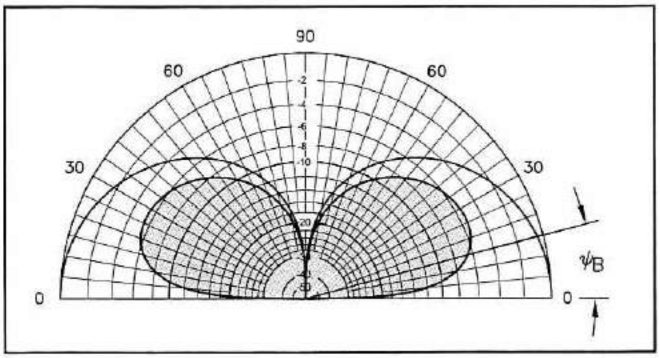


Fig 1-8—Vertical-plane radiation pattern for a 14-MHz ground-mounted quarter-wave vertical antenna. The solid line is the pattern for perfect earth. The shaded pattern shows the pattern over average ground. In this case, the pattern over ground is about 6 dB worse than the pattern over perfect ground.

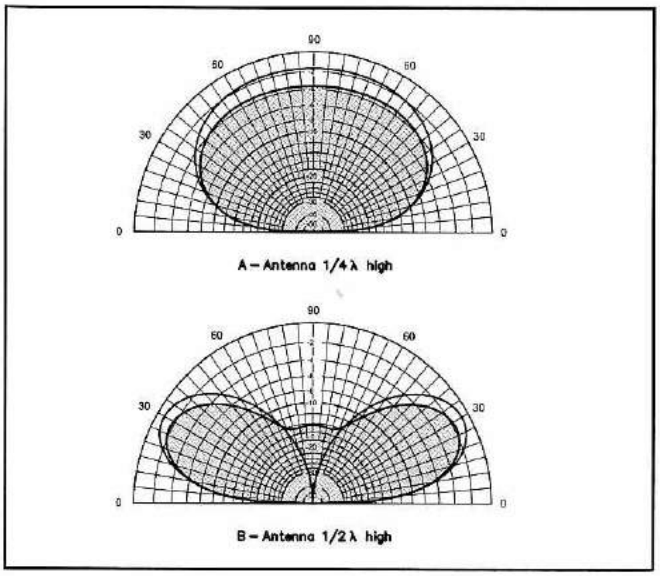


Fig 1-9—At A, the approximate pattern that will be obtained from a half-wave dipole 1/4-wavelenth high over perfect ground (solid curves) and real ground (shaded curves). At B, the same dipole at a height of 1/2 wavelength.

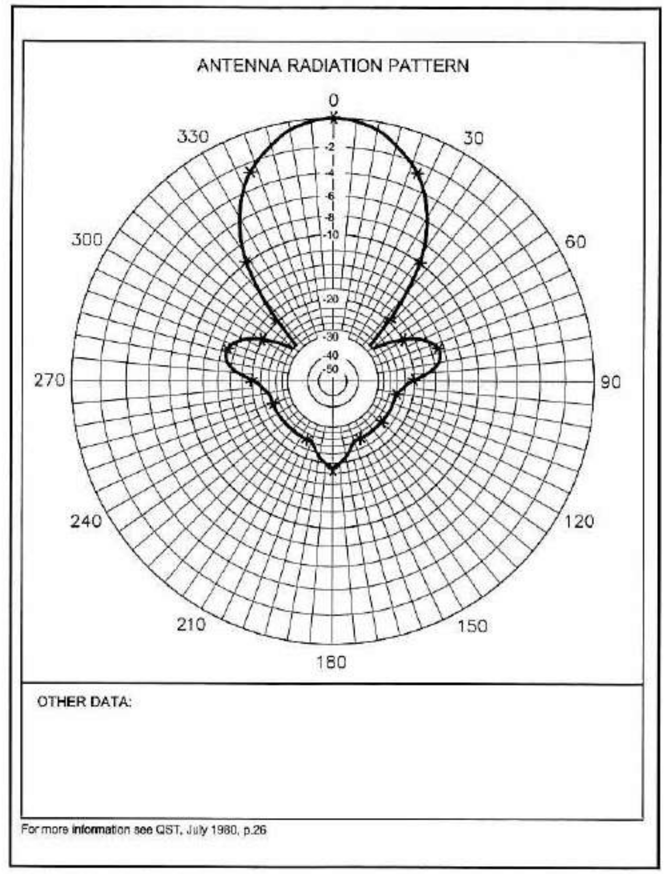


Fig 1-10—A sample radiation plot of the measured response for a typical Yagi antenna. Notice how the RF appears to be focused primarily forward.

the lower part of HF, especially during the daytime. See **Fig 1-9A**. So a horizontally polarized antenna up 1/4-wavelength may be a good 40-meter antenna for daytime work out to a couple of hundred miles, while horizontal antennas that are up a half-wavelength or more are generally good for DX communications, on both lower and higher HF frequencies. See Fig 1-9B. It can be difficult, however, to get an antenna up that high.

Q How do you measure the radiation pattern of an antenna?

A Of all antenna measurements, the radiation pattern is probably the most difficult and demanding. The information is very useful, however, in determining if an antenna is functioning as intended (if a beam, for example, is focusing the RF energy as well as predicted). See **Fig 1-10**.

Any antenna radiates to some degree in all directions. Therefore, the radiation pattern of an antenna is a three-dimensional representation of phase, magnitude and polarization. In general, and in practical cases for Amateur Radio applications, the polarization is well defined and only the magnitude of radiation is important. In many cases the radiation in one particular plane is of greatest interest: the plane corresponding to that of the Earth's surface, regardless of polarization.

Because of the nature of an antenna test range setup, measurement of a radiation pattern can be successfully made only in a plane nearly parallel to the Earth's surface. With beam antennas it is usually sufficient to take two radiation pattern measurements, one in the polarization plane and one at right angles to the plane of the polarization. These radiation patterns are referred to as the E and H-plane patterns respectively. The E plane, meaning parallel to the electric field, which is the polarization plane, and the H plane, meaning parallel to the magnetic field. The magnetic and electric fields are always perpendicular to each other in a plane wave as it propagates through space.

Most hams do not have the equipment to make accurate radiation pattern measurements. You must be able to rotate the antenna in the azimuth plane (horizontally) with a fair degree of accuracy. You also need a signal-strength meter calibrated over at least a 20-dB dynamic range with a readout resolution of at least 2 dB.

Q What is wavelength? I remember memorizing some material for my tests that related frequency to meters. The 40 meter band, for example, is 7.0-7.3 MHz. Is that wavelength?

A Electromagnetic or radio waves can be visualized as waves in water. If you put your hand in the water and move it very fast, small ripples will move out from your hand in all directions. If you move your hand more slowly, the ripples move just as fast, but are spaced farther apart. The distance between the peaks (or valleys) of the ripples is the wavelength of the waves you are creating, and this wavelength is related to the speed the wave is traveling and how fast you are wiggling your hand. The rate could be expressed in wiggles per second, thus expressing it as a frequency.

The hand being used to generate ripples in electromagnetic waves is usually a transmitter. The transmitter is generating an electrical ac signal, at a fast enough rate to be called radio frequency (RF). Rather than expressing it as wiggles per second, the transmitter rate is expressed in cycles per second. The unit for cycles per second is Hertz, abbreviated Hz. This RF signal, when applied to an antenna creates an electromagnetic wave.

The actual wavelength of a wave is related to both its frequency and the speed at which a wave moves. The formula for wavelength is:

λ (meters) $\approx 300 \times 10^6$ (meters/sec) / f (Hertz) = 300 / f (MHz)

where λ (meters) is the free-space wavelength in meters.

Expressed in feet, this becomes:

λ (feet) = 393.6/f (MHz)

So, to try this for a few frequencies in the ham bands, you end up with the following. In common parlance, amateurs round these wavelength off to the nearest convenient number.

3.5 MHz = 85.7 meters
4.0 MHz = 75 meters
7.0 MHz = 42.9 meters
10.1 MHz = 29. 7 meters
14.0 MHz = 21.4 meters
144 MHz = 2.1 meters

The frequency of a particular signal can be expressed either as a frequency, as in 14.0 MHz or as a wavelength. Either one says the same thing. You probably notice that the wavelength numbers are pretty close to what hams call 80 meter band, the 75 meter band, the 40 meter band, the 30 meter band, the 20 meter band and the 2 meter band. Although the exact wavelength for the 3.5 MHz signal is 85.7 meters, hams have rounded these bands off to a convenient number and use those rounded numbers in common reference to the bands.

You will think of that wavelength relationship when you think about antenna size—a half-wave dipole (neglecting factors that make a real dipole a little bit shorter than its electrical length) is, well, a half-wavelength long. So an 80-meter band half-wave dipole is about 40 meters long. On 40 meters, an antenna that is $^1/_2$-wavelength in the air will be 69.3 feet in the air. Many hams can get an antenna up this high. But it would be a lot harder to get a 1.8 MHz antenna a half-wavelength in the air!

More About Dipoles

Q I'm about to string up an outdoor dipole for the 40-meter band. The hard part so far is finding a place to put it. Any tips?

A Just remember that your antenna should be as high and as far away from surrounding structures as possible. Never put an antenna around or even near power lines! Your dipole will require one support at each of its ends (perhaps trees, poles or even house or garage eaves), so survey your potential antenna site with this in mind.

If you find space is so limited that you can't put up a straight-line dipole, don't give up. You can bend the ends of the dipole and still make plenty of contacts. Some hams have been known to become very frustrated when they cannot put up a 135-foot long dipole that looks like it came out of an engineering design manual. For example, some dipoles are installed very close to the ground and their radiation patterns do not resemble "textbook" patterns in the least. Who cares? As long as you are able to talk to other hams, that's all that matters. Do the best you can with what you have.

Q In the case of sloping dipole antennas, I've always heard that the lower leg of the dipole must be connected to the shield of your coaxial cable. But if you're using a balun, there's no way to know which leg is connected to ground. What's the solution?

A The notion that the lower leg of a sloping dipole must be connected to the shield of a coaxial cable is a myth. When it comes to sloping dipoles, it doesn't matter which leg is connected to the coax shield.

Keeping the negative side down seems to make sense at first. After all, the shield is grounded and you'd want the grounded leg of the antenna to be closest to the Earth. But then you realize that RF signals are just high-frequency ac waves. They're constantly switching polarity from negative to positive and vice versa. So, the ground side of the sloping dipole is only negative 50% of the time. The same is true for the so-called hot side; it's only hot 50% of the time.

Putting a balun in the line doesn't change this scenario in terms of the sloping dipole. It still doesn't matter which end is closest to the Earth.

Q What is an inverted-V antenna?

A Most half-wave dipoles are mounted horizontally, although they could be mounted vertically, or even at an angle. However, to have a dipole be straight generally requires two supports. It is also possible to use a single support and mount the center of the antenna on that support and allow the ends to slope toward ground. This type of antenna looks like an upside-down V, so it is commonly called an inverted V antenna. The same principle can be use to position an antenna in an upside-down L configuration. Not surprisingly, this antenna would be called and inverted L. See **Fig 1-11.**

Q Which antenna works best, an inverted V or a dipole?

A This is a question that hams have been discussing for decades. You'll hear strong opinions on both sides of the argument. We won't attempt to state the all-time correct answer, but will let the computer take a crack at it.

Running a *NEC-4* analysis of an 80-meter flat dipole at

60 feet versus an 80-meter inverted V with the apex at 60 feet and the ends at 10 feet (ground was assumed to be "average"), here is what we found:

80-meter dipole, feed point: 72.9 Ω, gain 4.14 dBi at 30° elevation angle, 6.71 dBi at 90°.

80-meter inverted V, feed point: 41.2 Ω, gain 0.41 dBi at 30° elevation angle, 4.21 dBi at 90°.

The inverted V was more omnidirectional at 30°; the dipole showed a more typical dipole pattern, with –8 dB nulls off the ends at that angle. If I wanted maximum gain in the direction perpendicular to the antenna, I would select the dipole, but if I wanted best coverage in all directions, I would select the inverted V.

Q What is a cage dipole antenna and what advantage does it offer compared to a standard single-wire dipole?

A A cage dipole is basically an attempt to achieve a broader SWR bandwidth by using a thicker radiator. Building a dipole out of, say, a large-diameter aluminum tube isn't very practical, but you can create almost the same thing, electrically speaking, by using a number of individual wires properly spaced to create a antenna that looks like a round birdcage (see **Fig 1-12**). That's the principle behind the cage dipole. A typical HF cage dipole can exhibit a 2:1 SWR frequency range almost 2 times broader than a single-wire dipole (see **Fig 1-13**). There are other means of creating an electrically thick antenna. The bow tie, for example, makes use of the same principle.

Q As an apartment dweller I find it difficult to put up an HF antenna. I've been told that I should look into a small broadband antenna. I'm not sure what this means.

A The term *broadband* refers to the fact that the antenna can provide a low SWR (less than 2:1) over a relatively broad range of frequencies. Many modern transceivers begin reducing their output power when the SWR rises above 2:1, so having an antenna that can offer a low SWR across a large portion of a band is convenient. The problem with designing a broadband antenna is that there is always a trade-off between broadbandedness and efficiency.

Unfortunately there is no ultimate antenna for apartment dwellers. You could probably design and build a small an-

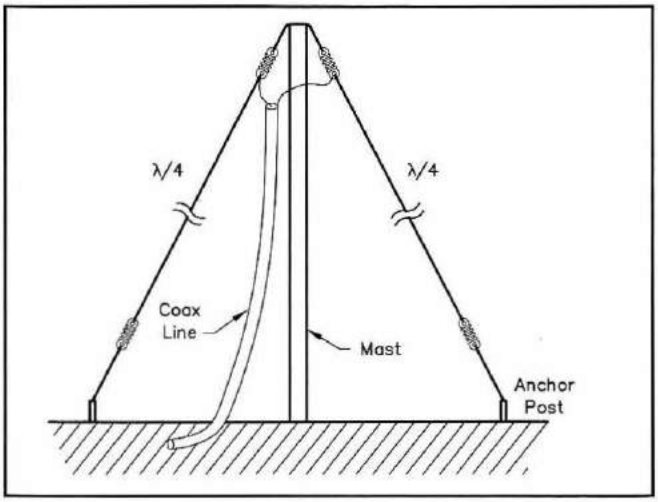


Fig 1-11—This antenna is shaped like an upside down V.

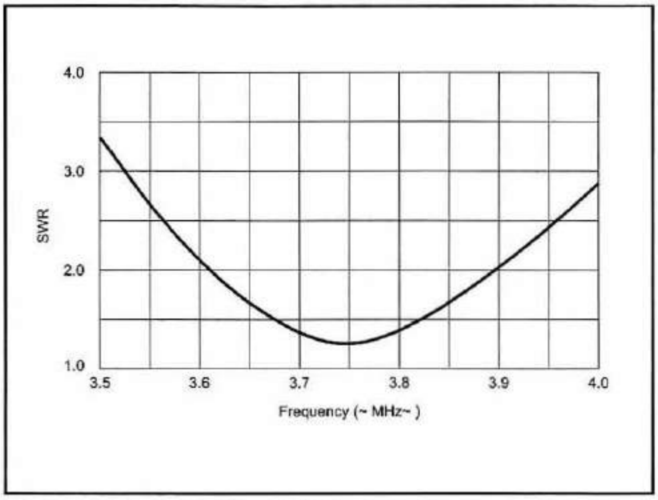


Fig 1-13—The theoretical SWR versus frequency response on 75 meters for a cage dipole that's 122 feet 6 inches long with a spreader diameter of 6 inches, fed with 50-Ω coax.

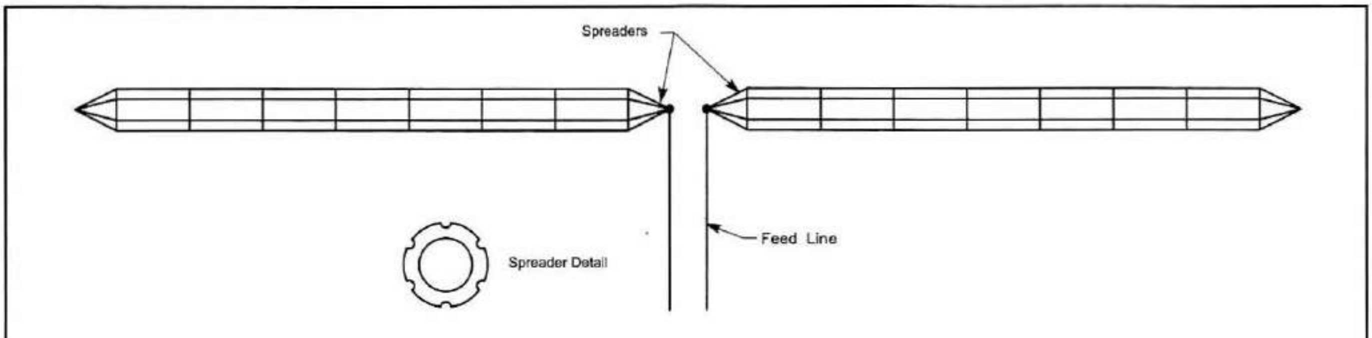


Fig 1-12—A cage dipole resembles a round birdcage. Circular spreaders can be used to separate the individual wires. The spacing between wires should be 0.02-wavelength or less.

tenna that would present a terrific SWR bandwidth, but you wouldn't radiate much RF. After all, a dummy load has an extraordinary SWR bandwidth, but most of the RF power applied to it is wasted as heat.

You may want to consider a compact, narrow-bandwidth design such as the portable HF antenna described in the Feb 1999 *QST* in the article "A Briefcase-Portable HF/VHF Antenna," by Robert H. Johns, W3JIP.

The G5RV Antenna

Q I've heard a lot about a legendary HF antenna called the G5RV. What is it?

A While many folks use a G5RV as a general-purpose multiband dipole antenna, most don't realize that it's a design specifically optimized for operation on 20 meters (as a 3/2-wavelength center-fed long wire). Although it permits multiband operation with an antenna tuner, there is a performance compromise on the lower HF bands when compared to a full-size dipole on 80 meters. There is a lot of myth and misinformation surrounding the G5RV because of the many commercial versions available. The original design by Louis Varney, G5RV, is optimized for gain on 20 meters and is a performance compromise compared to a full-size dipole for 80 meters on all the bands other than 20 meters. The original antenna does not use a balun at all. A complete treatise on this antenna, written by Louis Varney, G5RV, himself, appears in the *ARRL Antenna Compendium, Volume 1* and on the ARRL TIS web page.

The physical dimensions of the full-size G5RV are:
Flattop: 102 feet, center fed
Matching section: 34 feet of open wire or ladder line
Balun: 1:1, choke or current type
Coax: any length

In later experiments, G5RV determined that the balun between the ladder-line and the coax was not really necessary (*ARRL Antenna Compendium Volume 1*, p 89, under "The Feeder"). The various commercial versions of the antenna usually include a 4:1 balun. However, if you are not interested in optimum 20 meter performance, you would be better off with a simple ladder-line-fed multiband dipole, as described in the Dec 93 *QST* article, "The Lure of the Ladder Line" and Mar 94 *QST*, "On Center-Fed Multiband Dipoles" (which includes a discussion of the G5RV).

Q I put a G5RV antenna up about 40 feet (at the center) in the trees, removing tree limbs and branches so the wire would not touch anything. The ends are facing northwest and southeast. Should the ends be facing north and south so I would be able to communicate better with Europe, Africa, Japan and Australia? The classic dipole antenna patterns show the strongest radiation is broadside to the antenna.

A The G5RV antenna is electrically similar to a dipole folded up a little in the center on the lower HF bands. On the upper HF bands it acts as a dipole of multiple wavelengths. Bone up on this theory with the appropriate sections from the *The ARRL Handbook* and the *The ARRL Antenna Book*. See **Fig 1-14**.

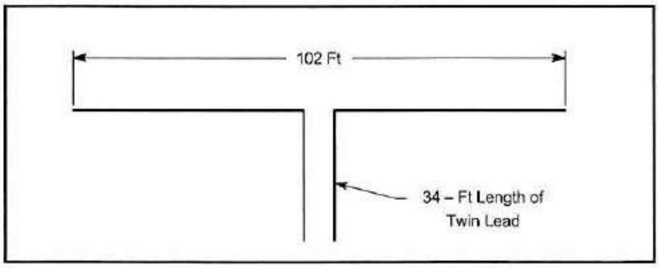


Fig 1-14—The G5RV multiband antenna covers 3.5 through 30 MHz. Although many amateurs claim it may be fed directly with 50-Ω coax on several bands, Louis Varney, its originator, recommends the use of a matching network on bands other than 20 meters.

You'll soon discover that the G5RV's RF pattern approaches the classic dipole donut pattern only where it is close to ½-wavelength long. The beauty of the G5RV isn't related to its radiation pattern. It has more to do with the fact that the antenna allows you to radiate well over a wide portion of the amateur HF bands. Of course, this convenience comes at the expense of the kind of performance that you would expect to get on any *one* band with single-band dipole properly cut and mounted. But even the predicted pattern of a dipole antenna would only be approached in reality by a dipole installed about ½ wavelength over perfect ground!

Your G5RV's directional pattern should be of relatively minor concern to you because of the factors I've cited above. Any performance you get right now in the direction of Australia and Japan is proof to you that it works to one degree or another. If you still find yourself losing sleep over loss in a particular direction on HF, think of putting up a beam antenna on a rotator, or another type of directional antenna.

HORIZONTAL VS VERTICAL ANTENNNAS

Q So, which is better—a horizontal antenna or a vertical antenna?

A I am afraid I have to give you an, "it depends" answer. What are your communications objectives? On 40 meters, for daytime communication, a high horizontal antenna or a vertical antenna might not be your best choice. A low horizontal antenna may work much better! For DX work, though, you would probably be disappointed in that same antenna.

Q I don't have nearly enough room. About all I think I can manage is a vertical antenna. You said earlier that they don't work well over poor ground, though. Does this mean I should not use one?

A Some hams mistakenly believe that only the *best* antenna will radiate a worthwhile signal. The "best" antenna for many will be a 5-element monoband Yagi at 200 feet. How many hams can put up that antenna? In reality, if that vertical is the best antenna you can put up in the space you have, it *is* your best antenna. If it were operating at 25% efficiency, you might think it a pretty poor antenna, but if you are running 100 watts into a 25% efficiency antenna, that is like running 25 W into a perfect antenna, and QRPers use less power than that to make contacts all over the world. With that antenna, you will make a lot more contacts than you will with no antenna at all, and that is what really counts. With antennas, the advice is to do the best you can and make the best of the results. Some hams have to make do with indoor antennas, and they make plenty of contacts when the band is open.

Q I feel better now; I was afraid that I wouldn't get out at all. Now, on a somewhat related note, I do a lot of QRP backpacking and I want to bring along an antenna for 40 meters. I bought a 33-foot DK9SQ fiberglass mast (available from Kanga US, see www.bright.net/~kanga/kanga/). I have a choice of whether I want to put up a 33-foot vertical, with a few radials for ground, or a horizontal dipole at about 30 feet. Which is best?

A In this case, there *is* an answer. I can tell you right away that technically, on 40 meters, there is one clear choice between the two antennas you are recommending—the horizontal half-wave dipole up 30 feet.

To determine this, I used the *EZNEC* program, written by Roy Lewallan, W7EL (**www.eznec.com/**). This program lets me enter the coordinates for various conductors and then predict antenna pattern, gain and feed-point impedance, among other things.

I ran the model for both a horizontal half-wave dipole up 30 feet and a quarter-wave vertical antenna with four radials, both over "average ground." Because you plan to use this antenna backpacking and camping, I put the radials about an inch above ground. You can see the result in **Fig 1-15**.

In this figure, the antenna whose pattern shows the most energy directed upward is the horizontal dipole; the one whose energy is directed toward the horizon is the vertical. It is pretty clear from these compared patterns that at all angles, the dipole has a distinct gain advantage over the vertical, sometimes by as much as 10 dB! That DK9SQ mast will get either antenna up for you, so if you have the room to spread out, a 40 meter dipole up 30 feet will buy you a lot.

Even over "very good" ground, the dipole has the advantage. Fig 1-15 shows the pattern of the two antennas over very good ground, such as you may find near a body of freshwater or very damp loam soil. The vertical does have a slight advantage at very low angles, but these are not apt to be the angles that most QRP operation on 40 meters will use, so for most of your "stateside" contacts on 40 meters, the dipole has the edge.

Even if you can't get that antenna up in the air very high, it will still have a gain advantage over the vertical. The patterns in **Fig 1-16** show the performance of a 40-meter dipole at 10 feet, 20 feet and 30 feet in height, along with the vertical, over average ground.

Now, this is not a blanket condemnation of vertical antennas. With a better ground system than you intend on using, they do work better than these graphs would indicate. But for portable use, especially for QRP, you want to get as much antenna as practical. Antenna modeling programs sure do help give answers, don't they? And they are pretty fast, once you know the ropes; we did all of this work in about a half hour, including cutting and pasting to the jpg file editor and saving them on our web server.

Of course, there are other considerations. In heavy brush or trees, that vertical will go up a LOT easier than the dipole, an if you intend on communicating over a path that you expect will give you a good signal-to-noise ratio, you may have great results with the vertical. QRPers and backpackers have used them successfully for many an enjoyable contact. As in all things in life, you will have to weigh the different factors and come up with a solution that is "best" for a particular circumstance and a particular QRP-to-the-field adventure. This answer is just a guideline to your doing that.

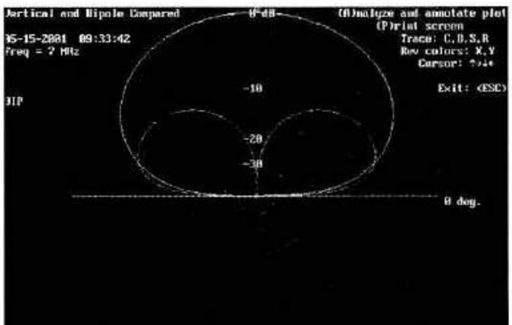


Fig 1-15—This shows the vertical elevation pattern for a vertical quarter-wave antenna with 4 radials over a surface of average ground, compared with a half-wave dipole up 30 feet.

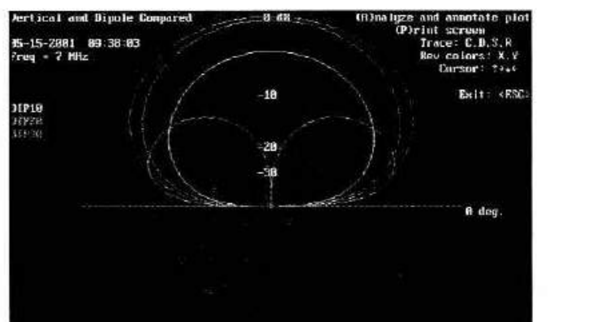


Fig 1-16—This drawing shows how the vertical compares to horizontal dipoles at different heights.

Q **I have two HF antennas: A vertical mounted on a fence post and a horizontal wire dipole. I notice that I hear a much higher noise level on the vertical. Why?**

A Two possibilities come to mind. First, the vertical antenna might be physically closer to the noise source. (You don't mention how far the antennas are from your station or other buildings.) Second, vertical antennas tend to pick up more noise because these types of signals are usually *vertically* polarized. Your dipole antenna, on the other hand, is *horizontally* polarized. As a result, it would not pick up noise quite as well as your vertical.

VERTICAL ANTENNAS

Q **I have recently purchased a dual-band 2 meter/70 cm radio. I want to put up an omnidirectional antenna for both bands. I have seen dual-band verticals and discones advertised. Would a dual-band vertical have advantages over a discone, or vice versa?**

A Most VHF/UHF discones are designed to be multiband antennas, often providing coverage from 28 MHz through 1.2 GHz. If you're an apartment dweller and want to avoid a rooftop antenna farm, a discone is probably a decent choice. One antenna will give you access to several bands, although the performance is usually mediocre.

On the other hand, if you only care about operating on 2 meters and 70 centimeters for the time being, the dual-band antenna would be a superior investment. Chances are you'll enjoy better performance from a properly designed VHF/UHF dual-bander than you would from a multiband discone. See **Fig 1-17**.

Q **I'm familiar with ground-plane antennas for VHF and UHF. Can they be used on HF?**

A Nothing prevents you from creating a ground-plane vertical antenna for the HF bands, assuming you have supports of sufficient height. A number of years ago Chuck Hutchinson, K8CH, ARRL Senior Assistant Technical Editor, described the HF ground-plane antenna shown in **Fig 1-18**.

The antenna is very simple. Two radial wires are soldered to the coax braid at the feed point. Another wire forms the vertical radiator, which you can attach to a tree limb or other convenient support. (You'll need to trim the vertical radiator for the lowest SWR.) The radials should be mounted high enough that people will not come in contact with them.

Each wire is $^1/_4$ wavelength, so this tends to limit practical use of the antenna design to 40 meters and up. After all, a 40-meter version would have a vertical radiator more than 33 feet in length. However, wire ground-plane antennas are popular with low-band DXers. Some hams have great success with them on 80 and even 160 meters. If you don't have a support that's high enough, just run the vertical radiator as high as you can and bend it horizontal when you run out of room.

Q **I've read descriptions of a $^1/_4$-wavelength HF vertical antenna with above-ground radials for use as a low-band DXing antenna. Could I feed this type of antenna with ladder line and use it just like a $^1/_2$-wavelength dipole? In other words, if it is cut for $^1/_4$-wavelength at 80 meters, can I tune it for use on the higher bands as well? How would it perform?**

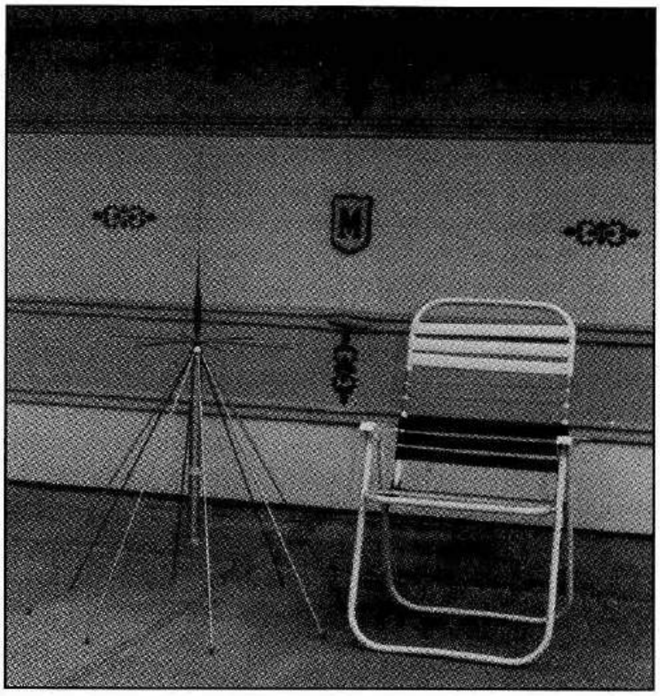


Fig 1-17—A VHF/UHF discone antenna shown beside a patio chair for scale. Photo courtesy of Dave Miller, NZ9E.

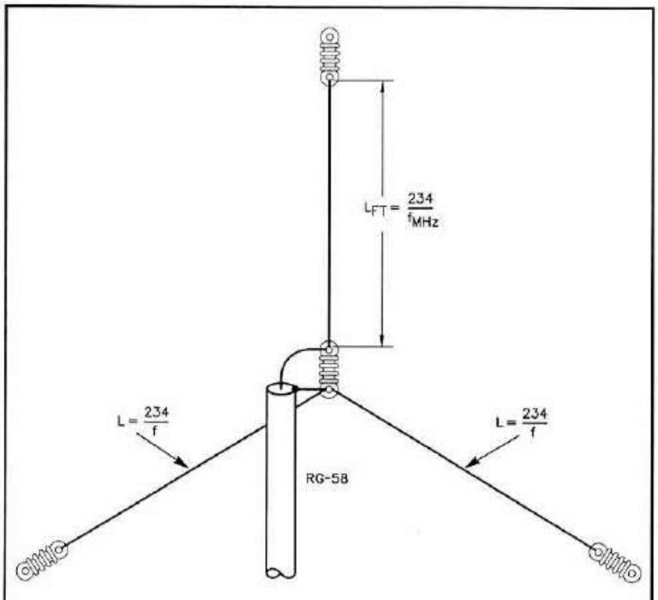


Fig 1-18—Dimensions and construction of the tree-mounted HF ground-plane antenna.

A The ¼-wavelength vertical is exactly that: A quarter wave-length long, with ¼-wavelength long radials or an earth-ground connection, at one frequency. Changing the frequency, by definition, changes the wavelength for a fixed length of wire, so the antenna system will no longer perform as you expect. The real problem in a ground plane installation may be seen when the radials are a half-wave-length or a full-wavelength long at a particular frequency. The radials, together with the earth itself, act like a transmission line, transforming the high impedance at the ends to a high impedance at the feed point. This is not what you want for a vertical, because the ground plane is no longer acting like a ground plane and will definitely not be the equivalent of a half-wavelength dipole!

What can be done to achieve multiband operation with this sort of ground-plane antenna? You can parallel radials of different lengths at the feed point, much as the manufacturers of multiband trap verticals do right now. If you feed the antenna with open-wire line, you should be able to have an efficient system up to about twice the fundamental frequency of the antenna, where the pattern will begin to fall apart because the length of the antenna, in terms of the wavelength, has gone past half-wavelength resonance.

Take a look at the article by Paul Protas, WA5ABR, "A Homebrew Seven-Band Vertical" in *The ARRL Antenna Compendium, Vol 5*, for another solution—paralleling a number of vertical radiators at the feed point.

Q I use a 40/80 meter vertical antenna (a Butternut HF2V) to work the higher bands with the help of an antenna tuner. Ignoring the effects of line losses because of the (presumably) lower SWR at the feed point, would I gain any efficiency by switching to a similarly sized vertical designed for multiband operation? Would the performance of the HF2V on other bands be improved if I added shorter radials cut for the higher frequencies?

A The crux of the problem with your present system is that you *cannot* ignore the effect of line losses when you try to use the HF2V on higher frequencies, where it is not resonant. In other words, the SWR on the higher bands is *not* low. While your antenna tuner in the shack is able to provide a 50-Ω load to your transceiver, there is probably quite a bit of loss in the transmission line between the tuner and the antenna. Remember: The 1:1 SWR you see on your antenna tuner's meter is only present between the tuner and the radio. The higher SWR between the tuner and the antenna, and the resulting loss in the feed line, remains! In addition, there may be considerable loss in the tuner itself since it may be encountering impedances that are difficult to match efficiently.

Let me illustrate, using a model of a simple quarter-wavelength long vertical for 40 meters. I'm going to assume that the ground plane is perfect, so that we have a baseline from which to compare. At 7.1 MHz the feed-point impedance is the theoretical value of 36 Ω and the SWR at the feed point is 1.39:1 for the 50-Ω line. (I'll also assume that the feed line consists of 100 feet of RG-213 coax.) The total loss in this coax at 7.1 MHz is 0.566 dB, computed using the program *TLA* bundled with the 18th edition of *The ARRL Antenna Book* . The coax loss is essentially the matched-line inherent loss if the cable were working directly into a 50-Ω load. There is very little additional loss due to the small SWR at the load.

Now, this very same vertical at 14.1 MHz would be close to a half wavelength long and the feed-point impedance would be very high. The *EZNEC* program by W7EL computes it to be $814 + j\,119\ \Omega$. At this impedance the SWR on the RG-213 would be an impressive 52:1, and the loss in the cable would now be 7.5 dB! The loss in a typical antenna tuner feeding the input of this 100-foot length of coax would be on the order of an additional 0.35 dB. Feeding 1500 W into the tuner would result in only about 247 W radiated by the antenna! Something is going to get hot, mainly the coax.

At 21.1 MHz the situation would be somewhat better since the 40-meter vertical is three quarter wavelengths long and the feed-point impedance would be $63.4 - 58.8\ \Omega$ according to *EZNEC*. This is an SWR of only 2.77:1 and the total loss in 100 feet of RG-8 would amount to only 1.47 dB, according to *TLA*. A typical tuner would lose only a negligible amount more, again because the impedance to be matched is reasonable. In this scenario, the total power delivered to the antenna for 1500 W input is 1057 W. That's a lot better than on 20 meters.

Unfortunately, another little problem rears its head at this point. Because the electrical length of the antenna is long at 21.1 MHz, the radiation pattern has developed lobes pointing up in the air. You're heating the clouds rather than aiming for lower angles that are most useful for DXing on the higher frequencies. This problem will get only worse on 12 and 10 meters where the electrical length is even greater.

So, you can see that having a multiband antenna that is quarter-wavelength resonant in the bands you desire would provide far better performance than trying to force-feed your existing dual-band antenna by using an antenna tuner in the shack. Of course, you could move your antenna tuner to the base of your Butternut. In this position most of the loss would be in the tuner only. But unless you installed an automatic tuner at the base of the antenna, it would be very inconvenient to use. (See "One Stealthy Wire" by Steve Ford, WB8IMY, Oct 1998 *QST*.) And you would still be presented with the problem of energy wasting higher angle lobes due to the electrical length of the antenna.

My recommendation would be to switch to a multiband vertical. Butternut and other manufacturers make such antennas.

Q I have just acquired a used aluminum HF vertical antenna. What is the best way to clean it up for operation?

A You didn't say if your antenna has traps. If so, they should be cleaned with a mild detergent solution. Any stubborn insect residue can be cleaned with common alcohol. Of course, be careful not to get anything inside the traps themselves.

The aluminum portions can be made to look like new with a product called NevrDull. It is available at hardware and home improvement stores, and one can will last many, many years. It's probably the best stuff we've found for polishing metal of any kind. (No, we don't own stock in NevrDull and the company is not a *QST* advertiser!)

Q Eventually I want to put a 3-element Yagi on top of a 90-foot tower. On top of that I was thinking of putting a multi-band vertical. The reason that I want to put the vertical on the same mast is to keep the little munchkins in the neighborhood (kids, deer and moose, just to name a few) from getting too close to the antenna, especially if I happen to be on the air running high power. The instruction manual says to connect the shield of the coax feeding the antenna to earth ground. Is such a plan feasible without compromising performance or would I be better served to put the vertical on the deck and build a fence around it?

A This will probably not work out very well in practice. This type of vertical antenna is designed to work against ground or a ground-plane. Unless the vertical is specifically designed by the manufacturer to operate high above ground (like the Cushcraft antennas) it could be detrimental to the performance of the antenna. You could use quarter-wave radials to make a ground plane antenna, but although a vertical antenna can be an excellent low angle radiator, it is put up high in the air, it radiates much of its energy at high angles, not useful for DX. Some types of verticals are designed to operate without a ground connection, but the vertical would still be high in the air, and radiate energy upward instead of at low angles.

The tower would also become part of your antenna system, with unpredictable results. You would be better to ground mount your vertical and install a nice rock garden or some small bushes and an attractive (plastic or wooden) fence around it.

Q I am using an electrically quarter-wave 4-band trap antenna fed with coax. At the antenna end, the coax is attached to the antenna not by a connector, but by the shield and center conductor to screws. I assume that this is proper, since the antenna does not have an SO-239 connector. The antenna is mounted about three inches above ground with no radials. I have been using this rig for a number of years, but power out on phone is only about 45 W from a 100-W transceiver. Is this type of vertical considered a balanced or an unbalanced antenna? Do I need a balun?

A A balun will not enhance the performance of a vertical antenna fed with coax since they are both unbalanced devices. That type of vertical antenna does, however, need a good ground or radial system to work against. Without the ground, the antenna is *not* a 50-ohm load for your coaxial feed line, so it is operating at a high SWR. Most modern transmitters have circuitry that reduces the power if the SWR is high. This appears to be happening in your case. As a minimum, you need to install a ground rod, such as an 8-ft copper pipe, or install a radial system on the ground. Adding a radial system will have an additional benefit—you'll radiate a stronger signal!

In any case you may have no need for any of these as the numbers you give are nominal for the transmitter. Remember that the meter on your rig is very probably an average reading meter and therefore on phone 45 W is a good reading. In the CW position holding the key down should yield 100 W on the meter; check that.

While you're at it, check your SWR. If it is below 2.5:1 or 3:1 you are okay. If not, the grounding hints above should help.

Q I recently moved to this area and am finally trying to get on the air again. No large antenna system this time. I am seeking your recommendation for the best way to attach a large vertical (a Cushcraft R7000) to a tall brick chimney. Your help would be greatly appreciated.

A Attaching a large antenna to a chimney is risky business and has proven at times to be expensive if the chimney fails. I would advise against it. However, you might want to ask the advice of a building engineer—a local construction or chimney company or your town building inspector. An alternative is to mount the antenna, using the proper brackets, to the side of the house near the peak.

Q What is a Battle Creek Special antenna?

A The Battle Creek Special is a transportable vertical antenna for low-band DXing. It is a favorite of DXpeditions because it offers excellent performance on 40, 80 and 160 meters, yet it can be broken down into sections and packed into a single 66-lb shipping crate. See **Fig 1-19**.

The Battle Creek Special is a descendant of another design known as the Minooka Special. Charles Dewey, WØCD, of Battle Creek, Michigan, modified the Minooka Special by replacing its loading coil with top-loading wires—one for 80 meters and another for 160 meters. The modified design also incorporates coaxial cable traps for 80 and 40 meters. Although the Battle Creek Special looks somewhat like a vertical antenna, it functions electrically as an inverted L on 80 and 160 meters. Only on 40 meters does it act like a full-size, quarter-wavelength vertical. The antenna is supported by guy wires and employs an extensive network of radials.

Q I worked a fellow on 160 meters recently and he said that he was using a shunt-fed tower. What is that?

A Anything can be made to radiate RF if you feed it properly—including towers. The shunt-feeding system shown in **Fig 1-20** was used by K6SE (ex-W5RTQ) to get his 70-foot crank-up tower to radiate on 75 and 160 meters. The beam at the top of the tower isn't a problem. In fact, it provides some beneficial top loading.

In Fig 1-20 you'll notice two wires running up each side

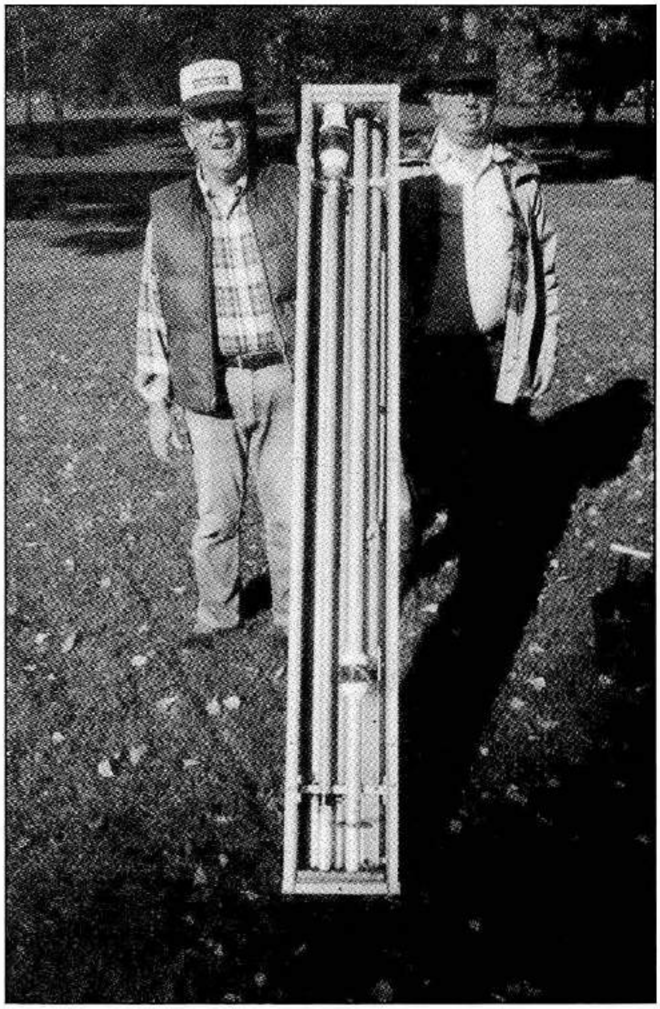


Fig 1-19—W8UVZ (l) and K8GG (r) with a wooden crate containing the Battle Creek Special, a three-band (160, 80 and 40-meter) vertical antenna. The crate is designed to ensure safe transportation to remote parts of the world.

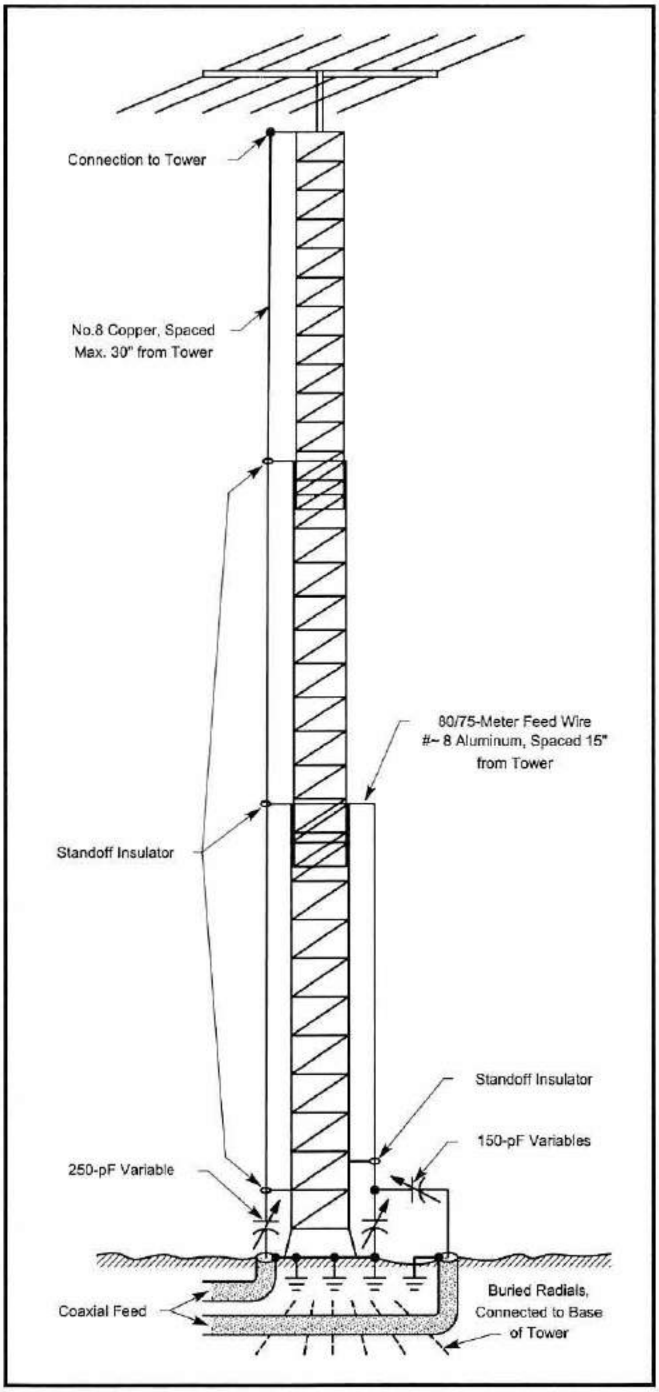


Fig 1-20—The details of the shunt feeding/matching system designed by K6SE and described in ***The ARRL Antenna Book***. The 1.8 MHz feed (left side) connects to the top of the tower through a horizontal arm of 1-inch diameter aluminum tubing. The other arms have standoff insulators at their outer ends. The 80-meter side (right) is similar, connecting to the tower at a point 28 feet above the ground.

of the tower and connected to variable capacitors. This is the actual shunt-feed matching system. You tune the system for resonance by first adjusting the capacitors for the lowest SWR on the desired band, then increasing or decreasing the spacing between the wire and the tower to reduce the SWR further. Shunt feeding a tower in this fashion requires a very good ground system for optimum performance, but the results can be impressive on the low bands for DX work. You'll find more shunt-feeding methods described in *ON4UN's Low-Band DXing*, available from the ARRL.

Q I was wondering if you could give me some input on a good vertical antenna that would cover HF and 6 meters. I'm looking to put up a antenna to use with my new Yaesu FT-920. I would appreciate any input you have to offer. The little antenna I have does OK for 2 meters but does not cover 6 meters.

A On 6 meters, like other VHF bands, FM work is generally done with vertical polarization. That antenna would be just right for 6-meter FM work. If you want to talk locally on SSB or CW, however, your signal may not be very loud because most of the 6-meter weak-signal work is done with horizontal polarization.

Q Is that why vertical antennas aren't recommended for 6-meter sideband work?

A Vertical polarization isn't as much of a problem as you might imagine. It might even be an advantage, if you treat 6 meters as a DX, rather than a local ragchew band. Cross polarization will significantly reduce signal strength of local stations, since most 6-meter stations do run horizontal polarization. However, E and F layer ionospheric propagation does not preserve polarization, so vertical polarization is equally effective as horizontal polarization for working DX stations. It can be an advantage, since excessively loud local signals can cover up weak DX stations. Any technique that reduces the strength of local stations without affecting the DX signals will help pull DX stations out of the noise. The vertical polarization works just fine for working locals on FM, which is vertically polarized by convention on 6 meters.

Q Why can't I use my 2-meter 5/8-wave mag mount as a 6-meter antenna for working DX from my car? It seems to load up just fine. The SWR is only 1.4:1.

A That 5/8 wave 2-meter antenna is just about a quarter-wave on 6 meters. If it tunes up and gives you a good SWR, you can indeed use it on 6 meters. Have fun!

Q How do I build a J-pole antenna?

A A J-pole antenna is essentially a half-wave antenna, fed at the end. The impedance at the end of a half-wave antenna will be very high, perhaps as high as a couple of thousand ohms. The "J" part is a quarter-wavelength transmission line. This mismatched line functions as a transmission-line transformer, changing the impedance at the end of the pole to 50 ohms. Its length and spacing are chosen to give the correct transformation. In most J pole designs, the feed line is tapped up the J at the point where a 50-Ω impedance exists.

The length of the 1/2-wave portion is calculated using the standard 468/F(MHz) formula (same as a dipole), although if there is significant dielectric present near the conductor, its actual physical length will be a bit shorter. The length of the 1/4 wave section is calculated using the free-space wavelength, multiplied by the velocity factor of the section as a transmission line (with twin lead J antennas, this is about 0.85; for copper pipe J antennas, this is about 0.95). You adjust the attachment point to get the best SWR, but to start it should be roughly 0.015 wavelengths from the shorted end of the 1/4-wave stub.

A construction article for a copper pipe J antenna appears in *The ARRL Antenna Compendium, Volume 4* and one for a simple twin lead J antenna appears in Sep 1994 *QST*, with article feedback appearing in Feb 1995 *QST* in "The Doctor is IN" column. Assuming the velocity factor of your 300-Ω twin lead is indeed 0.85, you can build a 146-MHz J-pole in a few hours time. A drawing of this antenna is shown in **Fig 1-21**.

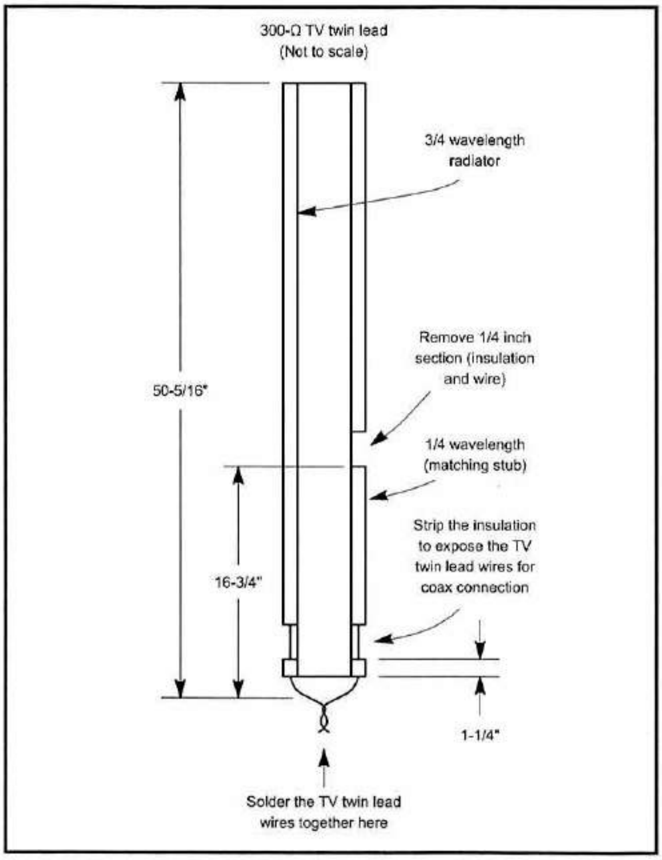


Fig 1-21—This simple J pole antenna can be easily constructed by most beginners. It will significantly outperform a 2-meter rubber duckie antenna.

1. Start with a 5-inch length of twin lead. At one end, strip 1/2-inch of insulation.
2. Twist the exposed leads together and solder them. (This is the bottom of the J.)
3. Measure 17 inches up from the bottom and cut a notch in one side of the twin lead.
4. At a point about 1 1/4 inches from the bottom, carefully remove about 1/4 inch of the insulation from both twin lead conductors (leave the center part center part of the insulation in place).
5. Attach the coax to the exposed conductors. It doesn't matter which side is which.

Because you are feeding a balanced line (twin lead) with an unbalanced line (coax), you need a balun. The best way to make one for a twin-lead J that is fed with coax is to buy a split ferrite bead (for VHF, the ferrite material should be equivalent to Amidon Type 43) and place it around the coax about 13 inches from the antenna's feed point (this is a high current point on the coax). You can use electrical tape to hold it in place. If you don't have a ferrite handy, you can purchase an Amidon 2X-43-251 directly from Amidon.

A PVC-enclosed ladder line J-pole appeared in Jul 1995

QST ("Build a Weatherproof PVC J-Pole Antenna"). Other J pole articles have appeared in *QST*. One was made using small diameter aluminum tubing (Nov 1982, *QST*, p 40), from coax (in an older editions of *The ARRL Antenna Book*) and even one made from soup cans! (Oct 1982, *73 Magazine*). Additionally, ARRL published a couple of 2-meter beam designs that use a J-pole driven element (Nov 1979, *QST*, p 32 and Apr 1987, *QST*, p 57).

The origin of the J configuration is the end-fed Zepp antenna. In fact, the original Zepp, patented in Germany in 1909, was an antenna that hung vertically from the bottom of a (manned) balloon (an upside down J-pole). However, the first use of the letter J to describe the antenna did not appear until 1942 (in *The ARRL Handbook*).

RADIALS FOR VERTICALS

Q Can you explain how radials and counterpoises work? I want to use my Outbacker mobile whip from my home station by putting it outside the window, but I don't have enough room to put the car out the window to act as the ground! What do I do?

A A mobile whip antenna such as one of the Outbacker antennas is called a *vertical monopole*, where the word monopole means literally "one pole." Let's compare a monopole to a dipole, one of the most fundamental types of antenna. The word dipole means "two poles." It has two terminals, to which the two conductors of a feed line are attached. The feed line can be either coax or open-wire—it doesn't matter for this discussion. Let's assume that you want to use coax to feed your mobile whip.

Do you remember that rather goofy Zen-like question: "What sound does one hand clapping make?" Well, one hand can't make much of a clapping sound by itself—and neither can a monopole do much by itself! Our monopole needs a second terminal for the second conductor of the feed line. Another way of looking at this problem is to figure out how to make a monopole imitate the action of a dipole.

Here's where so-called "image theory" comes into play. The monopole whip needs an "image plane" to act as a sort of electrical mirror (see **Fig 1-22**). The "reflection" of the whip in the conducting image plane makes up for the missing half of a regular dipole. Whoever came up with this idea gets *my* vote for being pretty clever!

A theoretically perfect image plane is sometimes described as a sheet of copper that is infinitely long and infinitely wide. Good luck finding one of those. In practice, a real *ground plane* (another term for an image plane) can be made up from a system of wire radials laid out around the base of the vertical radiator, or it could be comprised of one large conducting surface, like a car. When a mobile whip monopole is mounted on a car's bumper or rooftop, the mass of metal in the car body acts as an image-plane conducting "mirror."

Now, let's get back to your question, since you obviously can't put a car out the window to act as an image plane! Before you accuse us of getting too deep into that one-hand clapping business, consider the dipole again. If you were to place two Outbacker whips back-to-back and connect your coax to the end terminal of each one, you would create a resonant loaded dipole. The drawback here is that you need two whip antennas.

Another approach is more suited to a typical ham's budget—use whatever is on hand as an impromptu ground plane! Perhaps you are located in a high-rise apartment and you can mount the Outbacker on a deck railing, or perhaps a fire escape outside. The metal in the railing or fire escape can serve as a ground plane. You may need to supplement the railing with one or more quarter-wave radial wires—especially if you get "bit" by RF from your transmitter chassis when transmitting. The additional radials can be brought back into the apartment and snaked around the baseboard of the room to make them inconspicuous.

Another approach for a house installation is to use at least two quarter-wave radials at the base of the Outbacker. For 40 meters, these radials would be 33 feet long; for 20 meters, 16.5 feet long and for 15 meters, 11 feet long. The vertical radiator and each radial must be kept away from people and animals. The radials should be well insulated at the outer end, where some pretty high RF voltages can occur. Fishing line tied directly to the ends of the radials can be used both as an insulator and as a support. With only two radials the efficiency won't be perfect, but if you can elevate the base of the antenna up at least 10 feet above ground, the losses will be quite acceptable.

Q What is the purpose of a counterpoise wire?

A To assist with this particular case, the Doctor requested the opinion of noted antenna designer Roy Lewallen, W7EL.

"Even though many antennas, like dipoles, are open circuits at dc, they must behave like a complete circuit at radio frequencies. This means that all antennas effectively have *two* terminals, and the current into one terminal has to equal the current out of the other. A rubber-duck antenna (the

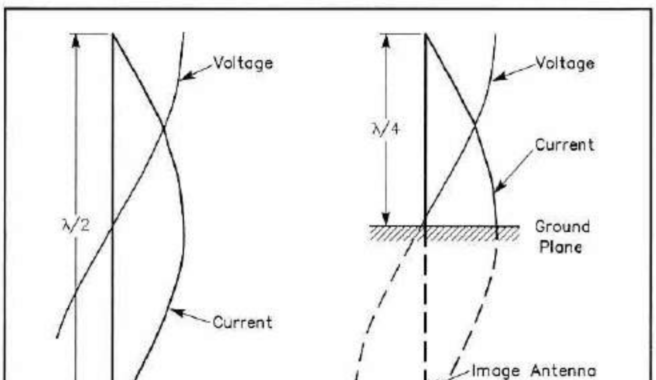


Fig 1-22—The half-wavelength antenna (left) and its quarter-wavelength counterpart (right). The missing quarter wavelength appears as the "image" in the ground plane.

type popular with hand-held radios) seems to have only one terminal (the antenna), but it really has two. Whatever RF current flows into the rubber duck to produce the field you use to communicate, an equal current is forced along the outside of the hand-held and your body. The radio and your body then become the rest of the antenna system (the second terminal).

"So, a *counterpoise* is a wire or object used as the remainder of the antenna system when the intended radiator has a single connection. In general, a counterpoise isn't intended to radiate significantly. An example is the use of a fence as a counterpoise for a vertical antenna."

Q I'm about to install a homebrew vertical antenna and a system of buried wire radials. My only question concerns the radials. What sort of wire should I use? I would imagine that some wires would corrode in soil faster than others.

A Uninsulated copper wire can be expected to last several years in just about any kind of soil. Insulated copper wire is even better. Copper-clad steel wire should be avoided, however, because it has a relatively short life. And stay away from aluminum wire; it will turn to powder in a year or less!

The problem isn't just the pH of the soil, but what the radial eventually connects to via the shield at the station end. It's quite easy, even in what appears to be favorable soil, to have an electric potential that erodes the radials since there is a complex dc path that involves everything connected to the radial system. The only safe solution is to use copper wire—#16 or larger—bare or insulated. Some bare copper radial systems buried at broadcast sites in the '20s have been uncovered and found to be virtually perfect! It's hard to go wrong with copper.

Q My HF antenna is a homebrew vertical that uses six radial wires buried beneath the lawn. I'm thinking of adding more radials, but I'm not sure if the improvement would be worth the effort. I could try a test, but I don't have any test equipment. Any ideas?

A Why not build a simple field-strength meter similar to the RF sniffer shown in the Jun 1998 "Doctor is IN" column of *QST*? All you need are a couple of inexpensive diodes and a 100-µA meter. You could also buy an inexpensive commercial field-strength meter.

When you're ready for your test, place the field-strength meter close enough to your antenna that you get a half or quarter-scale reading when you transmit a continuous carrier (AM, FM or CW). Write down this reading and leave the meter right where it is. Don't disturb it.

Attach a long wire to an alligator clip and connect it to the same point where your existing radials tie together. Lay the wire on top of the grass in approximately the same position you'd use if it was going to be a permanent radial. Transmit again and take another reading from your meter.

If adding the temporary radial increases the reading substantially, it's worth the sweat to make it a permanent addition to radial system. Try another temporary radial to see if the reading goes even higher.

On the other hand, if the needle barely rises, don't bother digging up your lawn. Adding more radials will not significantly improve your antenna's performance.

For any given radial system, there is an optimum number of radials. At this number, adding more radials does make an improvement, but one of rapidly diminishing returns. This number is related to the length of the radials and the soil type. **Table 1-1** shows the optimum number of radials for average soil.

Q Following your advice, I added a temporary radial to the six I already had and found the change in signal strength was so slight that I didn't bother to add any more radials. Then, a few months later in another magazine, I saw a column by a writer who bills himself as the "Kaped Krusader." He labeled your advice as "more antenna hogwash." Who am I to believe?

A You wanted to gauge how much effort it would take to improve your vertical antenna system by adding radials. The answer was a thoroughly practical one. Adding one radial would be unlikely to produce much of an improvement. Even the Kaped Krusader seemed to agree with that, although he went on to say that adding *a huge number of radials* would improve the situation further. After you sort through all the Kaped Krusader's tables and bombastic verbiage, adding 107 more radials will theoretically improve your signal by about 3 dB, one-half of an S unit.

The Kaped Krusader has stated many times before in print that 2 dB is barely detectable at the other guy's receiver. So, you will have to decide for yourself whether an extra 3 dB is worth going through all the work of digging up your lawn to put down more than 100 radials. Yes, you will be beaten out more often in the big DX pileups without that extra 3 dB. But even if your vertical were theoretically 100% perfect, do you have any illusions that you're going to beat out stations with big Yagis on tall towers?

Q Can you recommend some antennas that will function reasonably well at low heights and over poorly conductive ground?

Table 1-1
Optimum Ground-System Configurations

Number of Radials	*16*	*24*	*36*	*60*	*90*	*120*
Length of each radial in wavelengths	0.1	0.125	0.15	0.2	0.25	0.4
Power loss in dB at low angles with a quarter-wave radiating element	3	2	1.5	1 0	0.5	0

A A poor ground would suggest that you may wish to look at a horizontally polarized half-wavelength antenna, such as a dipole, rather than a quarter-wavelength antenna, such as a vertical. A vertical is still possible, but will require radials or a counterpoise of some sort. (Even if ground conditions are good, radials are recommended for a quarter-wavelength vertical.)

For low heights, some hams have enjoyed good success with loop antennas. Another choice is a dipole fed with ladder line and tuned with an antenna tuner. Be sure the dipole is long enough for the lowest frequency of interest.

Q I saw an ad in *QST* for a Gap antennas, Titan DX. The advertisement mentioned that no radials are needed, but yet it also mentioned that you need to use a 80" counterpoise. Please clarify for me the difference between a radial and counterpoise. I thought they basically both do the same thing!

A The difference between the terms "radial" and "counterpoise" is subtle, but significant. Radials usually consist of multiple wires either buried in, or laid upon the ground and are not tuned to a specific frequency. Their purpose is solely to reduce ground losses (a very good article on this topic by Jerry Sevick, W2FMI, appears in his book, *Building and Using Baluns and Ununs*).

A counterpoise is usually a single wire, mounted above ground and cut to such length as to provide a low impedance on a specific frequency. Of course, there are exceptions and gray areas in between these two.

When most folks think of verticals, they are typically envisioning the ground-mounted type that typically uses dozens of radial wires. As such, they don't have much appeal to folks with small backyards or folks that have an aversion to having to construct a large system of wires (and possibly have to bury them). Hence, the Gap advertising statement letting potential buyers know they don't have to go to all that trouble.

Although there are minor differences, all of the commercial multiband 1/2-wave verticals currently on the market operate on the same general principle. In essence, they are sort of like trap dipoles stood on end. The differences between them stem from the loading scheme—linear loading is used on the Gap and loading coils with rod elements are used on the Cushcraft. With the Cushcraft, the "lower" half of the dipole includes four straight rods. By themselves, they are not a counterpoise; instead they are paired up with coil loading to form a complete resonant element.

It is perhaps useful to imagine the lower half of the Cushcraft as being a shortened 1/4-wave vertical with a capacitance top hat, but mounted upside down—this is the function provided by the four wires at the base of this antenna. The single counterpoise required for the Gap serves a similar purpose.

Q I want to operate 40-meter CW, but I live in a third-floor apartment. I can't put up a dipole, so an end-fed wire with an antenna tuner would be ideal for my particular situation. How do I achieve a decent earth ground?

A The short answer is, you can't. But you can give your antenna something to work against by setting up a *counterpoise*. A counterpoise is not an equivalent substitute for an earth ground, but you'll find that it works remarkably well.

Simply cut a piece of wire 1/4-wavelength long for the band in question. In the case of 40 meters, that would be about 33 feet. Attach one end of your counterpoise to the ground terminal on your tuner. Route the rest of the wire around the room, running it along the baseboards or wherever. You can use thin "magnet wire" for your counterpoise and it will be nearly invisible. If you intend to operate on other bands, you'll need separate counterpoises for each one.

Low-power operating is best with this kind of system (less than 10 W). If you run 100 W or so, you may discover that your rig and other bits of metal are uncomfortably hot with RF. Manufacturers such as Ten-Tec and MFJ sell counterpoise tuners (also called "artificial grounds") that may help alleviate this problem.

Q I'm interested in setting up an HF vertical antenna in my backyard. The problem is that I don't have enough space to bury all the 1/4-wavelength radial wires in straight lines. Do I have an alternative?

A You certainly do! There is no rule that says the radials must be 1/4 wavelength, or that you must bury your radials in straight lines. You can zig-zag them all over the place and they'll work nearly as well. You don't really need to bury the radials at all—you can just lay them on the ground. However, this can present a safety hazard to anyone unlucky enough to wander into your yard while you're on the air (or even when you're not, for that matter).

There are also several vertical antenna designs that do not use radials. They tend to be more expensive than traditional verticals, but the cost may be worthwhile compared to the hassle of burying a bunch of wires.

MULTIBAND HF ANTENNAS

Q I just upgraded and can't wait to explore HF. I'd like an all-band antenna, at least until I've had a chance to try them all. I'm looking for something simple, inexpensive and perhaps something I can build. A dipole would fit the bill, but only operates on one band. What options do I have?

A You have a number of multiband dipole possibilities. The best antenna for your particular application depends on such things as your operating habits, budget, antenna-size limitations and available supports. Multiband dipoles offer a variety of size, feed-line, pattern, bandwidth, band-switching and other options. You'll also find differences in complexity and efficiency. In general, homebrew dipoles provide surprising performance for the dollar. A little knowledge can go a long way when making your selection. Let's take a closer look and see which might be best for you.

Using a Half-Wave Dipole on Other Bands

Because a resonant dipole is also resonant somewhat above each odd harmonic (3f, 5f, etc), even a simple garden-variety dipole is suitable for multiband use. In the HF bands for example, a 40-meter dipole is also resonant *near* the 15-meter amateur band.

Jumpered Dipole

Another simple approach is known as a *jumpered dipole*. Start with a dipole cut for the shortest wavelength of interest and a pair of insulators at each end. Add more wire and insulators for each wavelength you desire (see **Fig 1-23**). Finally, install a jumper across each insulator within the antenna. Solder one end of each jumper and install an alligator clip or suitable connector on the other end. You can select any of the available bands by shorting the appropriate insulators. If you intend to operate with high power, be sure the jumper contacts are suitable. I use a little electrical contact grease on the jumper contacts to prevent oxidation.

When constructing dipoles, leave extra wire for each band segment and do not solder the end connections. Start tuning with the highest frequency and work your way down. Measure the SWR at points across band and adjust the segment length (shorter = higher frequency) until the lowest SWR is where you want it. (An SWR analyzer or similar instrument can be especially helpful when pruning multiband antennas.)

A jumpered dipole offers low loss (assuming negligible resistance across the jumpers), coax feed, uncompromised bandwidth and a standard dipole pattern without a tuner. The disadvantages are a bit hard to deal with, though. You need a halyard and pulley system to raise and lower the antenna *each time you switch bands*. Each band change requires a trip outdoors, sometimes in inclement weather—not a good choice for rapid or frequent band changes.

There are other types of multi-band dipoles. They include two types of multiresonant center-fed dipoles: trap dipoles and multiwire or fan dipoles. Once properly tuned, these antennas require no further adjustments or switching. First, let's talk about trap dipoles.

Trap Dipole

Traps are tuned circuits inserted along the length of the antenna. Resonant traps are parallel resonant at some frequency, where the trap's high impedance effectively isolates or disconnects the remaining wire a from the antenna segment between the traps. A resonant trap is a bit like a frequency-sensitive insulator. Correct trap placement and tuning are important. At frequencies other than resonance, however, the traps no longer act like traps and instead allow the RF to pass, usually functioning as an inductor that makes the antenna a bit shorter than it otherwise would be. When cleverly designed, a pair of traps can provide resonance on several different bands.

An antenna trap is designed for a particular operating frequency, and there may be several traps in the overall system, each designed for a specific frequency. Therefore, a 40 through 15-meter trap antenna, like the trap dipole shown in **Fig 1-24**, might contain traps for 20 and 15 meters. When you're operating on 15 meters, the 15-meter traps effectively shorten the antenna by blocking the RF from traveling beyond them. If you switch to 20 meters, the 15-meter traps suddenly become transparent to the 20-meter RF, effectively lengthening the antenna. The 20-meter traps, however, are a kind of impedance roadblock to RF, keeping the signal from traveling farther. On 40 meters, all of the traps are absorbed into the system to become part of the overall 40-meter dipole antenna.

Because of the loading effect of the traps, the 40-meter portion of the antenna will be somewhat shorter than a full-sized 40-meter dipole without traps. Also, the effective bandwidth on each (except the highest frequency) band will be narrower than that of a standard dipole.

A trap-style antenna is not quite as efficient as a full-size dipole, but if the traps are well designed, the losses are not significant. Most hams consider the losses a fair trade-off for the convenience of having an antenna that presents a 50-Ω match to coax on several bands.

Trap-dipole advantages include reduced size, instantaneous band switching and a standard dipole radiation pattern. Traps serve as inductive loading below their resonant frequencies, so the physical length of a trap dipole will be shorter than a resonant wire on the antenna's lowest band.

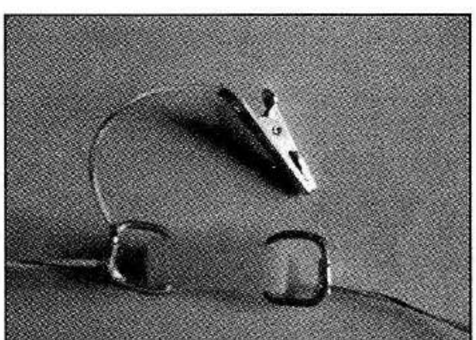


Fig 1-23—Bandswitching jumpers for a "jumpered dipole."

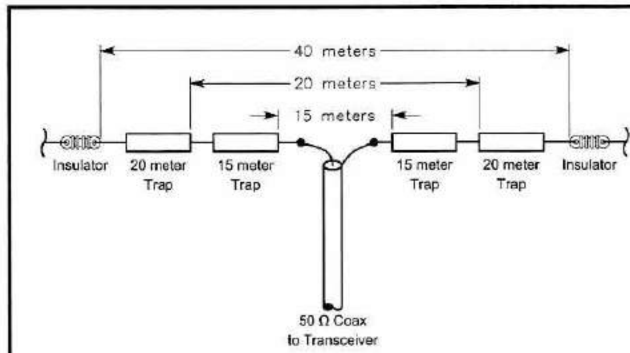


Fig 1-24—A typical 3-band trap dipole antenna. The traps block RF at a specific frequency, or allow it to pass. From an electrical standpoint, this effectively lengthens or shortens the antenna.

A trap dipole, therefore, may be just the answer for space limitations or a small lot. On the down side, traps increase loss, expense, complexity and maintenance. The added weight and wind loading require sturdy antenna supports. Traps also tend to decrease antenna bandwidth—a problem if you like to operate at the limits of a single band.

Fan Dipole

The other multiresonant dipole is known by many names: multiple dipole, multielement dipole, parallel-wire or fan dipole. It can be constructed a variety of ways, but **Fig 1-25** shows a technique that can be used. Each element is individually tuned to one of the desired bands. The total feed-point impedance becomes the parallel combination of all element impedances. Since the impedances of resonant elements should be around 50 to 75 Ω and those of nonresonant elements much higher, the total antenna impedance should be approximately that of a single resonant element. This provides a nice match for coax, and it means that only one element should be resonant on any band. HF combinations to avoid include 40/15 meters and 80/30 meters. For these cases, cut the element for the lower frequency and let it serve double duty at the odd harmonic.

In theory, we could fashion a four-wire antenna for the 80, 40, 30, 20, 15 and 10-meter bands. In practice, it may be difficult to obtain a good match on all bands. Since the resonant length of a given element in the presence of the others is not the same as a dipole by itself, tuning can be a tedious and difficult procedure. Adjust elements for resonance in order from lowest frequency to the highest. As with the jumpered dipole, we recommend leaving a little extra wire to facilitate pruning. All of these bandwidth, adjustment and matching problems are easily solved with an antenna tuner at the transmitter, feeding the antenna through 100 feet or less of RG-8 coax.

Fan dipoles offer many of the trap-dipole advantages except reduced size. In addition to the tricky and tedious

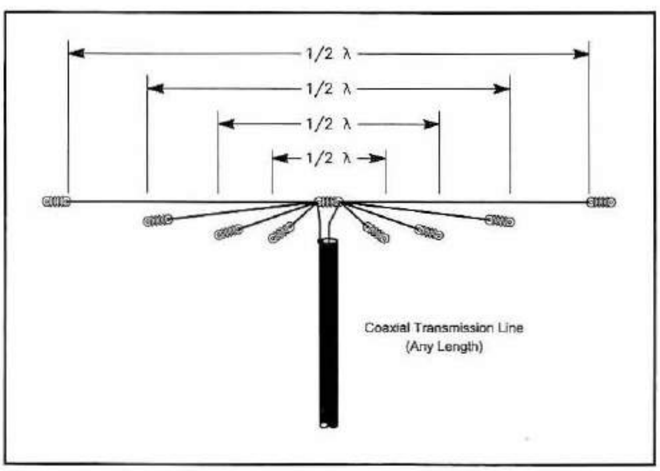


Fig 1-25—You can connect several dipoles together at the center to create a multiband antenna. Because of interaction among the various elements, however, careful pruning is necessary to bring each antenna to resonance.

tuning procedure, the disadvantages of this antenna also include reduced bandwidth. The cost of the additional wire and insulators is not all that great, so there may be some savings over a trap dipole. A fan dipole may be easier to construct, depending on the complexity of the traps being considered. If the SWR on the line of a fan dipole is low enough that transmission-line losses due to SWR are low, there may be an efficiency advantage over a trap dipole. The bandwidth advantage however, may go to the trap dipole. Trap losses, although generally considered undesirable, can help to improve the apparent bandwidth. The detrimental affects of interaction between fan dipole elements, coupled with beneficial effects of trap losses, tend to give the bandwidth edge to the trap dipole.

Pruning parallel dipoles to resonance can be tricky. The more wires you have in parallel, the trickier it becomes. We recommend that you cut the 80-meter dipole to length using the formula 468/frequency (MHz) and the 40-meter dipole about 5% longer than the formula says. Install them in parallel from the same center feed point, complete with whatever insulating material you are using to keep the wires apart (see Fig 1-25). Then, prune the 40-meter dipole for lowest SWR, followed by the 80-meter dipole. Don't be surprised if you have to go back and trim the 40-meter dipole again. Buying or borrowing an HF antenna analyzer is a good idea for this type of project.

Before you attempt a parallel arrangement, however, see if you can run the dipoles crossed at 90° angles to each other. You'll minimize mutual coupling between the antennas and, as a result, they'll be much easier to tune.

Center-Fed Zepp

Another popular technique is called the center-fed Zepp antenna. It is basically a dipole, of any convenient length, fed in the center with a low-loss line like transmitting ladder line or open-wire line. An antenna tuner is used to match the feed-line impedance to 50 Ω.

Fig 1-26 shows a center-fed Zepp. Other names for this antenna include the tuned doublet and dipole with tuned feeders. Unfortunately, this antenna is widely misunderstood. Let's clarify a few points—perhaps we'll even debunk a few myths in the process.

The dipole section should be at least a quarter-wavelength long on the lowest frequency used, although shorter lengths can be used with substantial sacrifice in efficiency. Ladder line is used because of its inherent low loss at HF. It does not radiate (assuming proper balance), nor does high SWR cause it to radiate. High SWR on a transmission line merely increases line losses relative to those of the matched line. The antenna radiates any power that is not dissipated in the feed line, tuner or transmitter.

The center-fed Zepp can be remarkably efficient, despite the relatively high SWR along its feed line. The secret is the ladder line's low loss, but the antenna tuner is another story. Tuner losses can vary widely with band, impedance mismatch, component quality and circuit design. A balun at the tuner output can be very lossy in this type of system.

The antenna length should be about a half wavelength at

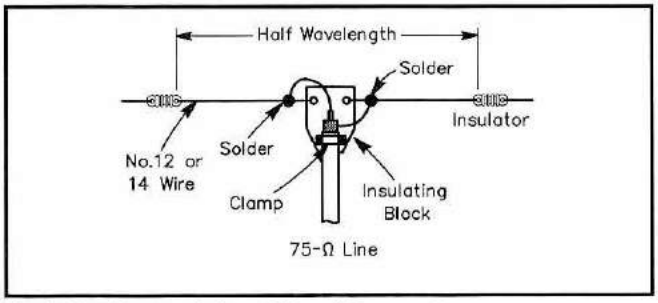


Fig 1-26—Center-fed multiband Zepp antenna.

the lowest frequency of interest for best results, but the length is not critical. A typical length for an 80 to 10-meter version is 127 to 135 feet. There is no magic feed-line length either, but it may require adjustment for your particular installation. Remember, the feed-line impedance varies along a mismatched line. If your tuner has difficulty on some bands or you experience RF in the shack, add or subtract $^1/_8$ wavelength (for the troublesome band) of antenna feed line. You may need to repeat this if other bands become difficult to tune, but a little perseverance usually fixes them all.

Advantages of the center-fed Zepp include all-band coverage, minimal weight and low cost. Disadvantages are the expense of the tuner and the need to retune when changing frequency or bands. The radiation patterns become increasingly complex at higher frequency bands, particularly if the antenna is installed in an inverted-V configuration, an undesirable, but common, compromise. See a late edition of *The ARRL Handbook* for plots of gain on different frequencies for a 135-foot center-fed Zepp.

Ladder line lacks the convenience of coax. You must keep it away from metallic objects by at least twice its width—about two inches for one-inch-spaced 450-Ω line. Make any bends as gradual as possible, say a 12-inch radius for 450-Ω line. Twisting the line helps stabilize it in windy environments—twist it 180° for every two feet or so. A high SWR also increases voltages and currents along the line, so the maximum-power capability of a mismatched line is less than its specified rating.

Q I want to make a multiband antenna. Should I use an 80-meter dipole fed with ladder line, an 80-meter dipole fed with coaxial cable and just let the antenna tuner adjust it for every other band I want to operate?

A Whether you want to use an 80-meter half-wave dipole (or any convenient length > 0.25 wavelength—there is nothing magical about resonance, other than as it affects SWR and thus efficiency). It all depends on what feed line you intend to use and what losses you can tolerate.

Generally speaking, use open wire line to feed the 80-meter dipole with an antenna tuner, and use coax to feed dipole only on its intended band (or on odd-numbered harmonics). Let us explain how we arrived at that conclusion. First, we used *EZNEC* to model an 80-meter half-wave dipole up 30 feet over average ground.

Freq. MHz	*R Ω*	*X Ω*
3.5	45.0	−48.6
3.6	44.7	+1.0
3.8	58.6	+99.7
4.0	70.5	+199.0
7.05	3796.0	+2764.0

The X column represents reactance—negative is capacitive reactance, positive is inductive reactance. Translation: if reactance is not zero, the antenna is not resonant. The higher the reactance, the farther from resonance it is. We then used *TLA*, the transmission line analysis software that comes bundled with *The ARRL Antenna Book*. We first modeled 50 feet of RG-58A. The program calculated the following:

Freq. MHz	*R Ω*	*X Ω*	*SWR at Ant.*	*SWR at Tx*
3.5	45.0	−48.6	2.59	2.37
3.6	44.7	+1.0	1.05	1.05
3.8	58.6	+99.7	5.47	4.41
4.0	70.5	+199.0	14.27	8.55
7.05	3796.0	+2764.0	117.8	13.49

You'll notice that the SWR is higher at the antenna than it is at the transmitter. This is because line loss absorbs some of the forward, then some of the reflected power, giving less reflected power than would exist if the line had no loss. A really lossy transmission line, like a mile of miniature RG-174, would show a wonderful 1:1 SWR—with an open or short circuit for a load!

Now, some of these SWR figures look pretty bad. On the upper end of 80 meters, the antenna will present an SWR of 14.27 to a 52-Ω feed line. Even on the bottom of the band, the SWR is 2.59:1. SWR purists will cringe. Just how bad is this?

If perfectly matched, 50 feet of RG-58A has about 0.4 dB loss on 80 meters, and about 0.6 dB of loss on 40 meters. If an S unit is 6 dB, this loss is clearly insignificant most of the time.

But the effect of a high SWR is that there is an additional loss due to that SWR compared to the inherent "matched-line loss" in a particular transmission line. The TLA program predicts that the losses will be lower than one might think, at least on 80 meters.

Freq MHz	*R Ω*	*X Ω*	*Additional Loss, dB*	*Total Loss, dB*
3.5	45.0	−48.6	0.4 dB	0.8 dB
3.6	44.7	+1.0	0.0 dB	0.4 dB
3.8	58.6	+99.7	0.4 dB	0.8 dB
4.0	70.5	+199.0	1.7 dB	2.1 dB
7.05	3796.0	+2764.0	8.5 dB	9.4 dB

It looks like the losses on 80 meters are quite acceptable, even at the high end of the band where the SWR at the antenna was greater than 13:1. Who would have thought that? How about using that antenna on 40 meters? 9.4 dB is certainly a lot of loss. Almost 90% of the power applied to that antenna/feed line system will be lost as heat. Sounds horrible. But if you are running even 5 W QRP at 10% efficiency, that would be like running 500 milliwatts to a perfect antenna, and plenty of hams have made contacts at this level of power. If you are looking to do a real minimal backpacking, and want to operate mostly 80 meters, with only a quick foray to 40 meters over a path for which you expect good propagation, you can accept 9.4 dB of loss. If you would have been S9 with a good antenna system, you will be S7.5 with 9.4 dB of loss, still useable. It is a system decision, in this case weight versus loss.

What about ladder line? Would that help? You bet! We won't repeat all the calculations, but on 80 meters, the 50 feet of 450-ohm window ladder line feeding the 80 meter dipole has a total loss of 0.3 dB. On 40 meters, even with that crazy load, the total loss was predicted at 0.5 dB.

Of course, now you must have an antenna tuner. It too will have loss, but once again the trusty *ARRL Antenna Book* software comes through. I can model the antenna tuner and estimate losses. It says that the tuner losses will be about the same as the line losses, at 0.3 dB and 0.5 dB respectively. So on 80 meters, the 80-meter dipole/ladder line/tuner combo has about 0.6 dB of loss; on 40 meters, the total loss is about 1 dB. This is acceptable under almost all conditions. If you are backpacking it, and can carry the antenna, ladder line and tuner, you will be golden. Of course, that ladder-line-fed antenna can be used on all the other bands with approximately the same efficiency, so if you get a hankering for 20 meters, you can simply retune the antenna tuner.

To make this very long story as short as it could have been, the bottom line is that a coaxial feed line can be used reasonably well on the lower HF bands if the SWR is less than about 15:1 or so! On the upper part of HF, the losses are higher, so the tolerable SWR is about 5:1. This is a good choice for 50-Ω antennas like half-wave dipoles, quarter-wave verticals, fan dipoles, etc.

If you use ladder line, you can usually manage to deliver power efficiently to nearly any antenna. A dipole, fed approximately in the center, at least a quarter-wavelength long on the lowest frequency you want to use, can be fed reasonably well with this combination.

YAGI/BEAM ANTENNAS

Q I just upgraded to General class and I'm trying to get active on the HF bands. My friends are telling me to put up a "beam" antenna, but I'm unsure. What are the advantages and disadvantages of HF beams?

A When hams speak of beam antennas, they usually mean the venerable Yagi and quad designs. These antennas focus your signal in a particular direction (like a flashlight). Not only do they concentrate your transmitted signal, they focus your *receive* pattern as well. For example, if your beam is aimed west you won't hear many signals from the east (off the "back" of the beam).

The problems with HF beam antenna systems are size and cost. HF beams for the lower bands are *big* antennas. At about 43 feet in width, the longest element of a 40-meter coil-loaded Yagi is wider than the wingspan of a Piper Cherokee airplane. Even a 10-meter beam is about 18 feet across.

In terms of cost, a multiband (20, 15 and 10 meter) beam antenna and a 75-foot crank-up tower will set you back *at least* $2500. Then add about $500 for the antenna rotator (a beam isn't much good if you can't turn it), cables and so on. In the end, you'll rack up about $3200.

If you have that much cash burning a hole in your pocket, by all means throw it at a beam antenna and tower. The rewards will be tremendous. Between the signal-concentrating ability of the beam and the height advantage of the tower, you'll have the world at your fingertips. Even a beam antenna mounted on a roof tripod can make your signal an RF juggernaut.

In truth, only a minority of hams can afford towers these days. Those who manage to scrape together the funds occasionally find themselves the targets of angry neighbors and hostile town zoning boards. (They don't appreciate the beauty of aluminum and steel like we do!)

But do you need a beam and a tower to enjoy Amateur Radio? The issue isn't whether they're worthwhile (they are). The question is: Are they absolutely necessary? The answer, thankfully for most of us, is no. You can enjoy Amateur Radio on the HF bands with nothing more than a copper wire strung between two trees. If a beam seems out of the question at the moment, consider a dipole, loop or similar antenna. *The ARRL Antenna Book* has plenty of design suggestions.

Q Can you describe how a Yagi "beam" antenna works without resorting to mathematics? Can you make some kind of physical analogy that anyone can understand?

A Take a look at **Fig 1-27**. This is a typical four-element Yagi antenna. The purpose of this design is to focus your RF energy in a particular direction (indicated by the arrow). The antenna also focuses *received* signals as well. The *driven* element connects directly to your radio via the coaxial cable. For the sake of this discussion, think of it as a simple dipole antenna. The element directly behind the driven element is the *reflector*. The two elements immediately ahead of the driven element are the *directors*. (In most Yagi antennas, all of these elements are made of aluminum tubing.)

When you key your transceiver, the RF energy reaches the driven element and begins to radiate. This is when the design magic comes into play. Some of the RF is picked up by the reflector and reradiated. Because of the spacing between the reflector and the driven element, and due to the tuning of the reflector (that is, its physical length and diameter), the reradiated energy is out of phase with the RF coming from the driven element. (You said "no math," so we can't get into the nuts and bolts of why this is so. You'll just have to trust us.) This out-of-phase RF combines with the energy from the driven element and they largely *cancel* each other out in the direction *away* from the main beam.

The directors also reradiate RF, but they are spaced and tuned in such a way as to *add* to the signal from the driven

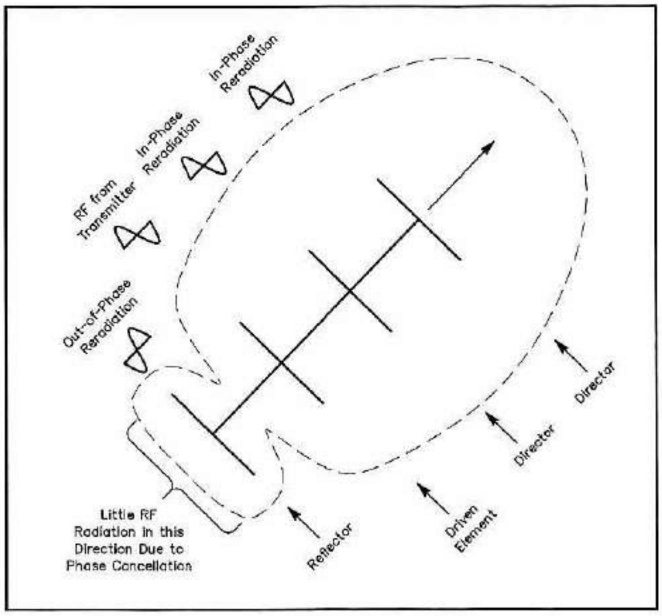


Fig 1-27—A Yagi antenna works its magic by manipulating the phases of radio waves. The driven element radiates the RF from your transmitter. The reflector responds by reradiating the energy, but does so out of phase with the driven element. The result is substantial cancellation "behind" the beam. On the other hand, the directors reradiate in phase with the driven element and effectively reinforce the energy in the direction you desire.

element in the direction of the beam. The result is the pattern shown in Fig 1-27. The combination of the reflector and the director(s) affect the overall pattern. When everything is working properly, the Yagi sends and receives RF in the direction you desire—and it does all this by manipulating the phases of radio waves. No moving parts!

Q What is the best beam antennas?

A A huge dish antenna. Unlike Yagis and other wire ar rays, these can be scaled up most easily to match whatever fortune you wish to dispose of. The 300-meter diameter dish at Arecibo has enough gain to work EME with a simple handheld transceiver. Attempting to achieve a similar amount of gain with Yagis or wire arrays is nearly impossible.

Q I have a 45-foot power pole in my front yard that has my 10-meter Yagi mounted above it and all of my coaxial feed lines are feed to this pole through PVC pipe buried under the ground. I have just put up a McCoy Dipole (non-resonant random length) and will be feeding it with 450-Ω ladder line from a tuner for operation on all bands (160-10). The run underground is approximately 70 feet through 2-inch diameter PVC pipe with 3 coaxial cables.

Question (1): Can I run the 450-Ω ladder line through the PVC pipe with no problems?

Question (2): If I can't run the 450-Ω ladder line directly in the pipe and make up a 100-Ω balanced line from 2 lengths of coax (using the center conductors as the feed line and grounding the braids), will I need a 4:1 balun at the point where the coaxial balanced line and the ladder line connect or will the impedance mismatch not matter since the lines are balanced?

A Running ladder-line underground through PVC pipe is not a good idea. Ladder-line needs to be free from conductors by about 2 feet when run for any distance. Running it through the pipe will have it just fractions of an inch away from ground (an RF conductor) for 70 feet.

Making a balanced line from two pieces of coax is also counterproductive. The reason for using ladder-line in the first place is because of its low loss—this advantage is lost when using the coax balanced line—you gain nothing. Our advice in your situation is to just go ahead and run a single (unbalanced) coax through the pipe to your antenna and not to use a balun to start with. If you have RFI problems, then use a balun as a possible part of your RFI suppression solution.

Q How should I aim my beam antenna to minimize possible damage in high winds?

A If the boom's projected wind-surface area (roughly the length times the diameter times 0.67) is greater than the sum total of the projected area of each element, then you want to head the boom into the wind. This is the usual case for most beams, like tribanders, which tend to have thin elements compared to their thick booms.

However, if there are many heavy-duty elements on a Yagi, then it is conceivable that the worst-case wind loading is looking into the elements broadside. So, the best thing to do in this case would be to head the elements into the wind. In other words, put the boom broadside to the wind direction.

Q How can you calculate, estimate, or approximate an antenna's wind load? I plan to build a large HF quad, so I need to figure out its approximate wind load so as not to overload the rotator.

A The key to estimating the wind load presented by an antenna is to visualize the quad looking with the boom either pointing directly at you or exactly perpendicular to you. Remember that mechanical drawing course you took back in high school? What we're talking about is the front view and the side view of the antenna, and the area we are looking for is the so-called *projected area* of each part of the antenna. If we look at each wire and each spreader in a quad, viewed directly from the front or the side, each part looks like a "skinny rectangle."

Assuming that the boom, the wires and the spreader poles are all cylindrical in cross section (a pretty good assumption), we use a multiplier of 0.67 (*drag coefficient* for cylinders) to convert the area of each skinny rectangle to the effective area for a cylinder. See **Fig 1-28**, showing a quad looking directly into the boom. We will add up the area of each of the four wires, plus the area of the four spreader arms to come up with the wind-surface area for this view.

Then, we multiply that number by 2. Why 2? This is because the element at the other end of the boom gets into the act also. Wind actually blows on both elements, provided that they are not on a very short boom, one directly behind the other.

Let's compute the cylindrical projected area of the four spreaders for each element. Assume for the sake of simplicity that each spreader is 1 inch OD (that is, 1/12 foot) and 13 feet long, yielding a projected area of $1/12 \times 13 \times 0.67 = 0.73$ square foot per spreader arm. For four spreaders, this totals 2.90 square feet. After counting the spreader arms on both ends of the boom, the total projected surface area for the spreaders is $2 \times 2.90 = 5.80$ square feet in the boom-on view.

Now, let's say that each of the four wires shown is made out of #14 copper wire and is 18 feet (216 inches) long at 14 MHz. From a wire table, we find that the OD of each wire is 0.064 inch. The projected area of each cylindrical wire is thus $0.064 \times 216 \times 0.67 = 9.26$ square inches. For all four wires on one element, the total is $4 \times 9.26 = 27.05$ square inches, or $27.05/144 = 0.26$ square foot. The total wind surface area for both sets of wires is $2 \times 0.26 = 0.52$ square foot. This isn't a lot—meaning that the wire in a quad doesn't really add much to the wind load, compared to the spreaders.

Fig 1-29 shows a side view of a quad. The projected cross-sectional area of the spreaders is equivalent to four times that of one spreader arm, or 2.90 square feet. Assuming that the boom is 8 feet long and is made of 2-inch-OD tubing, its projected area is $8 \times 2/12 \times 0.67 = 0.89$ square foot. The projected area of the wire is four times that of a single wire, or 0.26 square foot. The total area for the side view is $2.90 + 0.89 + 0.26 = 4.05$ square feet. Thus, the boom-on view has the worst-case projected wind-surface area, at $0.52 + 5.80 = 6.32$ square feet.

You should note that many rotator manufacturers are moving away from rating their products in terms of antenna square footage. Dave Leeson, W6NL (ex-W6QHS), author of *Yagi Antenna Design* points out: "Nowadays, manufacturers are beginning to rate rotators in terms of rotating or braking torque, and this is a better way to select a rotator. Even if an antenna is completely symmetrical in its distribution about the mast, there are unbalanced wind forces due to gusting and vortices that tend to rotate the antenna against the strength of the rotator (and which results in broken rotators in extreme cases)."

Q I overheard some fellows discussing a log-periodic antenna. It sounded like a multiband beam antenna of some sort, but I'm not sure. Can you tell me anything about it?

A There are many varieties of log-periodic antennas, but the type preferred most by hams is the *LPDA*—log-periodic dipole array. The antenna is really a system of driven elements (dipoles) designed for operation over a wide range of frequencies (see **Fig 1-30**). The advantage of a log periodic is that it exhibits approximately the same SWR and radiation pattern on several ham bands. Log periodics can be used for HF operating, or for VHF/UHF.

A well-designed LPDA can yield an acceptable SWR over a very broad frequency range. The gain and front-to-back ratio is not the same as you would enjoy with a Yagi or quad antenna, but you can expect an LPDA to have about 4.9 dB gain over a half-wavelength dipole (dBd). So, if you need a directional, multiband antenna and don't mind the gain deficiency, a log periodic might be worth consideration.

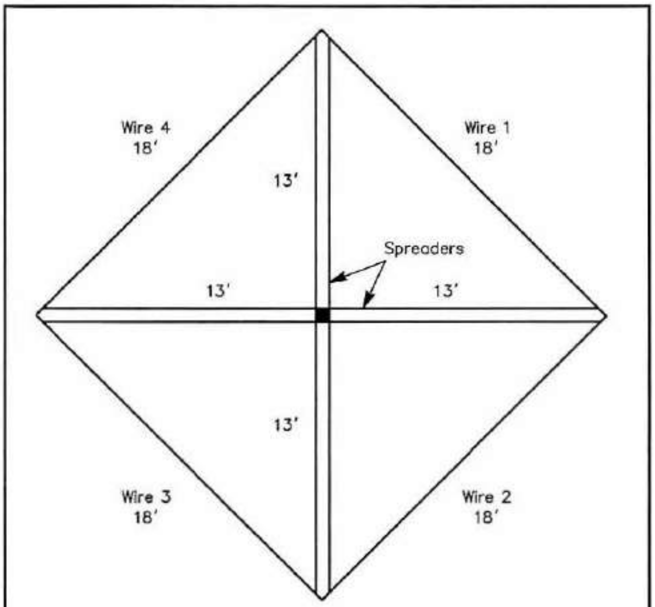


Fig 1-28—The "business end" of a quad looking directly into the boom.

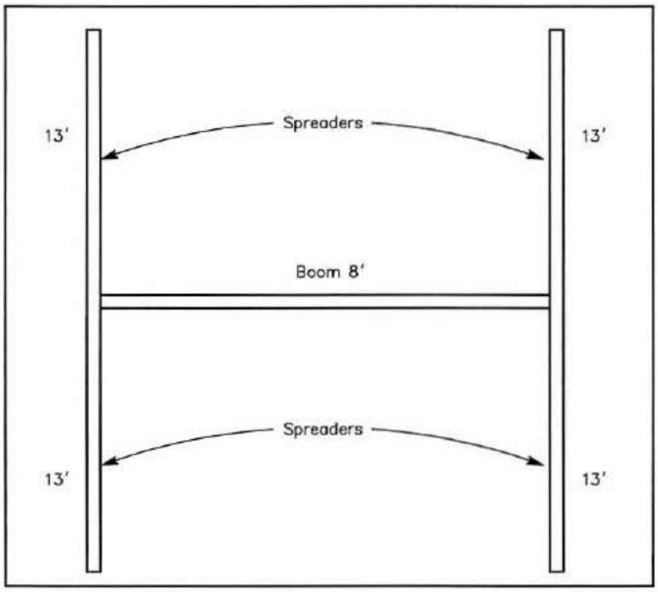


Fig 1-29—Side view of a quad antenna. The spreader projected cross-sectional area is equivalent to four times that of one spreader arm, or 2.90 square feet.

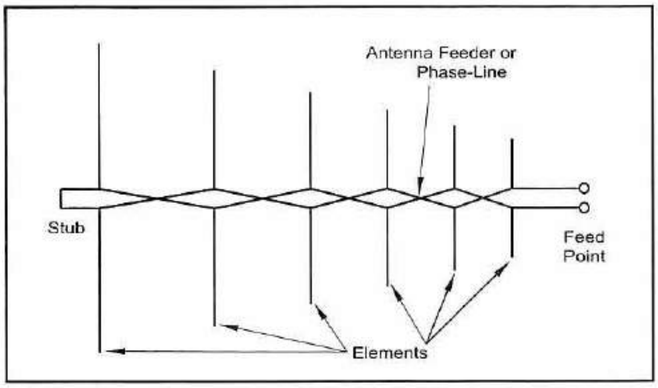


Fig 1-30—A log-periodic dipole array. All elements are driven. That is, there are no "directors" or "reflectors" such as you find with Yagis or quads. The forward direction of the array is to the right, as drawn. Sometimes the elements are sloped forward, and sometimes parasitic elements are used to enhance the gain and front-to-back ratio at particular frequencies of interest.

Q What are loop Yagi antennas and why can't you use them at HF frequencies?

A No one said that you couldn't use a loop Yagi on the HF bands, but you'd really be pushing the envelope of practicality! Loop Yagis are members of the quad family since each element is a closed loop of approximately one wavelength at the operating frequency. Line up a number of loops on the same boom and you create a fairly high-gain antenna. The loop Yagis shown in **Fig 1-31** can develop about 20 dBi gain (each) at 1296 MHz, but the individual loops are only a few inches in diameter. That's a substantial amount of gain in a relatively compact space.

But imagine supporting a similar collection of one-wavelength loops at, say, 14.2 MHz. The antenna would be monstrous! If you're a lover of rotatable loop-style antennas at HF frequencies, a traditional quad design is far more practical.

Q I picked up a used three-element Yagi that I think is probably designed for operation on 20, 15 and 10 meters. I'd like to refurbish the antenna, but how can I test the traps to make sure they're in good working order?

A An impedance bridge ought to work just fine for measuring the traps. At the resonant frequency of the trap, the impedance should be extremely high. Above the resonant frequency, the trap should be capacitive, while below the resonant frequency the trap should be inductive. Traps on either side of an element ought to measure the same.

Q Can you tell me which will give superior performance, a two-element 40-meter Yagi at 30 feet above the ground or a 40-meter rotatable dipole (such as the Cushcraft D40) at 90 feet above the ground?

A The full-size Yagi will generally work better for short paths and the dipole will work better for longer paths. However, at 30 feet high, the two-element Yagi may be significantly detuned such that it doesn't perform in the narrow band for which it was probably optimized at the factory. For example, it may have been tuned for the low end of the CW band; mounting it close to ground may shift the frequency response below the edge of the band! Most commercial two-element Yagis are quite narrowband and are designed to be installed at least 50 feet above the ground.

If you want to delve into this further, a good reference is a recent *ARRL Antenna Book* (18th or 19th Editions) with the propagation chapter rewritten by Dean Straw, N6BV. The idea is to plot the elevation pattern of the antenna against the predicted elevation angles from propagation studies and decide which will be the best compromise. Note that the foreground terrain may make a considerable difference in results, particularly if either antenna is located at the edge of a nice, steep cliff!

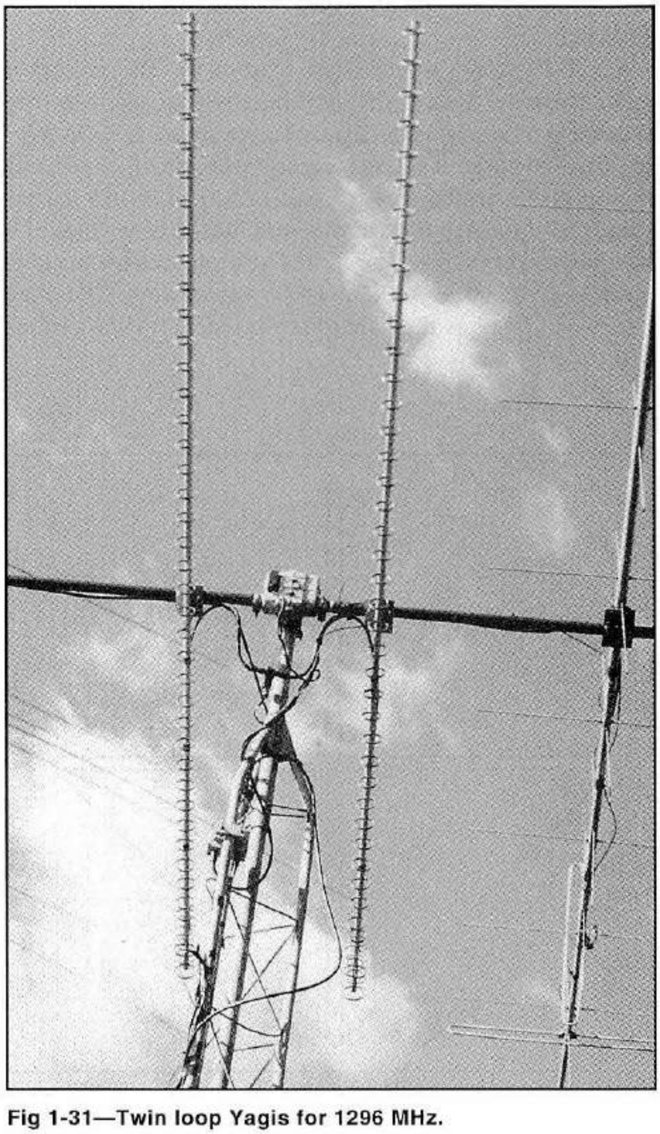


Fig 1-31—Twin loop Yagis for 1296 MHz.

Q I want to install 2-meter, 6-meter and triband HF Yagi antennas on the same tower. Is there a simple rule I can use to determine the necessary separation between each antenna?

A There are two common rules of thumb:

- The higher antenna should be separated from the antenna immediately below it by a distance equal to at least a half wavelength at the higher antenna's operating frequency (see **Fig 1-32**).
- The higher antenna should be separated from the antenna immediately below it by a distance equal to at least half the boom length of the higher-frequency antenna.

Using the second rule, for example, you can place your 6-meter antenna about half its boom length above the tribander. Then place the 2-meter antenna about half its boom length above the 6-meter antenna.

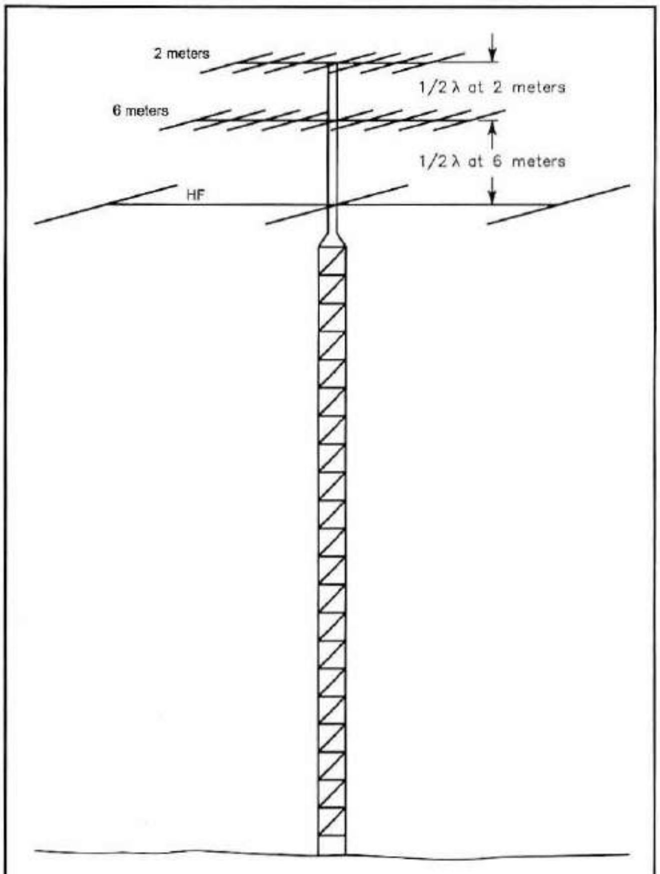


Fig 1-32—To minimize interaction between stacked Yagis on the same tower, a distance equal to a half wavelength at the higher antenna's operating frequency should separate the higher antenna from the antenna immediately below it. Alternatively, a distance equal to at least half of the higher frequency antenna's total boom length should separate it from the antenna immediately below.

For some installations these rules of thumb will yield separations that are impractical. If this is the case, simply install the antennas as far apart as possible.

Q I'd like to place an RF choke at my triband antenna beam. I understand that a coil of coax will work, but I don't know if the length or diameter is important. I keep coming up with the numbers 8 and 11. Is it 11 turns of coax with an 8-inch diameter, or is it 8 turns of coax with an 11-inch diameter? Is the difference important, or would either one work the same? Should I worry about supporting the weight of that coil somehow, or just let it hang from the tribander? Does it have to be dressed perpendicular to the beam, or can it be placed on the top of the center element, and taped to the center piece for support?

A It is not critical—the idea is to make something that is a high-impedance choke at the frequencies where the antenna will be operated. Smaller diameters are better, but there is a limit to how small you can go without causing conductor "creep" though the coax dielectric. Some coax can be bent to a 6-inch diameter and other (foam dielectric especially) shouldn't be bent smaller than a foot diameter. 8 turns is a good minimum, but 12 turns would be better (20 turns is probably just wasting coax...).

You should provide some means of support to prevent mechanical failure of the connection with the beam. It doesn't have to be perpendicular, but you should hang it underneath rather than try to hold it above the beam.

Q I recently tried my TA33 10,15 & 20 meter triband beam on 17 meter CW. The SWR was about 4:1. I contacted a European station and received a 579 report but noticed that my beam heading for maximum received signal as about 45 degrees off. Is there any way I can lower my SWR and efficiently use this antenna on 17 meters? I was thinking about using a tuner. The beam is fed with 52-Ω coax. I was surprised to find it workable on 17 meters. Any help would be appreciated.

A What you were really doing was using a random piece of metal as an antenna. Using an antenna tuner will lower your SWR, but you will still be using a random piece of metal as an antenna. Your pattern will be less than optimum and performance will not improve.

Q When I'm setting up a beam antenna, which "North" do I use to orient it? Should it be magnetic North or true North?

A You should orient your beam to true north. That way, you can point your beam to the correct great-circle heading when you're trying to communicate with a distant station. The equations for calculating great-circle headings appear in *The ARRL Operating Manual* and there are a number of free or shareware programs for computing these headings from your location.

You can easily determine true North using the North Star (Polaris)—if you don't mind working in the dark! Another way is to obtain the *angle of declination* from a topographic map. Often referred to as the *magnetic variation* in air and sea navigation, this angle is simply the difference between true and magnetic North at a specified location. By knowing this angle, you can correct your magnetic compass reading for true North.

You can learn more about coordinates, great-circle headings, topographic maps and associated computer programs by reading the "Lab Notes" column in Apr 1994 *QST*.

Q I plan to install a tri-band HF beam antenna on a roof tripod. My roof is insulated with thick foam sheets that have layers of metal foil on both sides. Will all this metal under my roof affect the function of the antenna?

A The foil sheets attached to your roof insulation should not affect the performance of your antenna because they are not bonded together into a single mass, electrically speaking. If they were, that would create a huge metal sheet, which could cause some unusual interactions. But when contractors install insulation, any electrical connections between the sections occur accidentally, if at all.

Q My HF antenna system consists of a Mosley TA33 Jr beam fed with coaxial cable and a G5RV wire dipole fed with ladder line. As long as the weather remains dry, the antennas function perfectly. But as soon as it rains, the SWR on both antennas jumps substantially. What's causing this?

A Concerning the TA33 beam, my guess is that rainwater is finding its way into the coaxial cable or the traps, or both. If coax is not properly shielded against moisture, water penetration can cause serious problems. If water is entering the traps, they should be disassembled and cleaned if possible. At the very least, check the traps for cracks or holes. It also pays to clean the antenna of accumulated grit and structures left by busy insects.

If you can get your hands on a 50-Ω dummy load, connect it to your coax at the point where the cable would normally attach to the TA33. (You're effectively replacing the TA33 with a resistor.) Carefully shield the dummy load to make sure it's watertight. Now, grab a garden hose and soak the coax thoroughly. Go to your radio and check the SWR on the coaxial line. Did it shoot up as you describe? If so, chances are water is entering your coax. If the SWR did not go sky high, suspect the traps.

You mention that you're using ladder line with your G5RV antenna. One of the problems with ladder line is that it is susceptible to impedance shifts caused by rain, ice or snow. There isn't much you can do about this except readjust your antenna tuner to compensate—and pray for sunny weather.

Q I have a seven-element Yagi that I use on 2-meter SSB. It is mounted on a mast with the elements horizontal, so I transmit and receive with horizontal polarization. Now I would like to use the same antenna to work through the repeater in the next town, where my buddy lives. Can I just turn it so the elements are vertical, and then use it on 2-meter FM?

A Sure! Just remember not to interfere with the design of the Yagi by putting a metal mast in the same plane as the elements. Use a wooden pole or a nonconductive fiberglass tube to mount the antenna. The same caution applies to the feed line. Either run it along the boom to the back and then loop it to the mast, or run it out at right angles to the plane of the elements. This will keep the feed line from disturbing the radiation pattern of the Yagi.

Q I'm thinking of mounting a 2-meter beam antenna on my roof. Any tips?

A You didn't say whether you intend to use your beam to work FM or SSB/CW. The difference is important—as you'll see in a moment. Beam antennas do a superb job of focusing your RF power in one direction. That's why they're called beams. A few watts from your radio will have greater punch if the energy is concentrated by a beam antenna. Before you get out your tools and ladder, though, you need to consider polarization.

FM operators use vertically polarized antennas. So do FM repeaters. If most of your operating is on FM, you'll need to mount your antenna so that it's vertically polarized. SSB and CW operators, on the other hand, use horizontally polarized antennas. If you plan to hunt 2-meter DX, you'd better mount your antenna horizontally (see **Fig 1-33**).

A *rotator* is used to turn the antenna in various directions. If your beam antenna is small, a standard TV antenna rotator will be adequate. Larger antennas require heavy-duty rotators. Be sure to buy a rotator that's powerful enough to do the job. If you're only concerned with working a particular

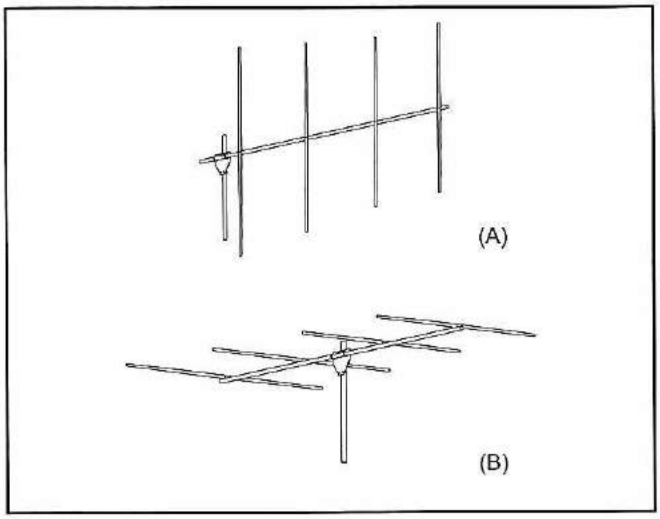


Fig 1-33—The beam antenna shown at A is mounted in the vertically polarized position with its elements perpendicular to the ground. This is the best configuration for working FM repeaters and simplex. The beam shown at B is horizontally polarized with its elements parallel to the ground. Horizontal polarization is preferred for SSB and CW enthusiasts.

station on a regular basis, you may be able to do without a rotator. Just mount the antenna so that it's pointing in the proper direction. Besides, you can add a rotator later.

Finally, use the best coaxial cable you can afford. For 6 meters and 2 meters, we recommend RG-213 or Belden 8214. If you decide to add an antenna for 222, 420, 902 or 1240 MHz, use Belden 9913 or even hardline. Weatherproof all connections so you won't have to make another trip to the roof for repairs!

Q I have a 2-meter beam antenna on my roof fed with 9913 coaxial cable. Recently I noticed that my SWR was going sky-high. I suspected a problem with the connector at my transceiver, so I decided to replace it. When I removed the connector, water began dribbling out of the cable! What could cause this?

A 9913 and similar low-loss coaxial cables use an air dielectric along with semi-solid polyethylene. In other words, your cable is partially hollow and filled with air. This provides a perfect channel for water—just like a pipe. Water usually enters the cable via the connector at the antenna. Even a tiny opening will allow moisture to penetrate the cable. Once this moisture is inside, it cannot readily escape.

A similar type of feed line is commonly used by commercial radio and TV stations, too. They solve the water problem by continuously dehumidifying the air in the cable, or by pressurizing the cable with a gas, such as nitrogen, to force the water out. Neither solution is practical for the average ham.

In your case, I'd suggest using N connectors at both ends of the cable. N connectors provide a superior seal against water. After you attach the cable to the antenna, weatherproof the connector with a putty-type sealer or self-vulcanizing tape. Some hams take the extra step of coating the connector with Scotchgard or Vaseline after it is installed.

Q I'd like to install my 2-meter beam antenna on my chimney. Any potential problems with this idea?

A Maybe—depending on the size of your antenna. Check your chimney carefully. Mortar can deteriorate over time, causing bricks to become loose and unstable. Attaching a large antenna (such as a 13-element 2-meter beam) to a crumbling chimney is a formula for disaster. The antenna effectively provides additional surface area, which results in greater windloading. As the antenna reacts to strong winds, it places extra stress on the structure. Over time, this additional wear and tear can cause the chimney to drop little surprises (in the form of airborne bricks) on you or your neighbors!

This is not to say that you can't use your chimney as an antenna support. Just make sure to evaluate the strength of your chimney first. If it seems to be in good shape, it's probably okay to use it to support a ham antenna about the size of a small TV antenna—they were pretty common on chimneys before cable TV. Even if your chimney appears to be structurally sound, do not use it to support large antennas (such as HF beams). Limit your chimney support to small VHF and UHF antennas.

Another problem concerns what comes out of your chimney—specifically, gasses and heat. If the antenna is positioned directly over the chimney opening, it may be "baked" by the heat from your furnace, fireplace, wood stove, etc. Combustion gasses can cause deterioration of certain components such as plastic insulators.

Q I'm going to put a 6-meter Yagi antenna on my chimney so I can start hunting DX. I think I'm going to need about 50 feet of coaxial cable from my radio to the antenna. What type of coax should I use?

A You want a coax that will keep your losses to a minimum. Thicker cables generally lose less signal than thinner ones. I'd recommend Belden 8214 or 9913. Use the best quality cable you can afford and be sure to weather proof your outdoor connections. You'll never regret it!

Q I have a 5-element beam antenna that I use for SSB and CW at the low end of the 6-meter band. I'd like to try the 6-meter FM repeaters, but my SWR at those frequencies climbs to 4:1. If I do manage to hit a repeater, my signal is weak. What's the solution? Should I buy an antenna tuner or an amplifier?

A Because the 6-meter band spans 4 MHz of spectrum, many antenna designs will not cover the entire band with a low SWR. Also, your beam is probably mounted in the horizontally polarized position for your CW and SSB work. Most 6-meter FM repeaters, however, use *vertically* polarized antennas. Mismatched polarization can result in a substantial reduction in signal strength between stations.

There's a good chance that the 4:1 SWR in the repeater portion of the band is causing a fair amount of loss in your feed line. Combine that loss with the polarization mismatch and your signal may indeed be weak at the repeaters.

An antenna tuner won't solve your problem. It will provide a low SWR at your transceiver, but the SWR will still be high at the antenna and won't mitigate the losses in your transmission line. Using an amplifier under high SWR conditions isn't a good idea, either. You could damage your feed line or the amplifier itself.

To get the best of both worlds (SSB and FM), you may need to invest in a separate antenna for the high end of the band. Because you're using repeaters, it doesn't need to be large. An omnidirectional antenna such as a ground plane may be adequate. If you have sufficient space on your mast, a small beam (mounted for vertical polarization) would be even better.

Q I want to put a 70-cm beam antenna in my attic, but I have a serious problem. The attic is small and the rafters are spaced such that I can't rotate the antenna. I suppose I can just point the antenna east and leave it, but I'd hate to miss activity to the west. Do you have any ideas?

A Why not use two 70-cm beams? Install one facing east and the other facing west. Then, use an RF relay to switch between them (see **Fig 1-34**). Just make sure that the relay you choose is rated for use at 70 cm.

Q I'm building a 2-meter, 4-element quad antenna. How should I connect the coaxial cable to the radiating element? If I route it through the antenna, will the performance suffer.

A Some quad designs call for a direct feed, connecting the coax directly to the driven element. Other designs call for a matching network and/or balun. The standard method for feeding the VHF quad you describe is to route the coax along the driven element support strut, then along the boom to the mast (see **Fig 1-35**). Routing the coax in the middle of the antenna elements in this manner will not substantially affect its performance.

INDOOR/LIMITED HF SPACE ANTENNAS

Q I'm about to begin building a home in an area where there is a 'no outside antennas' ordinance. What are my options for hidden HF antennas?

A If a flagpole does not violate the ordinance, you might consider encasing a vertical antenna in PVC pipe and creating your own antenna/flagpole. An amateur in Florida described his success with this technique in the pages of New Ham Companion ("A Disguised Flagpole Antenna," May 1993 *QST*, p 65). If you intend to try this approach, it's best to lay down your coaxial cable before the sod goes into place. Use coax that's designed for burial in soil. Be careful not to mistake noncontaminating coax for the buriable variety. They are not necessarily the same! Also, be sure to use UV-resistant PVC for a long-lasting flagpole.

If a flagpole is out of the question, look to your attic as a location for hidden antennas. Even a tiny attic can probably accommodate a multiband wire dipole antenna. You might tack a wire dipole onto your ceiling and feed it with 450-Ω ladder line. Don't worry about the overall length of the dipole, and don't concern yourself with keeping the antenna wires in nice, straight lines. Simply put up as much copper as possible, in any direction possible. Bring the ladder line to an antenna tuner with a balanced output. With luck you'll be able to use the tuner to get an acceptable SWR on several bands.

At the very least, you should be able to install a small HF loop antenna such as one of those made by MFJ Enterprises or Advanced Electronic Applications (AEA). These multiband loops are only a few feet in diameter and can be tuned remotely. In other words, you can place the loop out of sight in a closet or utility room and install the remote tuning unit beside your radio.

The downside of miniature loops is that their SWR bandwidth is extremely narrow. If you change frequency by as little as a few kilohertz, the SWR skyrockets. That's why the commercial loops (such as the one shown in **Fig 1-36**) use remote-controlled tuning capacitors. A tuning control—usually installed beside your radio—allows you to adjust the antenna in tiny steps. (You'll hear the signals and background noise rise sharply when you reach the point of resonance at your chosen frequency.) Retuning the loop every time you change frequency is a bit of a pain, but it's

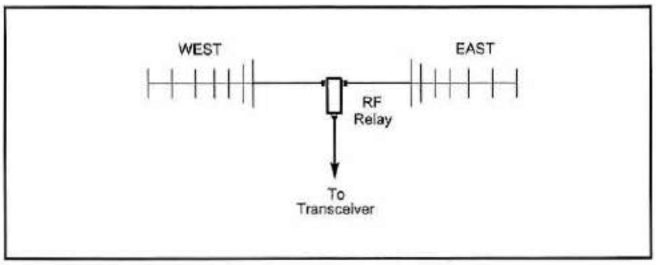


Fig 1-34—If you can't rotate your attic antennas, try installing two antennas and switching between them with an RF relay.

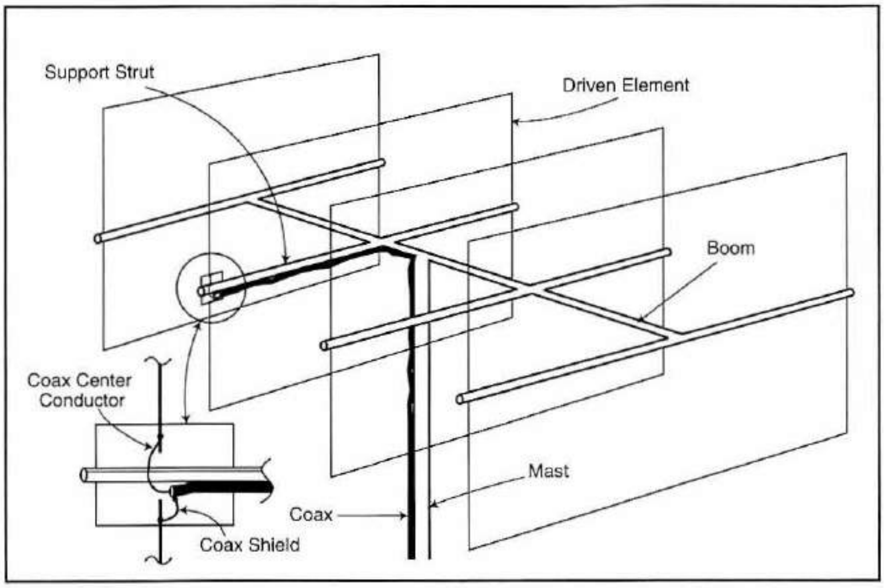


Fig 1-35—When connecting coaxial cable to a quad antenna, run the cable along the support strut to the boom, and from the boom to the mast. Secure the cable at several points to prevent it from moving in the wind. Vertical polarization is shown, which is standard for FM; for SSB and CW, horizontal polarization is the norm. Connections from coax to driven element should be soldered, and the exposed end of the coax should be waterproofed.

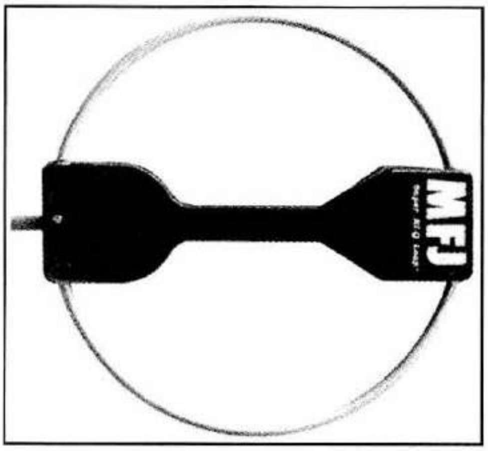


Fig 1-36—A miniature HF loop antenna manufactured by MFJ Enterprises. A similar version is offered by Advanced Electronic Applications (AEA). Check the advertising pages of *QST* for contact information.

a small price to pay for the ability to operate when you otherwise couldn't.

Don't let their size fool you. Miniature loops work remarkably well. One ham here at Headquarters used a loop to work 65 countries in one weekend during a DX contest. If you go the loop route, try to get the antenna as high as possible. Attics are often great locations for mini loops. As with any indoor antenna installation, keep your output power down and keep RF safety and RFI concerns in mind.

In any case, we recommend that you use low output power, 10 W or less. Beyond the obvious health concerns of generating a strong RF field in your apartment, higher power levels will probably wreak havoc to your neighbors' TV, stereos, VCRs and so on. You won't do much DX pileup busting with a low-power, indoor-antenna station, but you *will* make contacts, probably more than you might imagine.

Q How can I make a really simple *stealth* antenna?

A Many hams settle on a random end-fed wire, using #26 magnet wire for a reasonable compromise between strength and stealthiness. You can put up such an antenna up to about 50 feet in length using nylon monofilament fishing line for support and white shirt buttons for insulators. This works but is, of course, vulnerable to breakage from wind and ice. Still, it's better than no outside antenna at all! RadioShack carries several varieties of magnet wire.

Q I need to disguise my antenna. Can I spray paint it? Will the paint affect my signal?

A Yes, you can spray paint it. The few experiments people have done indicate no degradation, at least through microwave frequencies where the layer of paint is much less than a quarter wavelength. I'd stay away from metallic and conductive paints just to be safe.

Q I'm looking for an 80-meter antenna that doesn't require a lot of space. What can you suggest?

A How about trying the venerable inverted-L? This antenna, shown in **Fig 1-37**, is a top-loaded vertical that requires a fairly good ground system for efficient operation. Even so, it will work to a certain extent with whatever ground system you can manage. If nothing else, just lay as many radial wires on the ground as possible, regardless of length. Don't rely on a simple ground rod driven into the soil.

The overall dimensions of an inverted-L are roughly the same as those for a quarter-wavelength vertical. For use in the 75-meter phone band, that would translate to a total length of approximately 60 feet.

The antenna element can be bent at any point along its length. You'll get optimum DX performance when the vertical section is as long as possible. The top-loading horizontal wire doesn't have to be perfectly horizontal. It can slope up or down without drastically changing the feed-point impedance.

Q How can I use a mobile antenna on a balcony railing?

A There are a couple of approaches you can use. Ideally, the antenna would be mounted at right angles on the railing, sticking out perpendicular to the building. This isn't usually practical, however, so most hams mount their antennas vertically somehow. Some hams report excellent results using two mobile whips, forming a dipole and feeding it in the center.

Others use a single mobile whip and use the balcony railing as a ground plane. Unfortunately, this is rarely allowed in residential apartments, but does maximize the radiation efficiency. Even so, the "ground" formed by most balconies is pretty marginal. An improved ground plane can be made with one or more quarter-wavelength radials, connected to the shield of the coax, right where it connects to the antenna.

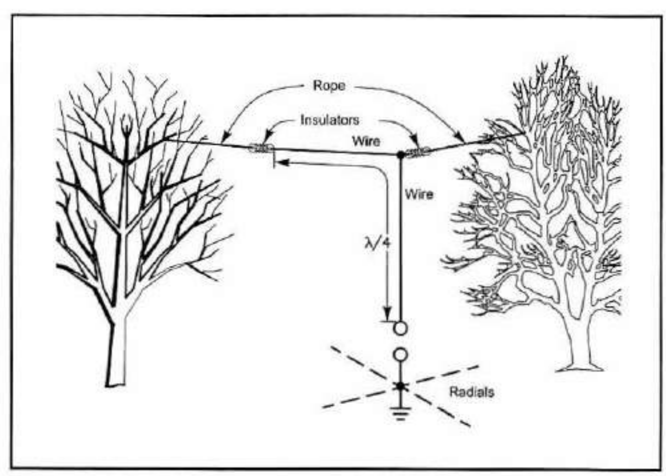


Fig 1-37—The inverted-L antenna can be supported by any convenient means.

Some hams have been able to mount their mobile whips on the roof of their building. You can use a small mast and a chimney mount strap if your building has a chimney, attaching the whip to the mast with a "mirror" mount designed for mobile whips. You can also make a bracket, bent at the angle of the roof, to mount the whip on the peak of the roof. You can attach quarter-wave radials to the bracket, and secure it to the roof with roofing nails.

Q Can I use a mag-mount indoors?

A This technique will generally work acceptably well at VHF and higher. In a pinch, mag-mounts have been placed on a metal surface such as a refrigerator, washer, dryer or even a metal TV tray. They should be mounted as close as possible to a window, or at least an exterior wall. They won't work as well as an antenna high and in the clear, but if you can hit a local repeater, that may be all you need. They generally will work a *lot* better than the inefficient rubber duckie antenna that comes with most H-Ts.

Q What is the "Shorty Forty"?

A The Shorty Forty is a compact 40-meter dipole antenna for limited-space applications developed by Jack Sobel, WØSVM. By using center loading (see **Fig 1-38**), the Shorty Forty can squeeze into less than 38 feet of horizontal space. Compare that to almost 67 feet required for a full-sized 40-meter dipole.

Q I want to put up a wire antenna for HF work, but I can't install a "traditional" center-fed dipole. Is there any way I could feed it from the end? That would be a lot more convenient for my particular installation.

A As long as you observe some precautions, why not? When a straight-wire antenna is fed at one end by a two-wire feed line (such as 450-Ω ladder line), the length of the antenna portion becomes critical if you want to minimize radiation from the feed line itself. Such an antenna system for multiband operation is the *end-fed* or *Zepp-fed* antenna shown in **Fig 1-39**. The antenna length should be 1/2 wavelength at the lowest operating frequency. The feedline length can be whatever is most convenient, but try to avoid lengths that are 1/4 wavelength at any of your operating frequencies. This will avoid impedances that are difficult to accommodate using an antenna tuner. Just connect the ladder line to a balanced-line antenna tuner and you're ready to go!

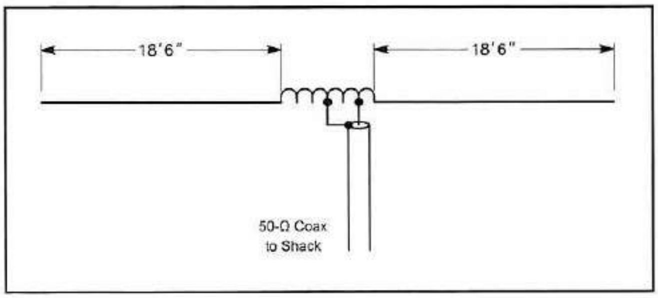


Fig 1-38—The WØSVM "Shorty Forty" is a center-loaded 40-meter antenna. The dimensions shown are for 7.0 MHz. The loading coil is 5 inches long and 2 1/2 inches in diameter. It has a total of 30 turns of #12 wire wound at 6 turns per inch (Miniductor 3029 stock). The coax shield connects to the center of the coil and the center conductor is offset 2 or 3 turns, or whatever provides the best SWR.

RANDOM-WIRE ANTENNAS

Q Aren't Long Wire and Random Wire antennas the same thing?

A Many hams use the terms somewhat interchangeably. They can be the same thing, but not necessarily. A "random" wire is one that is put up irrespective of length. It is not expected to resonant on any amateur band, but will be tuned to resonance and matched to a particular frequency with some sort of antenna tuner. They are generally worked against earth ground, meaning that one end of the antenna is connected to the center conductor of a coaxial feed line or to the single-wire output of the antenna tuner and the other end of the feed line or the case of the tuner is connected to earth ground.

A "longwire" antenna is made the same way, but is generally two or more wavelengths long. Although usually fed with an antenna tuner and worked against earth ground, it is long so that it can give antenna gain over a shorter antenna. Like all horizontal antennas, it will work best for DX if it is high and in the clear.

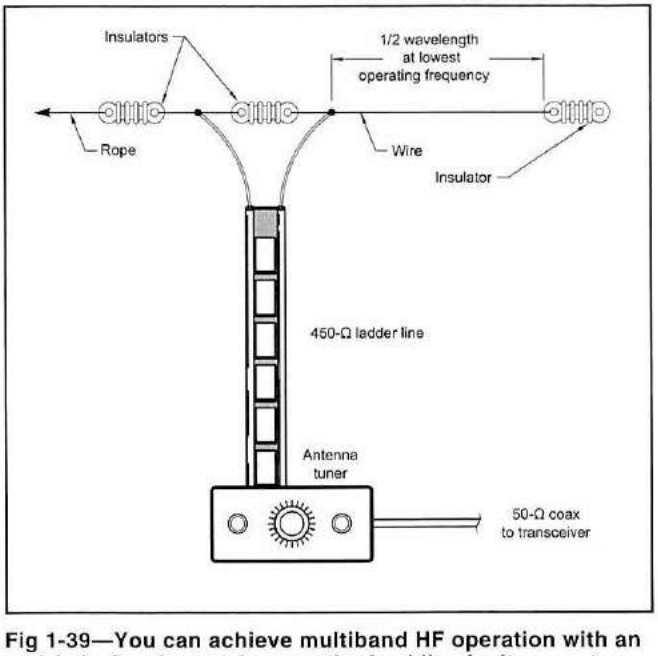


Fig 1-39—You can achieve multiband HF operation with an end-fed wire. Just make sure the feed line isn't a quarter wavelength at any of the frequencies on which you wish to operate.

Q **What is a Zepp antenna?**

A In the early days of short-wave communication an antenna consisting of a half-wave dipole, end-fed through a 1/4-wavelength transmission line, was developed as a trailing antenna for Zeppelin airships. In its utilization by amateurs, over the years, it has become popularly known as the "Zeppelin" or "Zepp" antenna. The term is now applied to practically any resonant antenna fed at the end by a two-wire transmission line. See **Fig 1-40**.

The mechanism of end feed is perhaps somewhat difficult to visualize, since only one of the two wires of the transmission line is connected to the antenna while the other is simply left free. The difficulty lies in the natural tendency to think in terms of current flow in ordinary electrical circuits, where it is necessary to have a complete loop between both terminals of the power source before any current can flow at all. However, you should consider the system as a transmission line terminated in an impedance not equal to the characteristic impedance of that line, and you'll understand better what is happening. The current flowing in each line of the two-wire transmission line is not equal and thus the line itself does radiate.

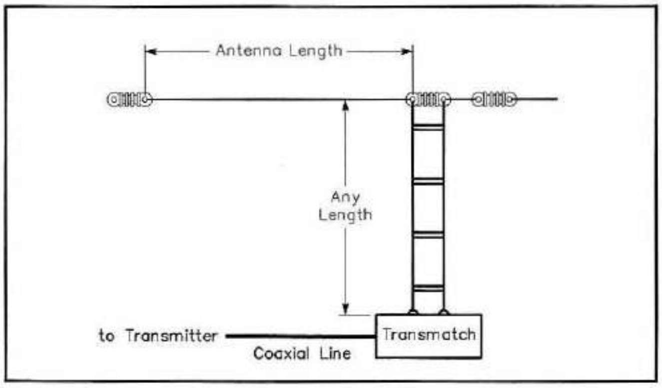


Fig 1-40—An end-fed Zepp antenna for multiband use.

LOOP ANTENNAS

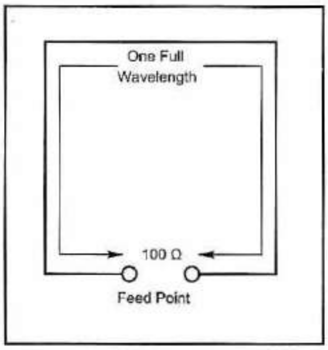
Q **When I study diagrams for loop antennas, I cannot understand how they could possibly work. They look like short circuits! Can you explain?**

A The essential concept that you need to understand about antennas is that the impedance exhibited at any point of the antenna will vary, depending on where you make the measurement. You should carefully look at the material about antenna impedance in *The ARRL Antenna Book*.

For example, consider a single half-wavelength piece of wire located up in the air, far from the ground. If you break the wire in the middle of the span and measure the resonant impedance at that point, you'll find a value of about 60 to 70 Ω. Instead, if you break the half-wavelength wire 1/4 wave along the length, the impedance you would measure at that point would be much higher than 60 Ω.

A loop antenna typically employs about a wavelength of wire overall. The impedance seen at the point where the two wires of the loop come back together is about 100 Ω (see **Fig 1-41**). Even though at first glance a loop looks like it must be a short circuit, it is not! To direct current (dc), a loop would indeed be a short, but not to RF (ac) energy. RF radiates from the loop of wire because the loop is relatively large in terms of wavelengths of RF energy. In fact, any conductor will radiate energy—and thus will exhibit impedance—if it is greater than a small fraction of the wavelength of the energy in question.

Fig 1-41—A loop antenna looks like a short circuit to dc, but as far as RF energy is concerned, a resonant full-wavelength loop has an impedance of about 100 Ω at its feed point.



Q **I do quite a bit of operating on 75-meter phone, primarily as a control station for a regional net. My antenna is a V-shaped horizontal dipole. The center is 36 feet above the ground with the ends attached to 32-foot wood poles. I know this configuration probably creates some odd radiation patterns, but I am constrained by my rather small house lot. Is there anything I can do to improve the overall performance? How about adding another dipole below the existing one, or switching to a loop antenna?**

A The way you've configured your 80-meter antenna system makes the best use of your present space. Using *EZNEC* to model your system, the resulting azimuth radiation pattern is not as bad as you might think (see **Fig 1-42**).

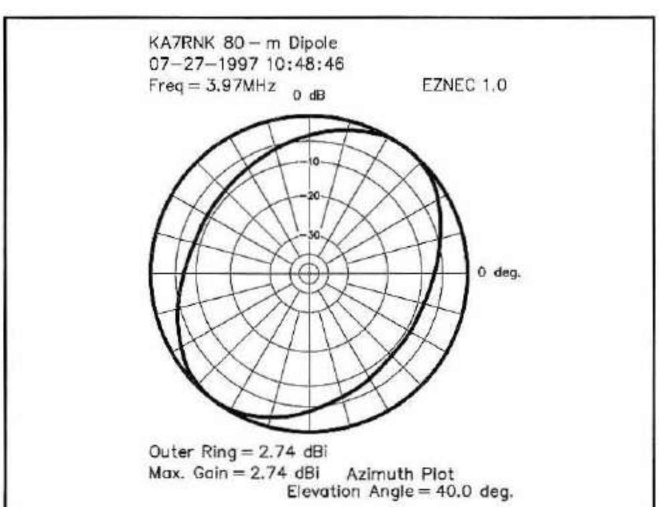


Fig 1-42—The azimuth radiation pattern of KA7RNK's 80-meter dipole as modeled by EZNEC.

In fact, it is probably close to optimal for net activities where you want a fairly omnidirectional pattern.

Adding another dipole so close below the original won't do you any good—the spacing is way too close and the height is way too low. Changing the configuration to a loop won't help much, either, except for making things a lot more complicated! The only way to improve the performance of your existing antenna is to raise it to an altitude of about 100 feet or more. That doesn't seem practical in your situation.

If you become interested in chasing DX on 75/80 meters, you might want to explore the possibility of adding a vertical antenna on your property. Install the antenna with as many radials as possible. With its lower angle of radiation, the vertical would give your long-range performance a boost. For domestic work, however, your existing dipole is still best.

BEVERAGE ANTENNAS

Q Beverage receiving antennas are well known for their low-noise, directional characteristics and are considered a must for serious low-band work. But what gives these antennas their low-noise characteristics? Is it the fact that they are directional (so they don't pick up noise from null areas), or does the relatively low height contribute to the low noise?

A A basic Beverage is simply a wire antenna, at least one wavelength long (and usually significantly longer), supported along its length at a fairly low height and terminated at the far end in its characteristic impedance (see **Fig 1-43**). The low-noise "magic" of the Beverage is in its inherent directivity. It discriminates against noise coming from other than the direction it's aimed. For example, in the northeastern US the main sources of noise on 80 or 160 meters are thunderstorms in the southeast. A Beverage aimed at Europe will be able to discriminate against signals coming off the back (ie, thunderstorms in Georgia) while favoring signals from Europe. The signal-to-noise ratio is thus improved in the favored direction.

You need a lot of real estate to erect a Beverage for 80 or 160 meters, the bands where this antenna is used to its best advantage. But even if set up properly, a Beverage is a very inefficient radiator. Therefore, Beverages are not suitable for use as transmitting antennas. For more detailed information on Beverages, see *The ARRL Antenna Book*.

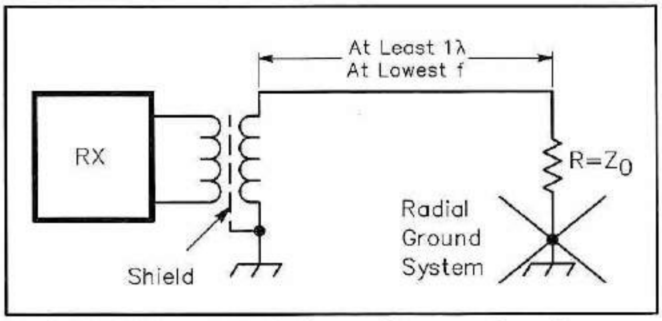


Fig 1-43—In its most basic form, a Beverage is a wire antenna, at least one wavelength long, supported along its length at a fairly low height and terminated at the far end in its characteristic impedance. A matching transformer is used to couple the transmission/feed-line to the receiver.

H-T ANTENNAS

Q I've heard that the so-called "rubber ducks" supplied with hand-held transceivers (H-Ts) are not very good antennas. Is this true?

A In terms of their ability to efficiently radiate signals, most rubber ducks are poor antennas. They're really little more than helical pieces of resistance wire encased in flexible rubber or plastic. They radiate, insofar as *any* piece of metal will radiate under the right conditions, but they don't do a very good job.

On the other hand, these flexible antennas are extremely durable. Considering the fact that H-Ts are often stuffed into car seats, jammed into coat pockets and operated under conditions that would snap a larger antenna in a heartbeat, they offer a reasonable compromise. Besides, H-Ts are designed primarily for use with repeaters whose sensitive receive systems compensate for the shortcomings of rubber ducks. If you intend to use an H-T at the fringe of a repeater's coverage area, replace the rubber duck with a longer telescoping antenna.

Q I purchased an H-T that was supplied with a screw-on rubber duck antenna. I also own a 1/4-wavelength telescoping whip antenna that I'd like to use, but it has a male BNC connector. Is there some sort of adapter that will allow me to use this antenna with my H-T?

A The type of connector your H-T uses is known as an *SMA*. In this case, it is a female SMA. To use your telescoping whip all you need is a male-SMA-to-female-BNC adapter. These are commonly available from several *QST* advertisers.

Q I need to replace the original equipment antenna on my ancient and honorable Yaesu 727 dualband H-Ts. Their BNC springs have plumb wore out. Have you any suggestions for evaluating replacements?

A ARRL has never done a review of replacement rubber duckie antennas. Keep in mind that the rubber duck on the HT is a very, very inefficient antenna. (We just can't be walking around with 3 feet of antenna sticking out of our shirt pocket.) Just about any of the after market antennas is as good as any other. You might even want to try to "roll your own." See Mar 1998 *QST* "Make Your Own "Rubber Duckies."

MATERIALS

Q Do I really need a fancy expensive center insulator for my dipole?

A A good center insulator is often useful for obtaining a reliable and weatherproof connection to coax. It is can be very difficult to weatherproof the end of a coaxial cable. Commercially available insulators have weatherproofing and a built-in SO-239 connector for your PL-259 connected coaxial cable. Many hams have built center insulators, especially for temporary installations, however. Paying close attention to mechanical considerations and waterproofing is important, though. Be assured: that antenna *will* come down just as that rare DX stations gives your call and signal report!

Q If radio waves are magnetic in nature, how come copper, aluminum, and other thing work as antennas? Isn't aluminum used for magnetic shielding?

A Radio waves are *electro*magnetic in nature. They consist of varying electric and magnetic fields traveling together through space. When they cut across a conductor, whether ferrous (containing iron) or non-ferrous, an electric current is induced.

Magnetic materials such as iron do make poor conductors for antennas, having much higher losses that one would calculate based purely on the resistivity of the material. Most conductors for antennas are copper if wire, and aluminum if tubing.

Q What is the effect of using insulated wire for antennas instead of bare wire?

A Insulated antenna wire exhibits some differences when compared to bare wire in the same application. For example, a dipole antenna made of insulated wire will be resonant at a lower frequency than its uninsulated counterpart. Depending on the material and the thickness of the insulation, the resonant frequency of the antenna could be lowered by up to about 3%. Generally, the effect on lower frequencies is less because the insulation thickness is such a negligible portion of a wavelength.

Q What is the absolute best wire to use for dipole, random wire, and long wire antennas?

A Superconductor, if you can get it... But seriously, copper is the most practical material for wire antennas of all kinds. Although solid copper is slightly electrically superior to stranded, the latter is far more flexible and durable. At HF, there is no significant difference between insulated and uninsulated wire. As to the diameter of the wire, #14 AWG stranded wire is by far the most common thing you'll find, although smaller and larger wires can also be used. If you live in a town where the zoning rules adhere to the National Electrical Code (NEC), then the minimum wire sizes you can use are #14 for unsupported lengths 150 feet or less and #10 for lengths longer than 150 feet. For "copper-clad steel, bronze or other high-strength material," the NEC specifies #12 for lengths greater than 150 feet (also #14 for shorter lengths).

A note on copper-clad steel—some of the available material uses very thinly-plated copper and this will pit over time, exposing the steel beneath. The steel then rusts fairly quickly and the antenna will break when the next gust of wind comes along. While hard-drawn copper does stretch causing antenna sag, it is still the most popular choice for antenna wire and if you have any doubt about your choice of wire, try copper.

Q PVC tubing is supposed to be a good insulator. I want to use a few short pieces as the end insulators for my new dipole, but the building supply store offers three or four different types. Does it make any difference which types I use?

A There can be a big difference. Various manufacturers use different additives to meet the strength requirements of standard PVC tubing. Some of these additives are conductive, and tubing containing them would not make good insulators. Unfortunately, you can't be sure by just looking at the color or manufacturer's code.

There is one quick test you can make at home. Place a 6-inch length of tubing in your microwave oven, with a glass of water. Run the oven at full power for 60 seconds or so, and then feel the tubing. If it is still at room temperature, run it for another 30 or 60 seconds. If there is still no apparent heating, the tubing was made with negligible amounts of conducting additives, if any. You can safely use it as an insulator. Any heating means there is a conductive additive present. Don't use this PVC with your antennas!

The glass of water is a safety precaution for the microwave oven. If the PVC is nonconducting, there would be no load for the microwave energy, which could result in damage to the oven. The glass of water acts as a load, thus insuring you don't harm the oven.

Q In wire antenna construction articles I often run into references such as "THHN stranded copper wire." What does THHN mean?

A THHN is one of many National Electrical Code conductor type designations. Specifically, THHN is the designation for PVC insulated, nylon-jacketed conductor for use in dry locations. Alternatively, THWN stands for a PVC insulated, nylon-jacketed conductor for use in wet *or* dry locations.

Some other NEC designators you may encounter include:

USE—underground service entrance cable
TC—power and control tray cable
TFN—PVC insulated, nylon-jacketed conductors in sizes #18 and #16 AWG for use in dry locations.
RTA—Thermoplastic insulated, aluminum shielded, polyethylene-jacketed communication cable.

Q Would 24-gauge wire be too thin to use for building an HF dipole antenna?

A No, electrically it works fine. Its impedance characteristics at various heights and frequencies may make such a dipole a little narrowbanded. This means that you may find yourself using your antenna tuner more often than usual.

If stealth is your objective, don't forget to use monofilament fishing line as your "rope" and shirt buttons as your insulators! And if you're installing an antenna outdoors, note that the National Electrical Code specifies at least #14 wire for spans less than 150 feet.

FEED LINES

Connectors

Q **Could you print the instructions on how to install a male BNC connector on RG-58 coax?**

A Sure. They say a picture is worth a thousand words. Enjoy. See **Fig 1-44**.

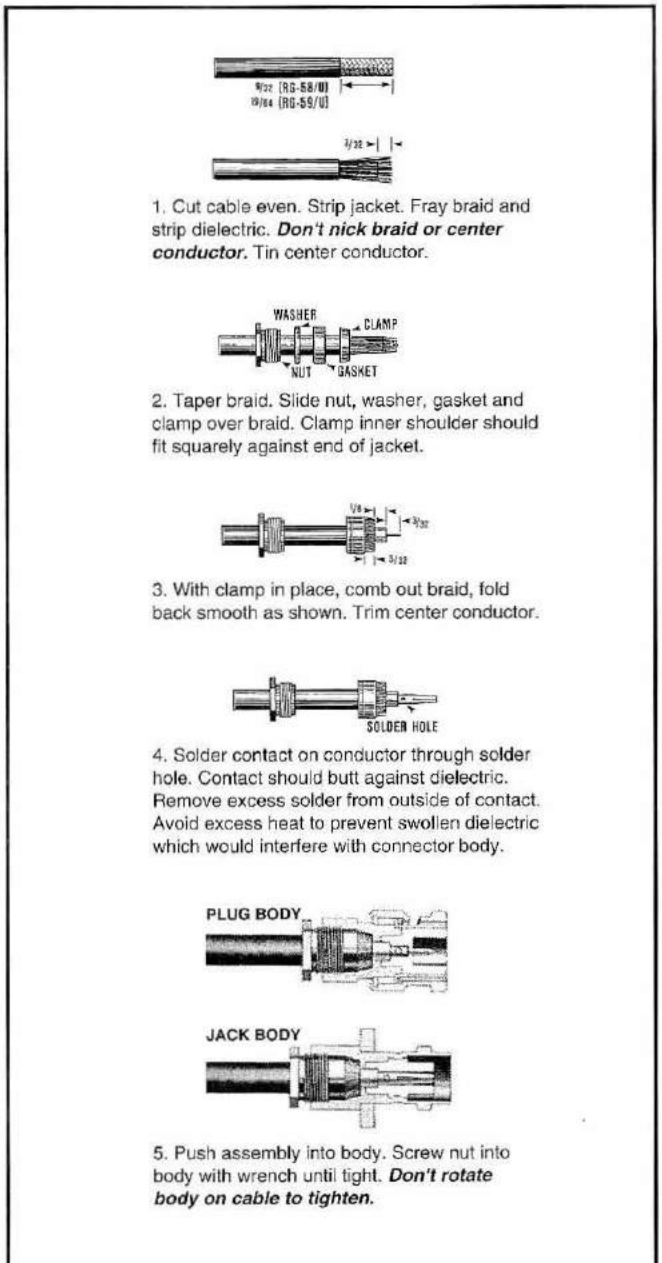


Fig 1-44—Installing a BNC connector in five steps.

Installation

Q **How do I get the coax into the house?**

A See **Fig 1-45**, which shows a method that avoids drilling holes in your house. Cut a piece of 2 × 4 lumber so that it fits snugly into the lower sash. Drill a hole large enough for your coaxial cable. Pass the cable through the board and through the window. Close the window onto the board and the upper frame to prevent the window from being opened from the outside. Connect the coax to your antenna, but leave enough slack in the cable to form a drip loop just outside the window. Finally, buy some packing-foam material and use it to block any drafty gaps created by your new installation. This can be insulated even better than shown with a bit of imagination. When it is time to move, the whole assembly can be removed without damage to the window.

If you can drill a hole in the building, you have even more leeway. Using a 1" or 1¼" wood bit, drill a hole for each coax cable coming through the sill of the house—that is the lumber just above the cinder block or poured concrete of the foundation. After passing the coax, caulk it to make it air (and bug) tight. If the sill is too small, then there is always another wooden structure just above it that can be accessed from the basement. Another, more radical and permanent solution for multiple coaxes is to choose an out of the way place and put a small section of PVC pipe through the wall. Use down facing elbows at each end stuffed with insulation to keep the weather from getting into the house.

Q **Can you offer some advice on waterproofing coaxial connectors?**

A Apply clear silicone grease to the threads and other parts of the connectors before you put them together.

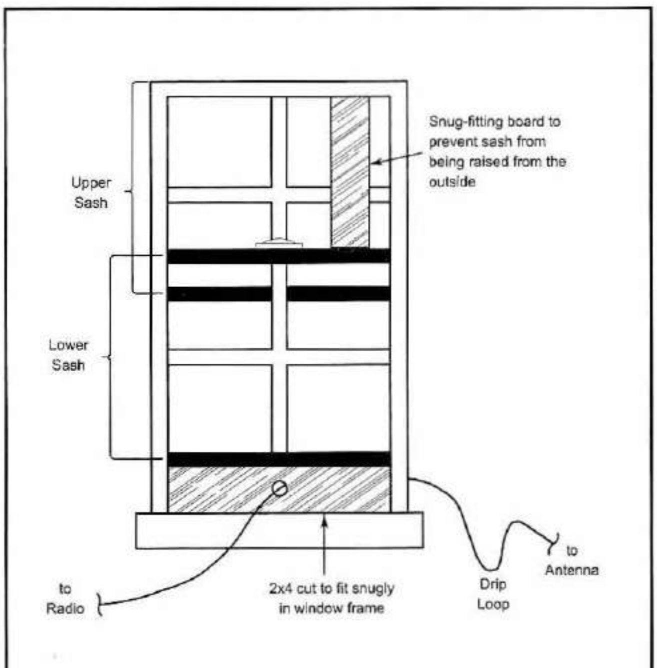


Fig 1-45—A narrow 2 × 4 with a properly drilled hole will pass a coaxial cable through a window without modifying the window itself.

This will help keep out moisture. (It also makes it easier to get them apart after years of exposure.)

Wrap a layer self-vulcanizing splicing tape around the assembled connection. You'll find this type of tape at electrical supply stores. Cover this layer with several wraps of Scotch 33 or 88, then Scotchkote. Be sure to overlap the edges of adjacent turns of tape to ensure watertightness. The combination of all these steps should protect your coaxial connectors for years to come.

Q I'm trying to put up a 15-meter dipole antenna for the Novice/Technician CW band. When I try to solder my coax to the antenna wires, the solder won't flow! What am I doing wrong?

A You aren't applying enough heat. Those long pieces of antenna wire act as heat sinks, quickly drawing heat away from the area you're trying to solder. If you're doing this outdoors, breezes or cold temperatures will make it even more difficult. You need a high-wattage soldering gun, or a small butane torch. Just be sure to wear gloves and goggles. At these temperatures, the solder can bubble and boil, splattering hot flux in all directions. You might also just assemble the antenna indoors before you go out and hang it in the air.

Q My wire antenna broke. If I solder the wires back together will the antenna still be mechanically and electrically sound?

A Yes, you can solder the antenna wires together to repair the break. Instead of relying on the strength of the solder to hold the taut wire together you must twist the broken ends into small loops, and then connect them together with the new piece of wire. Twist the wires and solder all around to make a strong physical bond.

Second, the reason the wire broke in the first place may be that it was too taut. You want to have a little sag in the antenna wire so that the tension on the wire isn't too great, and to allow it to swing a bit rather than snap in a heavy wind.

If the repaired antenna snaps again, even after you've introduced a little slack with the newly added length of wire, then you should use heavier wire.

Q I want to add some receive preamplifiers to my VHF and UHF antennas. Are they capable of electronically switching about 100 W of RF?

A If you want to mount an external preamp at the antenna, you'll need some sort of an RF bypass relay to take the preamp out of the line during transmit. Some *QST* advertisers offer preamplifiers with built-in bypass relays that will handle power levels from 25 to 100 W or more. Be sure to check the ratings. Some of these preamps offer RF sensing circuitry to automatically switch the bypass relay. Others are switched by a control line on your transceiver. (If your rig has one, it may be an external relay jack or a keying control line on an accessory jack.) Another approach is to purchase a preamplifier and coaxial relays separately and build your own. If you go this route, timing is critical: You need to be sure that the relay switches the preamplifier out of the line *before* the signal from your transmitter amplifier reaches the relay, or you will damage the preamp. Some hams use a *sequencer* to switch the preamplifier, power amplifier and transceiver in the right order.

Q My friend says you should change your coax feed line every few years because the line decays with time. Is this true? Is there any way to test the feed line without dropping the antenna?

A Well, yes and no! Coax does change with time, but fortunately it does not change that much or that quickly if properly weatherproofed. Although the best method to test coax is to feed power into an unterminated line and measure the return loss, you can also keep track of your coax and antenna condition by copying a few tricks from the old timers.

Assuming you are feeding a Yagi, dipole or some other antenna where there is no physical contact between one half of the driven element and the other, the first step is to measure the resistance from the coax connector center pin to the connector body. Normally, it should measure as an open circuit, on the highest resistance range of your meter. As an alternative, some hams solder a 100-kΩ resistor across the antenna at the feed point. (The resistor does not affect your signal.) Then the coax resistance measurement should show a value roughly equal to the resistor. If you measure an open circuit, however, you'll know that the coax is broken. If you measure less than the value of the resistor, you know there is some sort of short.

A second trick requires a power meter and a field-strength meter. Set your transmitter to some fixed power level, maybe just a few watts. With a field-strength meter mounted 20 or 30 feet from your antenna, record the reading on the meter as well as the power level of the transmitter and your transmitting frequency. If you periodically repeat this measurement using the same frequency, power level, field-strength meter and distance from the antenna, you can see if anything has changed. Remember, weather and other factors will always cause some changes—perhaps 20% of the measured field strength. But a slow decrease in field strength over several months, or any radical change, will tell you something is going wrong!

Q I am building a six-meter antenna. To minimize costs I have a short feed line out of RG-58 cable to the antenna. I have RG-8 cable I will connect to that to run to my radio. Do you think there will be interference within these two cables? Will they work to receive on 6 meters?

A There will be no adverse consequences in using the two types of cable since they are both 52 Ω. It would have been better to use all RG-8 in the VHF range looking at it from an efficiency standpoint though, since it is less lossy than the smaller-diameter RG-58.

Q What do manufacturers mean when they say that a coaxial cable is contaminating?

A Marc Abramson, KC9VW, of Cable X-Perts, Inc. states:

"A coaxial cable with a noncontaminating jacket is one that will stand up to long-term exposure to the elements. When most coaxial cables endure the harshness of constant weathering, the chemicals in their outer jackets begin to deteriorate and migrate into the shield. The result is a change in electrical characteristics over time. A noncontaminating cable is designed to resist this deterioration much longer than standard coax. This *doesn't* mean that you can bury noncontaminating coax. For underground installations you must use a cable that's specifically designed for that purpose."

Q I've been told that you have to be careful not to crimp coaxial cable. Why?

A The impedance of any feed line is determined by the spacing between the conductors and the type of insulating material that separates them. Many hams use 50 Ω *coaxial* cable in which the center conductor is surrounded by a solid or braided shield (see **Fig 1-46**). If the distance between the center conductor and the shield is not maintained, the impedance will change. When you put a crimp in coax, you effectively change that separation distance by moving the shield and the center conductor closer together. This will cause an impedance change (or "bump") at the point where the crimp occurs.

An impedance bump becomes a problem if it causes a significant change in the total antenna system impedance "seen" by your transceiver. If the deviation isn't serious, you (and your radio) will never notice. A substantial shift, however, can manifest itself as an unacceptably high SWR (more than about 2:1 for modern solid-state radios). If you don't have an antenna tuner to cope with the mismatch, your radio may scale back its output. Even with a tuner in the line to make the radio happy, RF attenuation in the coax will increase.

So it makes good sense to avoid crimping your coax. Don't bend it too sharply, or compress it in a door or window. And remember that the prohibition against crimping applies to open-wire feed lines as well!

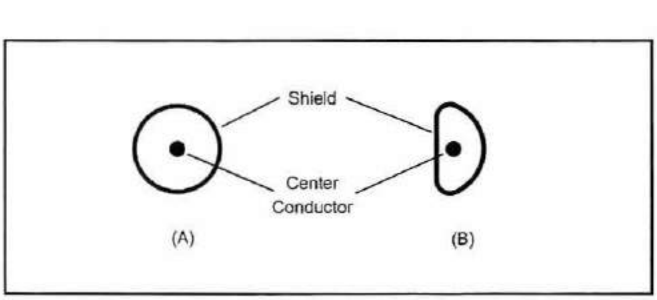


Fig 1-46—A cross section of standard 50 Ω coaxial cable is shown at A. At B, the effects of crimping. Notice how the shield and center conductor are now closer together.

Q I know that the impedance of an antenna will be matched at the end of any ½-wavelength feed line (adjusting for the velocity factor of the feed line). This is an important concept because it effectively eliminates the need for a matching transformer between the feed line and the antenna, even if the two are of very different impedances. Although the authors I have read don't come right out and say so, wouldn't it also be true that any multiple of a ½-wavelength feed line (eg, a full wavelength or a wavelength and a half) would have the same characteristic?

A Yes, an electrical half wavelength (or an integral multiple of a half wavelength) will duplicate the impedance at the load end at the input end. However, there will be a slight change due to losses in the line.

For example, 92.77 feet of RG-213 cable at 3.5 MHz is a half wavelength long, since the velocity factor is 0.66 for this cable. Placing a 100-Ω resistor at the load end of the cable causes the impedance at the input of the cable to be $94.7 - j\,0.1\ \Omega$, since the loss in this length of cable is about 0.40 dB at 3.5 MHz.

If the cable length is 2×92.77 feet = 185.55 feet (ie, a full wavelength long), the same 100-Ω resistive load will show up as $90.2 - j\,0.47\ \Omega$ at the input of the line, since the loss is now up to 0.79 dB. Note that the input impedance has gone slightly more capacitive in reactance.

If you have Web capability, download *TL.ZIP* from *ARRLWeb* at: **www.arrl.org/files/bbs/programs/**. The file contains the program *TL.EXE* plus its document file *TL.DOC*. This program will let you play with transmission lines on your computer and see what happens for many different situations. A more sophisticated version of *TL.EXE* (which, by the way, stands for "Transmission Line") is bundled with the 18th edition of *The ARRL Antenna Book*. This program is called *TLA.EXE* (standing for "Transmission Line, Advanced"). It will do even more computations for transmission lines. An even more sophisticated Windows version is in the 19th edition, called *TLW* (for "Transmission Line for Windows").

Q Believe it or not, I was recently given a 200-foot roll of Belden 9913 coaxial cable. I know 9913 is often used at VHF and UHF, but what about HF? Can you put this stuff to work with HF antennas? If you can, why don't more hams do so?

A Any feed line that is useable on VHF or UHF is useable on HF. In fact, 9913 and other low-loss cables have excellent performance characteristics at HF frequencies. The main reason you don't see more hams using such feed lines at HF is primarily economic.

For example, assume a matched 50-Ω antenna system, 200-feet of cable and a transmitted signal on 21.300 MHz. By using 9913 in this system you'll have a total loss of 1.2 dB. Switch to RG-8 foam coax at about half the price per foot and your loss rises slightly to 1.5 dB—an undetectable difference on the receiving end!

Since your 9913 was free, all this talk about economics is moot. There are other things to consider, though. Ask any veteran ham and you'll hear stories about water getting into 9913 coax. This is because 9913 is essentially hollow with a spiral of plastic supporting the center conductor. If you don't weatherproof your exterior connections *thoroughly*, water will find its way into the cable. Also, be careful not to bend your 9913 too severely. It can't handle turns and corners as well as solid or foam cables.

Q Can Cable TV coax be used for Amateur Radio applications?

A Cable TV (CATV) coax is, for the most part, RG-6, RG-59 and a few varieties of hardline. All of these cables have characteristic impedance of 75 Ω as opposed to the 50 Ω feed lines that hams usually use.

Does this mean that you cannot use Cable TV coax? Not at all. Assuming you have a modern-day rig, its output network is designed to accommodate a 50-Ω load, but the network can usually handle a 75 Ω impedance with little difficulty (you would see an SWR of approximately 1.5:1). Most dipole antennas, for example, have feed point impedances between 50 to 100 Ω, depending on a number of factors such as height above ground. So, a 75-Ω feed line should present a reasonably good match.

So why don't hams use Cable TV coax? The answer is that some do, but there are several factors that make the traditional 50-Ω cables more attractive. Cable TV coax uses an aluminum shield and it is often difficult to solder. And as I've already mentioned, the 75-Ω impedance isn't suitable for all amateur antennas. Having said all that, the price of Cable TV coax is often too low to refuse—as in *free!* This cable often arrives at your local cable company on 2000 foot+ spools and they often can't use the left-over reel ends. For a company, which may be stringing miles of cable, a remnant spool may contain 100 feet or more of coax that they may be willing to sell at a nominal fee, or simply give away.

Q Is it possible to use RG-174 coaxial cable as part of a "stealth" dipole for 40 meters? I need an antenna that's hard to see! How bad would the losses get if I tried to use this antenna on other HF bands?

A RG-174 is *tiny* coax, only about 0.1 inch in diameter! It is usually used for short-distance coaxial connections in a radio or transceiver. At 10 MHz, 100 feet of RG-174 will lose 4 dB into a 50-Ω dummy load (ie, this is the *matched-line* loss). At 7 MHz, the matched-line loss is about 3.3 dB/100 feet. If you were to pump 100 W into one end, and have a perfectly matched dipole at the other end, you'd burn up more than 50 W in the line. You'll probably burn up the line itself!

When you talk about loading your 40-meter antenna on other bands, the situation gets worse. The impedance will vary all over the place, causing lots of feed-line loss due to a high SWR on bands where the dipole isn't resonant. For example, if you tried to feed a 40-meter dipole on 20 meters with 100 feet of RG-174, the loss would be about 14 dB. This means that 100 W on the transmitter side would result in 4 W at the antenna side of your RG-174—or at least that's what you'd measure just before the coax melted.

Q Best length or multiples thereof to cut feed lines?

A The best length is usually the shortest length that will connect the antenna to the radio. Of course that was an obvious answer! In practice, there is little to be lost by adding more cable indoors, for example, if you move the radio and find yourself a few feet short. Be sure to use high-quality connectors designed for use at the intended frequency.

If the feed line has a different impedance from the antenna and you find yourself needing an antenna tuner to working with the resulting SWR, there may be an optimum feed line length that results in the lowest overall system loss in conjunction with that antenna tuner. Some tuner configurations are notoriously lossy when trying to work into very low impedances.

The *TLA* or *TLW* programs available with the *The ARRL Antenna Book* can be useful for looking at different situations, once you know the feed-point impedance up at the antenna, either by modeling it or measuring it. *TLA* or *TLW* can calculate tuner loss, feed-line loss, and the impedance presented to the tuner, along with the stresses placed on the components used in various tuner configurations.

BALUNS

Q Do I need a balun on my dipole?

A The answer is yes and no. A common-mode choke balun may be useful on a dipole if you have a problem with RF coming down the outside of the coax. This might manifest itself by your having RF floating around the shack—with such things as blinking TNCs, biting microphones, unintentionally keyed 2-meter rigs, and such. I would not purchase one unless I had such problems and until was sure that all my grounding was good.

Q I'm confused about the issue of whether to place a balun at the center of a dipole antenna. Some references say "Yes," but others say, "No." Which is it?

A The discussions (and arguments) about baluns and antennas will probably go on forever. Technically speaking, if you want minimal radiation from a coaxial feed line attached to a balanced antenna such as a dipole, you should use a balun. But with a well-designed dipole, feed line radiation is minimal anyway.

In the case of a beam antenna, however, even a small amount of feed line radiation can be a problem. The absence of a balun can skew the pattern a bit. On a large VHF or UHF antenna, aiming can be critical and a few degrees of error can cause problems. Even more important, however, is that the use of a balun on a beam helps preserve the designed front-to-back or front-to-side ratio of the antenna system. Feed-line radiation also means feed line pickup, and even a small amount of feed line pickup can degrade a 20 dB front-to-back ratio. This means that when you point an antenna at Europe, you could also be picking up more US stations than you intend.

In the case of a dipole antenna, however, feed line radiation and pickup might not be all that bad! A low dipole is an omnidirectional antenna (more or less), and a small amount of feed line radiation would tend to fill in any holes that might exist in the radiation pattern. If you are running modest power, and your antenna feed line does not pass close to susceptible equipment (with possible RFI problems), you may find that the balun really doesn't make much difference at all.

Q I have two questions:
When 300- or 450-Ω ladder line is connected to the center feed point of a 1/2-wavelength dipole, why is a matching device such as a 4:1 balun never indicated at the feed point? Isn't the feed-point impedance about 50 to 70 Ω?
Why is a 4:1 balun used at the junction of ladder line and 50-W coax at the house and near the antenna tuner, while other designs specify a 1:1 balun when the junction is somewhat farther away?

A I think we can answer both questions with one discussion. Let me start off by saying that ladder line is designed to be used with a balanced load and a balanced source. A half-wavelength dipole is inherently a balanced load, but at the other end of the line, your transceiver is an unbalanced source—it's designed to work into an unbalanced 50-Ω load. Enter the balun, a contraction of the words BALanced-to-UNbalanced.

The main function of a balun is to provide the transition from a balanced source or load to an unbalanced load or source. It can only do its job properly when it is operated at the impedance levels for which it was designed. You can find several varieties of baluns in the amateur world: 1:1 and 4:1 baluns are the most common. A 4:1 balun is usually designed to transform 200 Ω balanced to 50 Ω unbalanced over a specific frequency range. A 1:1 balun is designed for 50 Ω to 50 Ω, balanced-to-unbalanced applications. If you present a balun with impedances it was not designed to handle, some nasty things can happen, often involving smoke, sparks and perhaps some cussing.

In the case you describe, a 1/2-wavelength dipole does indeed present about a 50 to 70-Ω impedance to the feed line connected to it—if the dipole is close to resonance. If you use a coaxial cable feed line like RG-213 with this antenna, the SWR will be low and the transmitter will work just fine. Because it must be resonant, a dipole fed with coax is basically a single-band antenna (although a 40-meter dipole is often used on its third harmonic resonance on 15 meters).

However, many people have only limited amounts of physical space. In fact, they consider themselves lucky to put up a single dipole, which they'd love to be able to use on several bands. When an antenna is not resonant, its feed-point impedance will vary over a wide range, meaning that the most efficient way to feed such a multiband antenna is to use open-wire transmission line.

Here, the dipole is balanced, and so is the open-wire transmission line. There is no need for a 4:1 balun—yet. Once the balanced feed line gets down to the transmitter in your ham shack, we need to make the transition from balanced to unbalanced. This is where the antenna tuner comes in, along with some sort of balun again. Amateur antenna tuner designs have often used a 4:1 balun at their unbalanced output terminals so that they could be used with balanced feed lines. Baluns used in this manner are exposed to a wide range of impedances, and they are generally made extra rugged so that they don't arc or burn up.

These baluns are not being used in an optimal manner when used in this fashion, but they do well enough. See the fine two-part article on evaluating antenna tuners in April and May 1995 *QST* by Frank Witt, AI1H.

Q I need your assistance in determining the correct length for the ladder line on a 147-foot dipole. Does it have to be a specific length or will a random length be sufficient? Would the use of a 4:1 balun help in tuning this dipole on 80 to 10 meters?

A A random length may be sufficient—many amateurs will just put up a length of wire and try it out, seeing if they can get the tuner to load properly on all bands. It is possible for computer-savvy amateurs to calculate the impedance of the antenna and the effect of the feed line with modeling programs, such as *NEC-2* and Serenade SV. Perhaps the best approach may be measure the impedance of the antenna and feed line, and then use a modeling program or Smith chart to calculate the impedance of the antenna. This is better than antenna modeling, since many HF dipoles are too close to interacting wires and other conductors for simple computer models to be highly accurate. The length of the feed line can then be determined to minimize system loss with an accurate model of your antenna tuner.

A 4:1 balun is difficult to use properly in this situation. The balun will see impedances on a typical center-fed multiband dipole on many frequencies that may cause it to operate inefficiently. It may be possible to feed the antenna off center, and get more manageable impedances. However, an off center feed line may have significant interactions with the antenna, causing feed line radiation that may be very difficult to control.

Q I am planning to put up a folded dipole and was going to feed it with RG-8 coax through a 4:1 balun. In consulting *The ARRL Handbook* and *The ARRL Antenna Book*, neither suggest this method of feed. Is there something wrong with feeding the folded dipole with coax and a 4:1 balun?

A There is nothing wrong with feeding a folded dipole with a 4:1 balun, so long as you are going to use it as a single-band antenna. It's when you try to extend this technique to other bands that you can get into difficulties, such as burning up the balun, as mentioned previously.

Q Is there any way to test a balun before actually using it on the air?

A You can test a balun by connecting a simulated antenna load on the output (antenna) side of the balun. Connect your transmitter (with an SWR meter) on the input side. In the case of a 4:1 balun, use a 200 Ω resistor as your simulated antenna (see **Fig 1-47**). If the balun is functioning properly, you should see a low SWR—less than 1.5:1—when you key your transmitter. This means that the 4:1 balun is transforming the 200 Ω load to 50 Ω (200 / 4 = 50).

If you have a 1:1 balun, you can use the same test. Simply substitute a 50-Ω resistor for the load. The catch is that the load resistors must be noninductive and capable of dissipating the output power of your transmitter. Even if you turn your transmitter output down to 10 W, you'll still need a heavy-duty 10-Ω resistor.

Many hams have found that the low-power SWR analyzers available from MFJ and other manufacturers make this kind of test really easy, and they can use even ¼-W resistors without fear of burning them up.

Q What is the difference between a voltage balun and a current balun?

A The function of any balun is pretty straightforward. It acts as a transformer between a balanced and unbalanced line. For example, 450-Ω ladder line connected to a multiband dipole antenna is balanced, but the coax going to your transceiver is unbalanced. The balun serves as a "bridge" between the two. (That's why antenna tuners with "balanced outputs" contain baluns.)

The difference between current and voltage baluns is in the way their transformer windings are configured. Voltage baluns behave somewhat like conventional transformers. The voltage going in is transformed to a different voltage going out.

Current baluns operate by controlling the flow of the current in each of the balanced terminals. Some current baluns (such as the coax air-wound type) function simply as brute-force chokes, balancing the currents inside the coax by preventing the flow of current on the outside of the coax.

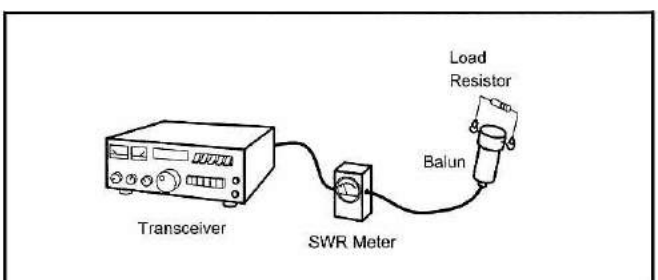


Fig 1-47—You can test a balun before you use it by simulating an antenna with a resistor. If you're testing a 4-1 balun, use a 200-Ω resistor. To test a 1:1 balun, use a 50-Ω resistor. In either case, if the balun is working properly, the SWR should be 1:1 or very close to it. Transmit with very low output power (10 W or less) and use a high-wattage resistor, or else use a low-power SWR analyzer instrument.

For much more detailed information on the way baluns work, pick up a copy of *Transmission Line Transformers*, which is now available from ARRL Publication Sales.

Q What is a W2DU balun?

A Common-mode currents on antenna feed lines are often the culprits when directional patterns are distorted or SWR readings become unpredictable. The solution is a balun—a contraction of the words *bal*anced to *un*balanced. Baluns eliminate these common-mode currents while making the transition between an unbalanced feed line (such as coaxial cable) and a balanced load (such as an antenna).

There are many types of balun designs, but Walt Maxwell, W2DU, developed the one you're asking about. It is a choke-type balun that consists of a number of small ferrite cores placed directly over a section of coaxial cable where it is connected to the antenna. The W2DU balun in Figure 2 is a low-power version using 50 Amidon FB-73-2401 cores slipped over a 1-foot length of RG-58 coax. Twelve Amidon FB-77-1024 cores on RG-8 or RG-213 will do the same job. The 70-series cores are best for HF work. Type 43 or 61 is best for VHF. The W2DU balun is very effective and, best of all, very easy to make. See **Fig 1-48**.

Q I want to put up a single dipole antenna and feed it with ladder line. Can I terminate the ladder line in a 4:1 remote balun just before it comes through my window? Maybe then I could bring coaxial cable the rest of the way into the shack. My window has aluminum sashes and I want to keep them from coming in contact with the ladder line.

A Yes, you can use that approach, but here's an alternative. Take a window in your shack apart and replace a pane of glass with a sheet of Plexiglas cut to the same size. Now you can drill (carefully!) through the Plexiglas to make a hole or slot to bring in the ladder line.

A dipole fed with ladder line can often be used as an effective multi-band antenna. On most bands, the ladder line is not matched to the antenna, resulting in a high standing-wave ratio (SWR). Although the characteristic impedance of the ladder line may be 450 Ω, the actual impedance looking into the line at the shack will not be 450 Ω; in fact,

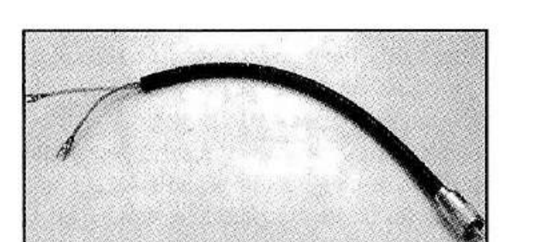


Fig 1-48—The W2DU balun consists of ferrite cores over a length of coax.

it is probably anything *but* 450 Ω! A remote balun works well near its design impedance, but if it used significantly away from its design impedance, it will not operate efficiently. You may find that on one or more bands, the balun gets hot, indicating that it is not functioning well on that band. If it doesn't get hot, though, you know it is operating efficiently and can be used.

If you do go the remote balun route, use as little coax as possible between the balun and your transceiver. This is important because the SWR on the coax is probably going to be high at times. Coax can get fairly lossy if the SWR is high, and keeping the length down will keep the losses down. Also, the coax must be able to withstand the voltages and currents present when it is operated at a high SWR. If you run QRP, you can probably use RG-58 type coax, but if you run 100 W or so, use larger diameter coax, such as RG-8 or RG-213.

Q It has been suggested that feeding a dipole with ladder line takes advantage of its low-loss characteristics to allow use the dipole on other bands. I tried this. I put up a 40-meter dipole and fed it with ladder line. The ladder line is connected to the balanced output of my antenna tuner. It works well on 40 and, all the bands above, but I can't use it on 80. When I try, the balun in the tuner seems to arc. Any suggestions?

A Don't give up hope! Transmission lines act as both feed lines and impedance transformers. Try connecting an additional 1/8- or 1/4-wavelength piece of transmission line in series with your current feed line. Loosely coil the new line and tack the coil up on the wall. Often, by changing the length of the line, the antenna tuner will see a different impedance—one it can match more readily without having a high-voltage node right at the connection of the balun in your tuner.

SWR

Q What is SWR?

A To visualize the way radio waves behave in a coaxial cable or open-wire feed line, consider a canal with waves of water flowing through it. With no obstructions, the waves flow smoothly, and they all reach their destination.

Now imagine a dam blocking a portion of the canal. The waves that strike the dam bounce off and return the way they came. These are called reflected waves.

You've probably heard of a feed line referred to by its *characteristic impedance*, expressed in ohms. Most hams use 50-Ω coaxial cable or 450-Ω open-wire line. The impedance value corresponds to the cross-sectional dimensions of these wire-and-plastic "canals."

You would think the impedance would be the same throughout the length of the feed line, but this is not always the case. Any abrupt change in the impedance is called an *impedance bump*. These bumps partially block the flow of RF energy—just like the dam in the canal. There may be impedance bumps at connections, sharp bends in the feed line or where other conductors come near non-shielded lines (such as metal gutters or siding near open-wire line). If the impedance of your feed line doesn't match the impedance of your antenna, you've got yet another impedance bump there as well.

At any point in the antenna circuit, the magnitudes of current and voltage in the forward and reflected waves are constantly changing. Nonetheless, the forward and reflected waves continually interact to produce a waveform that appears to be standing still. This is the infamous *standing wave*.

We measure the magnitude of this standing wave by determining the ratio between its maximum and minimum voltage. This is the *standing-wave ratio*, or SWR. (It's sometimes called voltage standing-wave ratio, VSWR but don't worry—SWR and VSWR are identical.) When there is no reflected power, the maximum and minimum voltages are equal and the SWR is 1:1.

What's the difference between a "good" SWR and a "bad" SWR—and why should we care? Generally, an SWR of 2:1 or less is desirable. The lower the SWR at the transmitter, the better. An SWR of 4:1 or more may indicate a problem. There are several possible problems that may result from high SWR.

- **Transceiver Damage**—Many transceivers do not tolerate high SWR conditions. Reflected power increases voltage (symptom: arcing) and/or current (symptom: overheating) in the final amplifier circuitry of your radio. (That's the part that generates the radio's output power.) We can overcome this problem by using an antenna tuner.
- **Reduced Transceiver Output Power**—In the interest of self-preservation, most modern SWR-protected transceivers reduce output power as SWR increases. Despite this protective measure, damage is still possible. Such output reductions begin with SWRs as low as 1.5:1.
- **Antenna System Damage**—In extreme cases, the voltage increase from high SWR can cause arcing in the feed line, connections or antenna. Arcing may cause no permanent damage if the arc only passes through air. Arcs through solid insulators in coax, connectors or twin lead leave holes and sometimes carbon tracks. These allow future arcs at much lower voltages. Damaged insulators, connectors and feed lines should be replaced.
- **Increased Feed-Line Losses**—All feed lines convert some of the power flowing through them into heat; this power is lost! (This loss is usually described in decibels [dB] per 100 feet of feed line at some frequency.) As the reflected waves bounce back and forth between the transmitter and the antenna, they lose some of their energy in this fashion. In the end, all of the power produced by the transceiver will be either radiated by the antenna or dissipated (as heat) by the feed line—although it may take many trips through the feed line for this to happen. Those extra

trips are where the loss from high SWR takes place. However, in low-loss feed lines (such as open-wire line or high-quality coaxial cable), the loss added by moderate levels of SWR is often insignificant.

Q **How can we reduce SWR?**

A We can reduce the SWR the transceiver sees by installing a matching network in the system. The most common cure is a variable matching network (commonly called an *antenna tuner*, although this is a somewhat of a misnomer since it's not the antenna that is being tuned) located at the transceiver.

The most effective method to reduce the SWR, however, is to match the antenna's feed-point impedance to the transmission line—up at the antenna. This usually involves pruning the length of your antenna to tune it to resonance. This produces an SWR that is as low as possible at your desired frequency, even if the minimum SWR isn't always exactly 1:1.

Q **How can I spot antenna problems with an SWR meter?**

A Most hams leave an SWR meter in their antenna feed lines all the time. Any sudden changes in the SWR means you have a problem, such as a broken wire or a bad connection. Problems may occur when you first install an antenna, or only after the weather batters your antenna for weeks, months or years. Either way, an SWR meter or power meter will indicate, and help you diagnose, antenna problems.

Here's how to interpret SWR meter readings that indicate a couple of common problems:

- A *loose connection* in the antenna system causes SWR to vary from one second to the next. Suspect the connections at the transceiver, antenna and any feed-line splices or joints. This problem is usually more noticeable on windy days.
- An unusually high (greater than 10:1 or so) but constant SWR indicates a worse problem. Caution: Do not operate your transceiver with a very high SWR any longer than it takes to read the meter! The problem could be an *open connection* or a *short circuit*. Carefully check your connections and feed line for damage.
- You may also get unusually high SWR readings if the antenna is far from the correct length. This would happen if you try to operate your antenna on the wrong band, the antenna has fallen, or come into contact with some other structure (a gutter, siding, a tree and so on).
- If your coaxial cable is deteriorating, you may see your SWR actually *improve* (go down) over time! How can this be? Well, the "improvement" is really power being lost as heat in the aging feed line. Your SWR meter sees a much lower standing-wave ratio, but you're actually losing more of your RF power as heat in the cable! If you've had your coax in place for a couple of years, be suspicious of SWR readings that seem to be better than when the cable was new.

Q **Recently I purchased a portable 10-meter radio and magnetic mount antenna. I used my Elmer's MFJ SWR Analyzer to tune the antenna. Now I understand that an antenna will have a "resonant" frequency and I believe the SWR should be lowest at the frequency. The best we could get on the analyzer was about 1.5:1 SWR. I don't understand why. I would expect that the SWR should be 1:1 at the resonant frequency.**

A It would if the designer properly designed the antenna for your particular installation. However, most antenna designers design their antennas for a hypothetical environment, which may be considerably different from your installation. There are techniques to reduce the effect of the environment, such as resistive loading, but this reduces the efficiency of the antenna.

Q **What is an acceptable SWR for my radio? Is 1.8:1 too high?**

A On HF, the noise level is typically too high for the SWR to affect receive sensitivity. However, at UHF and microwaves, a high SWR can impact the reception of strong signals because of extra loss in the transmission line. It may be wise to calculate the noise of your receiving setup by measuring sun noise and comparing it to cold sky and ground noise. The amount of degradation acceptable depends on the desired operating goals. Rarely is it important to have the ultimate receiving setup when working your first EME contact—you can often find someone to work who runs considerably more power than easily generated by beginners. However, after working hundreds of different EME stations, every little bit helps toward enabling you to work ever weaker stations attempting their first EME contact.

The transmit situation is a bit different—a 1.8:1 SWR might in fact degrade transmit performance. Many radios have foldback circuitry designed to reduce power when the SWR is too high. Thus, if the circuitry is very sensitive, one may see a power reduction with an SWR of 1.5:1—perhaps even less if the circuitry is hypersensitive. If the owner's manual doesn't detail the setback point, often the service manual will have useful information.

One other thing you should remember is that the output stage of a transmitter is designed to produce minimum distortion as well as maximum output when operated into its specified load impedance. Departing from that design impedance—in other words, operating at an SWR that isn't 1:1—with a solid-state transmitter will often generate more distortion, resulting in more "splatter" when you operate SSB.

Q **Why does my SWR change with power level?**

A This is usually the result of diode SWR detector voltage drops, which cause power meters to underestimate power at low power levels.

Q How do I tune a dipole—I have no equipment except my transceiver and an SWR meter?

A First, you plot the SWR versus frequency. Frequency intervals of 50 to 100 kHz are adequate. Plot a graph of SWR versus frequency to determine the frequency of the lowest SWR. This is the resonant frequency. If this frequency is too high, it can be lowered by adding to the length of the dipole. If it is too low, shortening the dipole will help. If resonant frequency is fine but the SWR is too high, you need an antenna tuner. Changing the height of the antenna will change the SWR, but this is rarely a useful solution. Lowering an antenna usually degrades performance, it is presumed that the antenna is already at the maximum height.

You can get a good approximation of the required length by can multiplying the original length by its measured resonant frequency and dividing by the desired frequency.

Q I have erected a G5RV but because of space limitations it looks like the letter M. I can't get my SWR below 2:1. Should the antenna be configured differently?

A There is the distinct possibility that reconfiguring the antenna so that it is straight and parallel to the ground would improve your SWR because in its present configuration we have no real idea what it's actual impedance is. However this seems to be impractical in your circumstance.

A 2:1 SWR is not a real problem, provided your transmitter will operate cleanly and properly into this load—here's why. The energy that is reflected back is again pushed back up the transmission line with the next cycle. The energy that is lost is in the form of heat in the transmission line. Following a single wave, some energy is lost on the first trip up (unavoidable), some more on its trip back. The wave is then pushed back up the transmission line by the following wave and a little more is lost on its second trip back up. Most of the wave's remaining energy is then radiated and a portion is reflected back incurring the loss of a little more energy. The process continues and each time the wave radiates most of what it has left and sends the rest back down the line. This is happening with each wave so a portion of your energy is actually being radiated.

As long as you are making lots of contacts and having fun, don't worry about it.

Q I'm using a trap vertical antenna with buried radials. It works fine in dry weather, but the SWR increases whenever it rains. What could cause this?

A A common problem with any antenna is that water may be seeping into the connection between your coaxial cable and antenna. Examine the connection carefully for signs of water and seal it with several layers of electrical tape and Coax-Seal, Scotchgard, plumber's putty or some other sealant. Another possibility is that moisture is getting into the traps. Most traps have drainage holes to allow condensation to escape. The drainage holes must be pointed the right way (down) and they must be clear. Check your traps carefully for cracks and holes in the seals. If you see anything suspicious, seal it with a silicone caulking compound that's rated for outdoor use. (But don't seal the drainage holes!) Caution: Antenna traps are carefully assembled and tested at the factory. Don't attempt to disassemble the traps without checking with the antenna manufacturer first—you may inadvertently change their electrical characteristics.

Q Whenever ice accumulates on my wire dipole antenna, the SWR shoots up nearly four-fold. I receive poor signal reports, too. What causes this phenomenon? Is it common to all outdoor antennas?

A When ice coats an antenna, it changes the antenna's *dielectric constant*. The effect is similar to placing a thick layer of insulation on your antenna. When the dielectric constant changes, the resonant frequency changes, too. By the same token, a shift in the resonant frequency causes a shift in the impedance value at the feed point. You see the end result as a higher SWR. Electrically speaking, it's as though your antenna had changed its length.

Depending on the type (and length) of feed line you're using, a high SWR can also cause a substantial loss in the line. That might explain the poor signal reports you received. The higher SWR also may cause your transceiver's protection circuitry to automatically reduce its RF output, and in addition your transmitter may create more on-air distortion because it is trying to operate into a load impedance for which it was not designed.

Q I live in a modular home on a rented lot and I must use low-profile HF antennas. My present dipole antenna is eight feet off the ground, wrapped around three sides of the house below the edge of the roof. My SWR is very high—at least according to my meter. How can I fix this problem and get on the air?

A Your wire dipole is indeed very low if it's only eight feet off the ground! The proximity to the house, its wiring and the ground itself is probably making the impedance very different from the 50 Ω our SWR meter is expecting to see. A 20-meter dipole operates best when it's at least 30 feet high, preferably 70 feet or even higher. Local contacts can be made with such a low antenna, but don't expect much DX work.

Since you're severely restricted, you may want to try one of the small new transmitting loop antennas, such as the *MFJ Super Hi-Q Loop* or the AEA *Isoloop*, or you can build one yourself. These small loops are inconspicuous enough to be mounted horizontally up in the clear off the ground for better performance, while still looking enough like an exotic sort of TV antenna to keep the neighbors happy. They can also be mounted vertically over the roof, although they will work better if they are mounted horizontally at least 30 feet off the ground.

Q I built a 2-meter quad antenna from a construction article. The article called for bare wire, but I made mine with insulated wire. The SWR was quite high and the antenna didn't work very well. When I used bare wire, the antenna worked just fine. How come?

A The insulation detunes the antenna, typically lowering the resonant frequency as much as 2% or so. On a directional antenna with parasitic elements, that could really wreak havoc with the gain, pattern and SWR—in other words, everything.

Q I am having a problem with my SWR on 2 meters. My antenna is a Cushcraft AR-270 dual-band Ringo. When I check the SWR at low power, I get a good match. But when I switch to high power (50 W), I get a bad match. What's going on?

A The match between a transmitter and an antenna doesn't change when you adjust the output power. It just looks that way. The problem is in your SWR meter, although it is not really broken. Most commonly used SWR and/or power meters have a built-in error factor caused by the fact that some of the power, forward and reflected, is lost in the diode detectors used to measure the RF energy. As a result, the meters err on the low side.

For example, if the SWR were 2:1, the reflected power would be about 10% of the forward power. Let's say the meter reads 500 mW low. This error wouldn't have much effect if you're measuring 50 W forward power with 5 W reflected power. The meter would measure 49.5 W forward and 4.5 W reflected power, and give a fairly accurate SWR measurement. But if you use 5 W forward power, the miniscule reflected power would be "lost" in the error factor. The meter would show almost no reflected power at all, making the apparent SWR look much better than it really is.

Most power and SWR meters specify their accuracy as a percentage of full scale. So, in most circuits, you'll get better SWR measurement accuracy at higher power.

Q A couple of years ago you listed some of the common myths about SWR. I think this is a message that bears repeating. Could you?

A We'd be happy to do so. Despite some claims to the contrary, a high SWR *does not by itself* cause RFI, or TVI or telephone interference. While it is true that an antenna located close to such devices can cause overload and interference, the SWR on the feed line to that antenna has nothing to do with it, providing of course that the antenna tuner, feed line or connectors are not arcing. The antenna is merely doing its job, which is to radiate. The transmission line is doing its job, which is to convey power from the transmitter to the radiator.

A second myth, often stated in the same breath as the first one above, is that a high SWR will cause excessive radiation from a transmission line. SWR has nothing to do with excessive radiation from a line. *Imbalances* in open-wire lines cause radiation, but such imbalances are not related to SWR.

A third and perhaps even more prevalent myth is that you can't "get out" if the SWR on your transmission line is higher than 1.5:1, or 2:1 or some other such arbitrary figure. On the HF bands, if you use reasonable lengths of good coaxial cable (or even better yet, open-wire line), the truth is that you need not be overly concerned if the SWR at the load is kept below about 6:1. This sounds pretty radical to some amateurs who have heard horror story after horror story about SWR. The fact is that if you can load up your transmitter without any arcing inside, or if you use an antenna tuner to make sure your transmitter is operating into its rated load, you can enjoy a very effective station, using antennas with feed lines having high values of SWR on them.

Fortunately or unfortunately, SWR is one of the few antenna and transmission-line parameters easily measured by the average radio amateur. Ease of measurement does not mean that a low SWR should become an end in itself. The hours spent pruning an antenna so that the SWR is reduced from 1.5:1 down to 1.3:1 could be used in far more rewarding ways—making QSOs, for example, or studying transmission-line theory.

Q I just put up an inverted-L antenna for 160 meters. It is fed with 150 feet of RG-213 coaxial cable. When I measure the SWR at the antenna feed point, I get an SWR of 1.7:1. When I measure the SWR at the rig end of the feed line, the SWR is about 3:1. I've used two different pieces of RG-213 with the same results. I have also replaced the PL-259 connectors at both ends. I can use an antenna tuner at the rig, which makes the antenna usable, but is there something else I could do to get the same SWR at the rig that I have at the feed point?

A What you are running into is covered in some detail starting on page 26-14 of the 18th Edition of *The ARRL Antenna Book*. The part under the heading "SWR Change with Common-Mode Current" is particularly relevant to your own case. What is happening is that your inverted-L is radiating *common-mode current* onto the shield of the coax going to your shack. Such a current can *only* flow on the shield (since the coax's center conductor is shielded), and hence the fields inside the coax are not equal and opposite in phase as they should be in a transmission line. As a result, the fields inside the coax are distorted by the presence of the common-mode current. The amount of this stealthy, undesirable common-mode current varies depending on the placement of the coax under the antenna and the length of the coax. The impedances seen along the coax will vary. When the impedance varies, your SWR meter will show different readings at different places along the coax. In extreme cases, common-mode currents can cause the SWR protection circuitry in a transmitter to shut down everything, protecting against what looks like excessive SWR.

The way to cure this problem is to employ *common-mode chokes*, often called *choke baluns* to "choke off" the current. See *The ARRL Antenna Book* or *The ARRL Handbook* for details on these devices. Your first step would be to put one right at the feed point of the inverted-L. That will probably knock the problem down somewhat, but you may have to place other chokes at $^1/_4$-wave increments down the coax to really tame the beast. Another good trick is to bury the coax, especially if it runs right under the top L portion of the antenna. In fact, coax runs that are elevated off ground (for convenience or to keep them away from mowers, small children and animals) is particularly prone to this "varying SWR" problem.

Q My father and I moved our ham shack into my room. Since our old antenna cable was too short, we used a coupler to extend it. When we hooked up the radio we found that an S9+ received signal would drop to S7 whenever we wiggled the cable. We checked our solder connections thoroughly, but they're okay. What else could cause this strange problem?

A You say the received signal strength changes when you shift the position of the coax. This is an important clue. Check the connections between the coupler and the coaxial cables. It may seem a though the sleeves of the PL-259 male connectors screw tightly onto the coupler. I many cases, however, the sleeves do not thread in far enough to make a solid electrical connection between the coupler and the shell of the PL-259. The result is a shield connection that separates depending on the position of the cables and the coupler. Ask your father to watch the S meter while you wiggle the cables at the coupler. If the signal strength fluctuates, you may have found the problem. Recheck your solder connections, too. you may think the braid is soldered properly when it isn't.

LADDER-LINE

Q What is meant by the terms "balanced" and "unbalanced" when referring to transmission lines? What is meant by the characteristic impedance of a transmission line?

A The physical differences between balanced and unbalanced feed lines are obvious. Balanced lines are parallel-type transmission lines, such as ladder line or twin-lead. The two conductors that make up a balanced line run side-by-side, separated by an insulating material (plastic, air, whatever). Unbalanced lines, on the other hand, are coaxial-type feed lines. One of the conductors (the shield) completely surrounds the other (the center).

In an ideal world, both types of transmission lines would deliver RF power to the load (typically your antenna) without radiating any energy along the way. It is important to understand, however, that both types of transmission lines require a balanced condition in order to accomplish this feat. That is, the currents in each conductor must be equal in magnitude, but opposite in polarity.

The classic definition of a balanced transmission line tells us that both conductors must be symmetrical (same length and separation distance) relative to a common reference point, usually ground. It's fairly easy to imagine the equal and opposite currents flowing through this type of feeder. When such a condition occurs, the fields generated by the currents cancel each other—hence, no radiation. An imbalance occurs when one of the conductors carries more current than the other. This additional "imbalance current" causes the feed line to radiate.

Things are a bit different when we consider a coaxial cable. Instead of being a symmetrical line, one of its conductors (usually the shield), is grounded. In addition, the currents flowing in the coax are confined to the outside portion of the center conductor and the inside portion of the shield.

When a balanced load, such as a resonant dipole antenna, is connected to unbalanced coax, the outside of the shield can act as an electrical third conductor. This phantom third conductor can provide an alternate path for the imbalance current to flow. Whether the small amount of stray radiation that occurs is important or not is subject to debate. In fact, one of the purposes of a balun (a contraction of BALanced to UNbalanced) is to reduce or eliminate imbalance current flowing on the outside of the shield.

The characteristic impedance of a transmission line is the impedance that one would see "looking" into a line that's infinitely long. Since our theoretical line has no end, there can be no reflected power. A real-world transmission line can be made to appear as if it were infinitely long by terminating it in its characteristic impedance. Once a line is so terminated, the SWR is 1:1, since there is no reflected power.

Typical characteristic impedances of coaxial cables are (nominally) 50 Ω and 75 Ω. Balanced lines are a bit higher, typically 300 Ω or 450 Ω and beyond.

Q Can you use open-wire feed lines for VHF and UHF? If you can, why don't more hams do so?

A Yes, you can use an open-wire feed line on VHF and UHF. Although this type of line is not as efficient as it is on HF frequencies, the losses are still low. The two wires that make up a VHF/UHF open-wire feed line must be spaced very close together in order to eliminate feed line radiation.

See pages 18-2 and 24-14 in the 19th edition of *The ARRL Antenna Book*. You'll see that the impedances for such close-spaced homemade open-wire lines are lower than the typical 600 Ω seen for HF home-brew lines. This isn't the most serious problem, though. The transition from balanced line to unbalanced coax down in the shack is the tricky part. You'll need some sort of balun transformer, and/or a VHF/UHF antenna tuner—an item rarely found in most stations. After going to all this trouble, you may find that you were better off using one of the newer low-loss flexible coaxial cables offered by several *QST* advertisers or Hardline. The benefit of open-wire feed lines at VHF and UHF is probably not worth the hassle.

Q I have three simple questions concerning the use of ladder line:

Should it be twisted? If so, how many twists per foot?

How close should it come to other metallic objects?

Any guidelines for the radius of curves? In other words, how drastically can I bend it?

A Okay, three simple questions nets you three simple answers:

1. Twisting isn't critical. Some hams believe that a 180° twist every 2 feet provides better stability in windy environments.

2. Try to keep your ladder line a minimum of twice the line width from metallic objects. In the case of commonly used 450-Ω ladder line, that's about two inches.

3. Make any bends and turns as gradual as possible. A one-foot minimum radius is a good rule of thumb for 450-Ω line.

Q I'm presently feeding my horizontal loop antenna with 450-Ω ladder line. However, I've heard other hams talking about using two pieces of coax in parallel instead. Can you really do this? If so, what are the advantages?

A You can indeed use two pieces of coaxial cable in parallel to create a *shielded* balanced line. A shielded balanced line has several advantages over common "ladder" line. The primary advantage is that a shielded balanced line can be buried, or routed through metal pipes, with no ill effects. It does not enjoy the same low-loss characteristics as ladder line, however.

You can make a 100 or 140-Ω line by using two equal lengths of 50 or 70-Ω coax, respectively. If you can get RG-63 (125-Ω) coax, you can make a feed line with an impedance of 250 Ω, more in accord with 300-Ω twin lead.

The shield braids must be connected together at both ends (see **Fig 1-49**). The two inner conductors constitute the balanced line. At the input side, the shields should be connected to chassis ground; at the output (antenna) side, they are joined, but left "floating."

Q I have about 130 feet of 3/4-inch 75-Ω CATV Hardline that I'd like to use for 2 meters and 70 cm. I looked in *The ARRL Antenna Book* and found a description of a broadband transformer, but it's only for 3 to 30 MHz. I also saw an article in Sep 1998 *QST* on how to make a matching transformer, but it seems to only work on one frequency or band. Is there another matching transformer I could build so that I could achieve a 50-Ω match to my transceiver on both of these bands at the same time?

A I do not recommend that you use 75-to-50-Ω transformers in this application. At 2 meters the loss in your CATV Hardline, if perfectly matched, would be 0.8 dB/100 feet, or a total of 1.02 dB. If you operate this line at a 1.5:1 SWR, the additional loss caused by the SWR would be 0.07 dB. It is very unlikely that you could obtain less than 0.07 dB of total loss between two matching transformers—one on each end. Instead of building transformers, why not simply use the Hardline as it is? The SWR on the line will be approximately 1.5:1 and the loss, even at 70 cm, will be negligible. Most likely, your transmitter will be perfectly happy to deliver full power into that load.

Q I vaguely remember reading someplace that one should not use RG-6 to feed antennas.

A There is nothing in the literature that says that "one should not use RG-6 to feed antennas." However, since the impedance of amateur transmitters is 50 Ω, hams like to use 50-Ω coax. The characteristic impedance of RG-6 is 75 Ω. Until the advent of Cable TV, 50-Ω coax was the easiest to get—of course all that has changed—now we can find free coax on the side of the road, or so it seems.

Since the impedance of a dipole is actually 72 Ω, it would appear that RG-6 could be better. But be careful with beams and verticals—follow the manufacturer's recommendation.

Q Which is a better transmission line, coaxial cable or ladder line? Can I build my own?

A Each feed line has its advantages and disadvantages. Coaxial cable is reasonably low loss if it is operated at a reasonable SWR. It can be snaked inside walls, or even taped directly to your tower or mast. Properly used, it can last for years. Connectors such as a PL-259 or an N connector can be attached directly to coaxial cable and easily waterproofed.

Open-wire line is lower loss than coax, so it can be used at a much higher SWR. It does require a few inches separation from nearby conductors, though, so it is not generally a good choice for running inside buildings. The choice depends on the application.

It is generally not practical to make coaxial cable. Many

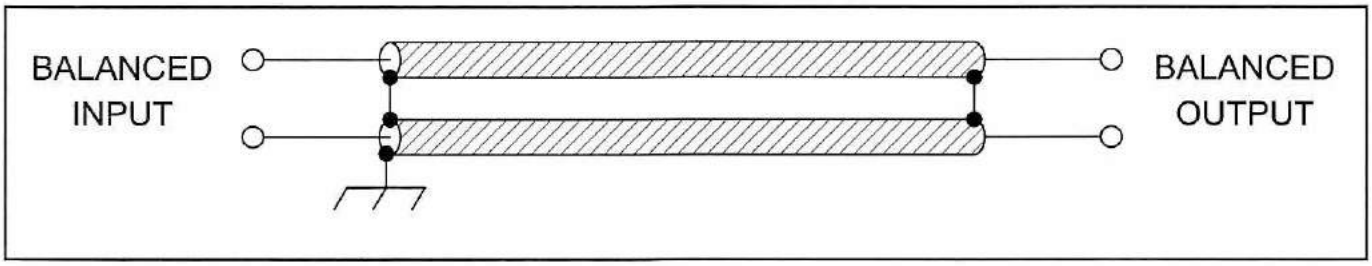


Fig 1-49—You can make your own shielded balanced transmission line by using two pieces of coax in parallel. Connect the shields at both ends; the inner conductors become the balanced line.

hams construct their own ladder line, though. What is needed are two conductors and a number of "spacers" to keep them separated. These spacers can be purchased commercially or can be made from any of a number of insulating materials. Others have made open-wire line using spacers that range from old plastic pens to old camera film containers.

Q I wish to put up a multiband dipole in the back of my property. This will require about a 100 foot length of coax. Will I encounter significant power/signal loss? Is there a particular grade of coax I should use?

A If you will be on the HF bands there will not be a significant loss, but use good quality cable, such as RG-8 or RG-213.

From the 19th Edition of *The ARRL Antenna Book* here are some figures for common coaxial cables. If the SWR on the coax is about 2:1 or less, these figures will be quite close to what will occur in real use:

Attenuation of Transmission Lines dB/100 feet

Coax type	*3.5 MHz*	*30 MHz*	*144 MHz*
RG-58	0.7 dB	2.6 dB	6.5 dB
RG-8 foam	0.3 dB	0.9 dB	2.1 dB
RG-8	0.3 dB	1.2 dB	3.1 dB
RG-8X	0.5 dB	1.6 dB	3.6 dB
9913	0.2 dB	0.7 dB	1.6 dB
450-Ω ladder line	0.05 dB	0.15 dB	0.4 dB

ANTENNA TUNERS

Q I want to feed my antenna with open-wire feed line (ladder line). The problem is that my transceiver has a built-in antenna tuner and it only accepts coaxial cable. Any solutions?

A Yes, use an outboard (remote) 4:1 balun to make the transition from open-wire line to coaxial cable. The approach is similar at to what actually goes on inside most antenna tuners. The 4:1 balun steps down the feed line input impedance to a value that may be within the range of your rig's antenna tuner. In addition, it acts as a bridge between the balanced feed line and the unbalanced tuner circuitry. In most cases, one side of the balun enclosure has dual binding posts to accommodate open-wire line. On the other side you'll find an SO-239 coaxial connector. The enclosure may or may not be weatherproof—something to consider if you intend to install it outdoors.

You can make your own 4:1 remote balun, or buy one from manufacturers such as MFJ, Radio Works and others. When you install it, keep the coax between the balun and your radio as short as possible. This is very important. Some manufacturers recommend a maximum coax length of 15 feet or so, but we suggest a much shorter length (a few feet).

When the SWR is high, your open-wire feed line will lose very little RF energy. That's one of its big advantages. The same cannot be said for the coax, however. The longer the coax between your rig and the remote balun, the more RF you may lose. If the cable is too long, its loss under high SWR conditions may be such that it effectively cancels the advantage of using open-wire line!

Q I was told my antenna tuner doesn't really tune my antenna. Well, what *does* it do?

A The antenna tuner is used to transform whatever impedance there is at the input of your transmission line going to your antenna to something close to what the rig was designed for, typically 50 Ω resistive. This is often necessary for proper operation of a transmitter, which may generated spurious signals or even oscillate when terminated with a poor load.

Q How do I use an antenna tuner (tuning up)?

A The simplest method is send a signal at a reduced output power, perhaps 10 dB down, and adjust the knobs until you find the lowest SWR settings. You could also measure the exact impedance with an SWR analyzer and model the situation on computer modeling program to determine the optimum knob settings. The first approach is usually the quickest, especially when you haven't a clue as to actual impedance. The latter approach will let you optimize the settings taking into account harmonic attenuation and insertion loss of the tuner. With T network tuners, a game plan has been devised by Andrew Griffith in the Jan 1995 issue of *QST*.

Q A strange thing is happening with my antenna tuner. I'm running it with an open-wire feed line and using the built-in 4:1 balun. On some bands it's fine. On others, I notice that the SWR increases slowly while I'm transmitting. Any advice?

A Yes–when you see that slowly rising SWR, stop transmitting! It sounds like the core of the 4:1 balun at the output of your tuner is heating up. The SWR is probably quite high on the band in question, and some hefty RF currents are present in your feed line as a result. For the sake of compact design and cost savings, some tuners use relatively small 4:1 baluns to provide an interface between the open-wire line and the tuner's matching network. A small balun can't dissipate much heat. Under high SWR conditions, its tiny ferrite core saturates. The temperature increases and the electrical characteristics of the balun change (that's when you see the rising SWR reading). If you keep transmitting, the insulation on the wires that surround the core can melt.

Contact your tuner manufacturer to see if you can replace the balun with a larger one. If a larger balun isn't available from the manufacturer, you can make one yourself. Several *QST* advertisers sell 4:1 balun kits. Be careful, though. You're looking for an internal 4:1 balun, not the type that you install at the antenna.

Q **I keep hearing tales of hams who operate the HF bands by using gutters, fences, and balcony railings as antennas. Is this true?**

A Believe it or not, it's true. With a good antenna tuner you can load RF energy into just about any ungrounded piece of metal of reasonable length (preferably $^1/_4$-wavelength or longer at your chosen frequency). It may not be a very efficient radiator, but you'll at least put a signal on the air.

Some of these low-profile antenna schemes work surprisingly well. We heard of one ham who seized an opportunity when he discovered that his aluminum rain gutters weren't grounded. He removed a small section in the middle of one gutter, effectively splitting it into two equal halves, each about 16-feet long. He replaced the cut-out section with a plastic piece that was painted to match the gutters. That plastic piece functioned as the center insulator, where he attached his 450-Ω ladder line. By using his antenna tuner he was able to load his "gutter dipole" on 20, 17, 15, 12 and 10 meters. A year later he worked his hundredth country and earned his DXCC certificate.

Note that it is very important to have a low-impedance connection between portions of such antennas. Otherwise, a semiconducting joint can cause rectification of the transmitted energy, radiation of significant harmonics and RFI to your neighbors. Arcing is another potential problem. Despite the good fortune of some hams, these types of antennas are best regarded as a last resort. Always keep your output at 10 W or less to avoid RF hazards.

Q **I recently put up a multiband dipole fed with 450-Ω ladder line. My antenna tuner loads up fine on all bands except 40 meters. What can I do to fix this?**

A You have selected the simplest multi-band antenna. It is not without possible problems, though. The impedance of the antenna wire element will vary from band to band, ranging from a relatively low impedance on some bands to several thousand ohms on other bands. In addition, it will contain inductive or capacitive reactance, depending on its length and the frequency in use. The 450-Ω ladder line is not terminated in 450 Ω on all bands (or possibly on any band) and will operate at a high standing-wave ratio (SWR) on most bands. (This is okay; ladder line has low enough loss to begin with that it can operate at a high SWR without much additional loss. This is why the antenna works so well.)

A mismatched transmission line will act as a transmission-line *transformer*, changing the impedance existing up at the antenna feed point to some other value down at the input end of the line. The resultant impedance looking into the transmission line from the tuner can range from a few ohms to several thousand ohms. When you're operating on 40 meters, the value is outside the matching range of your antenna tuner.

Although the SWR on the ladder line does not change materially along its length, the exact impedance does change with distance. The easiest fix is to change the length of the feed line. I suggest you add a $^1/_8$-wavelength piece (this is about 15 feet on 40 meters). This will probably change the impedance enough to make your antenna system load up fine on 40 meters. Unfortunately, this could simply move the problem to another band, so be prepared to experiment a bit with different configurations.

Q **I'm a little confused about how antenna tuners function in terms of reducing antenna system SWR. And what if you use ladder line with an antenna tuner? Should you even care about SWR in that situation?**

A When thinking about antenna tuners and SWR, it's important to remember that the tuner has no effect whatsoever on the SWR between itself and the antenna. It's the SWR between the tuner and the transceiver that changes.

In practical terms, all a tuner does is act as a kind of adjustable impedance transformer between the antenna system and the radio. It takes whatever impedance the antenna system presents and attempts to convert it to 50 Ω—or something reasonably close to that value—for the transceiver. When the transceiver "sees" a 50-Ω impedance, it is able to load its maximum RF output into the system, at its designed level of distortion. That power is transferred through the antenna tuner, to the feed line and, ultimately, to the antenna—minus any losses incurred along the way.

When the SWR increases, feed-line loss can become considerable as the reflected power bounces back and forth between the tuner and the antenna. Of course, your transceiver is blissfully ignorant because the tuner is providing it with a comfortable 1:1 SWR. Ladder line has an advantage over other feed lines in that its losses are low, even under moderate SWRs. But when the SWR really goes sky high, even ladder line will exhibit substantial loss.

Q **What is the correct way to tune an antenna tuner?**

A Most antenna tuners have an inductance switch and two capacitors. The capacitors are often labeled ANTENNA and TRANSMITTER. See **Fig 1-50**. In some antenna tuners the inductance switch is replaced with a continuously variable inductance, popularly known as a roller inductor.

Let's assume you're using a tuner with an inductance switch, because they are the most common. Place both capacitor controls at their mid-range positions. Don't trust the knob markers if this is your first experience with the tuner; remove the cover and turn the knobs until the moving capacitor plates are only half meshed with the stationary plates. If the knobs are pointing to half scale, consider yourself lucky. If not, loosen their Allen nuts and rotate the knobs so that they point to mid scale. Replace the tuner cover and you're ready to go.

Turn the radio on and, with the ANTENNA and TRANSMITTER controls at mid scale, crank the inductance switch until you hear the loudest noise or signals coming into your ra-

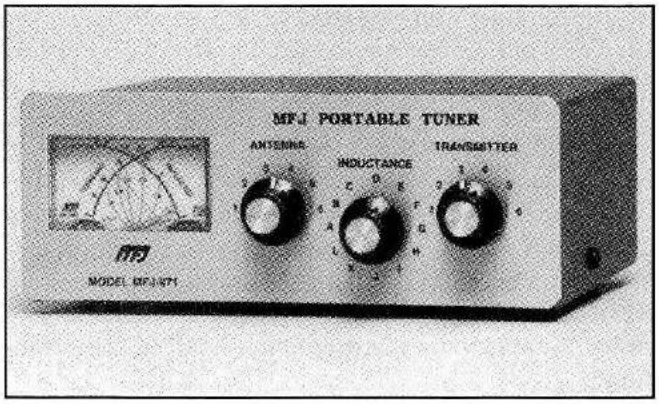


Fig 1-50—A typical commercial antenna tuner, this one is manufactured by MFJ. Notice the ANTENNA and TRANSMITTER controls and the INDUCTANCE switch.

dio. Then, rotate the ANTENNA and TRANSMITTER controls until you get to the absolutely loudest noise or signal level on the radio. This should be close to your best tuning spot.

With your rig set to low power, send an ID, then transmit a continuous carrier while you tweak the ANTENNA and TRANSMITTER controls for the lowest reflected power reading with the highest output power. You may find that you have to vary the position of the inductance switch a position or two to get your best match. Be gentle to your radio; keep the key-down periods as short as possible.

Depending on the impedance at the antenna input (and the overall design of the tuner) you may not be able to obtain a flat 1:1 SWR on all frequencies and bands.

Q I'm using my antenna tuner to load a shortened dipole on 160 meters. I am running 100 W output and operating CW most of the time. I think I'm really pushing the limits of my antenna tuner and I'm worried that it might arc. If this happens, how will I know? Will I hear it?

A Yes, you might hear a buzzing or frying noise as you key your transceiver. On the other hand, you may hear nothing at all. What will probably get your attention will be the bouncing needles on your tuner's SWR meter. I'm not talking about the dips you see when you're tweaking your tuner for the best match. When your tuner arcs—as it is most likely to do when you're adjusting it at full power—the SWR meter will begin jumping wildly. Try reducing your output. If the meter stops bouncing, the tuner was probably arcing. Better open it up and inspect for damage.

Q A friend of mine was attempting to load his 40-meter dipole antenna on 160 meters and his antenna tuner started arcing. Fortunately, there wasn't permanent damage, but it sparked (no pun intended!) a discussion about the nature of arcing itself. What exactly is going on when arcing takes place?

A The simple answer is that arcing is a manifestation of dielectric breakdown. All insulating materials, including the air itself, are dielectrics. In an ideal world we could take any two conductors and put as large a voltage as we wanted on them, no matter how close together they are. The dielectric material between them would prevent any catastrophe. In the real world, however, dielectrics have very specific limits on how much voltage (applied to a given area) they will tolerate.

The electrons in the atoms of the dielectric material feel an attractive force when placed in an electric field. If the field is sufficiently strong, the force will strip away electrons. These free electrons are now available to conduct current and they are moving at extremely high velocities. The free electrons slam into other atoms, freeing even more electrons. In a short time there are enough free electrons to produce a large current flow. When this happens, we say the dielectric has suffered *breakdown*. When the dielectric is air, you see the result as a bright spark or *arc*.

If the dielectric is a liquid or gas, it can heal when the voltage is removed. A solid dielectric, however, cannot repair itself. Solid state devices are ruined, holes are burned through insulated wires and so on. Arcing is most often seen in RF circuits where the voltages are high (such as in your friend's antenna tuner), but arcing is possible anywhere two components at significantly different voltage levels are closely spaced.

The breakdown voltage of a dielectric depends on its composition and thickness. See **Table 1-2**. The variation with thickness is not linear. In other words, doubling the thickness does not quite double the breakdown voltage.

Q I recently began using an Alinco DX-70 HF transceiver with an antenna tuner and a multi band wire dipole antenna (using a coaxial feed line connected directly to the antenna —no balun). For a while, everything was fine. Now, however, I suddenly find that the SWR remains extremely high on all bands. I inspected the antenna and the feed line and they appear to be okay. Do you have any suggestions?

A Obviously something has changed in your tuner and antenna system. Try the easy steps first (see **Fig 1-51**). Get a volt-ohm meter (VOM), disconnect the antenna coax from the tuner and measure the resistance between the center conductor and the connector shell. It should be infinite. If the VOM reads zero, you have a short somewhere in the feed line or at the antenna. Inspect the antenna again. Look for loose or broken connections between the coils or traps.

If you can get your hands on a dummy load, disconnect the coax *at the antenna* and substitute the dummy. A dummy load is just a resistor (or several resistors) in a box or can. It acts like an antenna without radiating much RF. Your transceiver should see a 1:1 SWR on all bands and your tuner should be able to "match" this easily. If your tuner and transceiver behave properly when the dummy is connected, you've just eliminated them from your list of possible suspects.

But if the antenna tuner still doesn't work with the dummy load, it's time to pop the cover and do a visual inspection. Rotate both tuning capacitors. If you hear a mild scraping or feel the plates rubbing each other at any points in their rotation, you must attempt to refashion the plates so that they don't touch at any point. Look for errant blobs of sol-

Table 1-2
Dielectric Constants and Breakdown Voltages

Material	*Dielectric Constant**	*Puncture Voltage***
Aisimag 196	5.7	240
Bakelite	4.4-5.4	240
Bakelite, mica filled	4.7	325-375
Cellulose acetate	3.3-3.9	250-600
Fiber	5-7.5	150-180
Formica	4.6-4.9	450
Glass, window	7.6-8	200-250
Glass, Pyrex	4.8	335
Mica, ruby	5.4	3800-5600
Mycalex	7.4	250
Paper, Royalgrey	3.0	200
Plexiglas	2.8	990
Polyethylene	2.3	1200
Polystyrene	2.6	500-700
Porcelain	5.1-5.9	40-100
Quartz, fused	3.8	1000
Steatite, low loss	5.8	150-315
Teflon	2.1	1000-2000

* At 1 MHz
** In volts per mil (0.001 inch)

der that could be shorting a coil or capacitor. Gently tug on the wires to make sure they are firmly soldered in place.

Q I'm having trouble with a small HF antenna tuner. One of the knobs, and only one, becomes "hot" when I operate at full output (100 W). My station is well grounded, so this is puzzling. Can you offer a suggestion?

A If only one of the tuner knobs is biting you and not the tuner case, then I'd have to say the shaft insulator for that particular control is defective or installed incorrectly. Inside the tuner, you should see either a short section of insulated shaft (fiberglass, plastic, etc) or an insulating coupler between the knob shaft and the capacitor. It may need to be replaced.

Q Someone told me that a change in your antenna-tuner settings means that you may have a problem with your antenna system. How much of a change are we talking about?

A Look for a big change before you begin to worry. Let's say that you have your tuner set for operation on 20 meters. We'll also say that your tuner uses a tapped-inductor design with two variable capacitors. The inductor setting for 20 meters might be **1** while the capacitors are at **3** and **5** (this is just hypothetical). If you wander into the shack one afternoon and find that you need to set the inductor to **5** and the capacitors to **8** and **9**, something has changed in your antenna system.

It is not unusual for the settings to meander a bit. A big change, such as the one illustrated above, means that the impedance at the input of your transmission line has jumped to a new value. The next question is, what caused the impedance to change?

It could be a temporary problem, such as ice on your antenna. On the other hand, the problem could be more serious—faulty traps, a break in your feed line and so on. If you see a serious shift in your tuner settings, determine the cause of the problem before you get on the air.

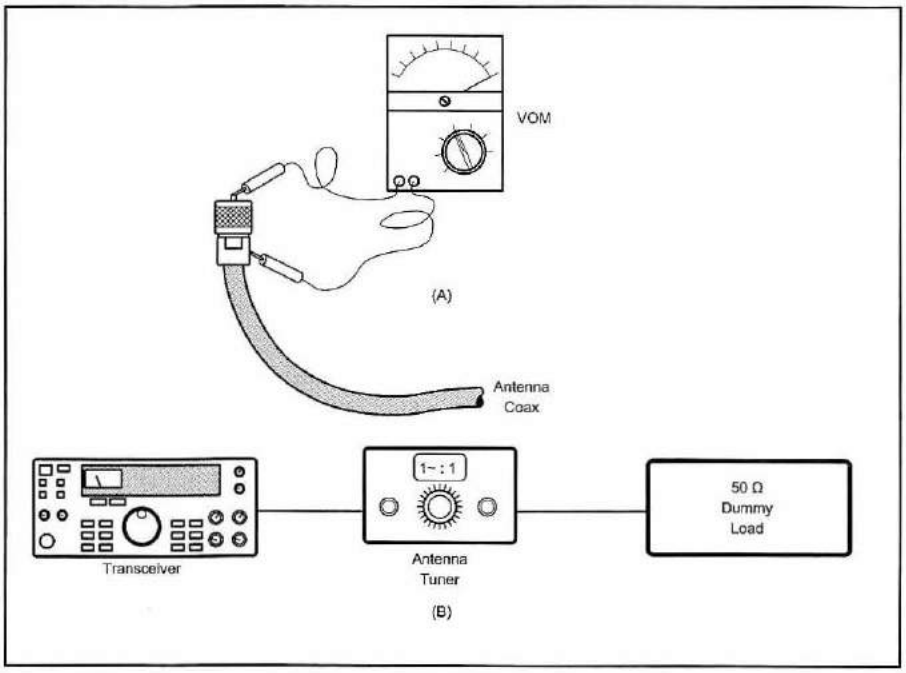


Fig 1-51—A volt-ohm meter provides a quick test for possible feed line shorts (A). Test the function of the tuner and feed line by substituting a dummy load for the antenna (B).

HF PROPAGATION

Q I've heard plenty about the D, E and F regions of the ionosphere. What about the A, B and C regions? Do they exist?

A In the early part of this century, the discovery of short wave skip revealed the existence of a reflective region high in the atmosphere (in the portion of the atmosphere that we would come to know as the *ionosphere*). At the time this reflective region was labeled "E" for *electrostatic*. As research continued, long-distance skip conditions implied the existence of a much higher region. It was arbitrarily labeled "F." In the years that followed, the "D" region was deduced (through the discovery of its absorptive characteristics).

There is no ionospheric region lower than D. Some well-meaning individuals attempt to label the atmosphere between the troposphere (15 to 20 km) and the lower D layer (40 km or so) using A, B, and C. This is not accepted practice, however.

Q What are the A and K geomagnetic indices?

A Geomagnetic activity is monitored by devices known as *magnetometers*. Small variations in the Earth's geomagnetic field are detected by the magnetometers and scaled to two measures—the A and K indices.

The *K index* provides an indication of magnetic activity during the previous three hours on a finite scale of 0 to 9. Very quiet conditions are reported as 0 or 1; storm levels begin at 4. A rising K index foretells worsening propagation conditions.

The *a index* (note the lower-case "a") is a 3-hourly "equivalent amplitude" index. The a index is related to the 3-hourly K index according to the following scale:

K	0	1	2	3	4	5	6	7	8	9
a	0	3	7	15	27	48	80	140	240	400

Finally, the *A index* (now we're talking about the upper-case "A") is a daily index of geomagnetic activity derived as the average of the eight 3-hourly *a indices*. So, the A index reflects geomagnetic conditions summarized over a 24-hour period.

Here in the US, stations WWV and WWVH broadcast the latest solar flux numbers, the average planetary A indices and the latest Boulder, Colorado K indices at 18 minutes after every hour. You can hear these broadcasts on 2.5, 5, 10, 15 and 20 MHz. Keep in mind that the A-index information you'll hear on any given day is a summary of what happened during the previous day—in Boulder, Colorado. Still, it is an important tool for measuring trends.

Q Can you explain knife-edge diffraction? I was told that you could use this technique to communicate on VHF or UHF with stations blocked by mountains or hills. Is this true?

A What you have heard is indeed true—at least under certain conditions. When a radio wavefront passes over the sharp edge of a mountain or hilltop, the portion of the wave adjacent to the edge is slowed down slightly. This makes the wavefront appear to bend around the obstacle (**Fig 1-52**). The net effect is to allow some RF energy to appear behind an otherwise solid object.

The crest of a range of hills or mountains at least 100 wavelengths long at the operating frequency can serve as reasonable knife-edge diffracters. (This would be about 683 feet at 144 MHz.) Crests that are sharp, clear of trees and horizontal make the best edges, but even rounded hills may work.

Knife-edge diffraction works in both directions. Although only a small amount of energy is diffracted, it may be possible to communicate over paths of 60 miles or more.

Q I am confused by the meaning of solar flux, A index and K index. do these numbers mean in terms of HF band conditions? Where can I get the latest data?

A Solar flux is an index of energy from the sun that correlates with the density of ionization in the ionosphere. In simpler terms, a higher flux value usually translates to a higher Maximum Usable Frequency (MUF) and better HF propagation. Solar flux roughly corresponds to a sunspot number, which is based on the size and number of sunspots on the visible solar disk.

The A and K indices have to do with geomagnetic disturbances. Higher A and K values correspond to greater absorption of radio waves, rather than refraction. This is bad news for HF propagation. When conditions are stable, the K index may get as low as one or zero. When conditions are truly awful, it may reach five or even seven. A change of one point in the K index is significant.

The A index is also a measure of geomagnetic stability, but a change of one point is not significant. It is based on the K index for the previous 24 hours. When the K index is three, the A index might be ten. A change of a point or two in the K index may send the A index to 20 or higher. When a severe geomagnetic storm appears and the HF bands shut down, the A index may reach 35 or more.

High A and K indices are typically a result of solar flares or coronal holes on the sun. Both may shoot ionized material towards the Earth. This material may cause the geomagnetic field to become unstable and increase absorption of radio waves. To span great distances, you want your radio waves to be refracted (bent) by the ionosphere, not absorbed!

Solar reports are transmitted regularly by W1AW and by time stations WWV and WWVH. If you have packet radio capability and a *DX PacketCluster* network nearby, you may find solar reports there as well.

Q A friend of mine in Colorado says that he works distant stations on 2 meters during the winter by bouncing his signal off the sides of snow-covered mountains. He's pulling my leg, isn't he?

A Your friend is probably telling the truth, but it isn't the ice and snow that makes it possible. The mountains

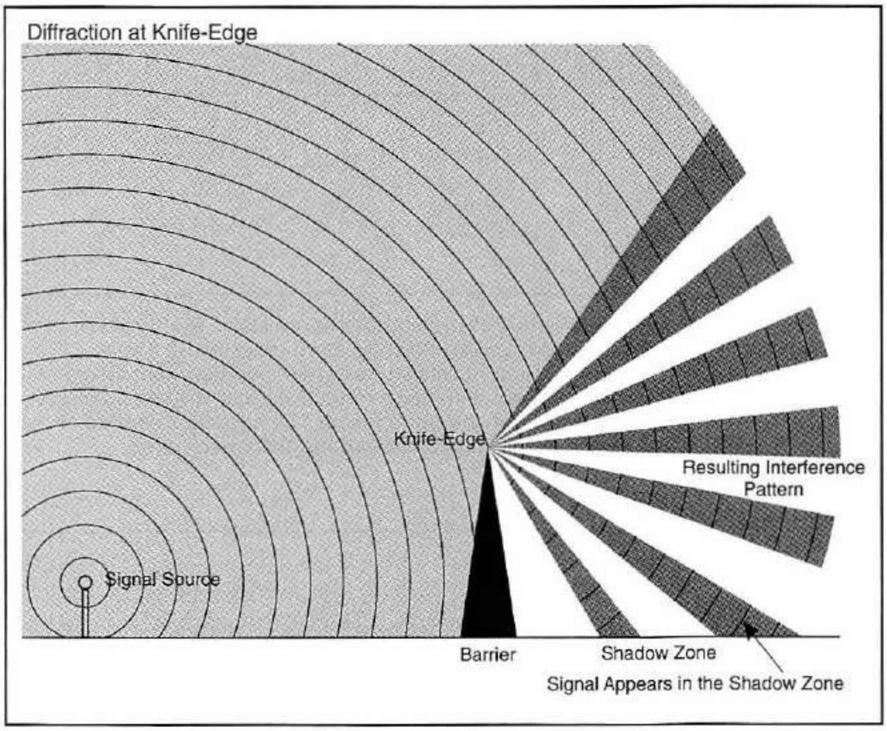


Fig 1-52—Radio, light and other waves are diffracted around the sharp edge of a solid object that is large in terms of wavelength. Diffraction results from interference between waves right at the knife-edge and those that are passing above it. Some signals appear behind the knife-edge as a consequence of the interference pattern. Hills or mountains can serve as natural knife-edges at radio frequencies.

themselves are acting as reflectors. If your friend is using a beam antenna to focus his power, he can aim his antenna at a mountainside and ricochet his signal in a somewhat predictable manner. Some hams are able to set up paths where their signals bounce off several mountains allowing them to penetrate much farther than they could otherwise.

Q I know that weather can cause band openings on VHF and UHF frequencies. Is weather a factor for skip conditions on the HF bands?

A Band openings caused by weather conditions are usually limited to the frequencies above 50 MHz, where the shorter wavelengths are more easily influenced by moisture, air density and so on. One possible joker in the deck is *sporadic E*. The jury is still out on the exact cause of this phenomenon. Some scientists say weather could play a role, others believe weather is irrelevant. Sporadic E is a big skip-generator on 6 meters, but you'll also find it on three HF bands: 15, 12 and 10 meters. Some hams have even reported sporadic-E propagation on 17 and 20 meters.

Q When is the best time of the year to expect 6-meter sporadic-E band openings?

A In May, the spring/summer sporadic-E season goes into full swing. We can usually expect sporadic-E openings on 6 meters almost every day until late July. (There is another sporadic-E season in December and January, but it is not as strong.) Sporadic E can pop up at almost any hour, but the most common times are from late morning through late afternoon. Park your rig on 50.125 MHz and turn up the squelch until the noise just stops. Then, crank up the volume and go about your business. If the band opens, you'll hear it. And don't forget to drop in a few CQs yourself. The band may sound quiet, but 6 meters can be very deceptive that way. You'll never know for sure until you call.

Q I often hear amateurs talk about 160 and 80 meters in terms of being "winter" bands. Why is this?

A During the summer months frequent thunderstorms play a major role in boosting atmospheric noise. The lower the frequency, the more intense the noise. In the summertime 160 meters is almost useless in the face of continuous static and lightning crashes. The situation is somewhat better on 80 meters, depending on the proximity of the storms. Thundershowers as far away as 500 miles will cause substantial noise on the band. Local storms will make listening almost impossible, but you shouldn't be on the air then anyway!

With the onset of winter in the Northern Hemisphere, the storms abate and the bands become much quieter. During these chilly months, 160 and 80 meters are hotbeds for DX.

By the way, don't buy a DSP noise filter to rid yourself of atmospheric static. Digital noise reduction is programmed to look for noise signals that repeat themselves continuously in regular patterns (automobile ignition noise is a typical example). Lightning and other atmospheric mayhem do not produce correlated signals, so DSP is helpless against them.

Q I enjoy 6 meters, even when the band isn't open. I've found that it is a terrific band for "local communications" up to a few hundred miles away. Some of the local signals, however, have an odd fluttering char-

acteristic. What causes this? Does the fact that I live near an airport have anything to do with it?

A Take a look at **Fig 1-53**. The energy traveling directly between the horizontally polarized transmitting station antenna and receiving station is attenuated to about the same degree as in free space. But unless the antennas are very high or quite close together, an appreciable portion of the transmitted energy is reflected from the ground as well as from buildings and towers. These two signals combine at your antenna, and that's where things get particularly interesting.

When the signal strikes another surface, its phase is reversed. If the distances traveled by both signals were exactly the same, and if the reflection phase reversal was exactly 180°, the signals would arrive out of phase with each other and cancel completely. This never happens in the real world or you would hear nothing at all! Instead, the reflected signal travels a little farther. Combine this with the less-than-180° phase reversal and you have partial cancellation at the antenna, not total. Your statement about living near an airport provides an important clue. Signals bouncing off aircraft can arrive at your receiver with rapidly varying phase and amplitude, causing considerable flutter.

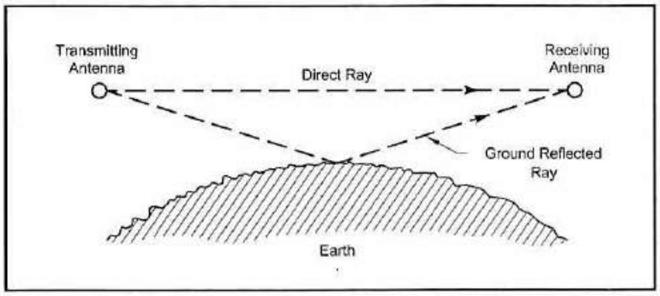


Fig 1-53—Part of the signal energy takes the direct path to the antenna, but another portion arrives as a wave reflected from the ground or other objects. There is a phase reversal with each reflection, and the distance the wave travels is greater as well. The signals combine at the antenna, adding and subtracting from each other.

Q This morning I was listening to 160 meters when, to my astonishment, I heard a moderately strong signal from Australia (a VK6)! That's on the other side of the world from my location on the East Coast. About 30 minutes later, he vanished. What caused this?

A You've just experienced the magic of *gray line* propagation. The gray line (astronomers call it the *terminator)* is a band around the Earth between the sunlit portion and darkness. It is an area of diffused light (see **Fig 1-54**). On one side of the Earth the gray line is coming into daylight (sunrise), and on the other side it is coming into darkness (sunset). Propagation along the gray line can be very efficient, so greater distances can be covered than might be expected for the frequency in use. One major reason for this is that the D region of the ionosphere, the region that absorbs HF signals, disappears rapidly on the sunset side of the gray line, and has not yet built up on the sunlit side. Think of this as a temporary DX window.

I'm willing to bet that you heard that Australian sometime around, or probably before, your local sunrise. On the other side of the world, it was probably his local sunset.

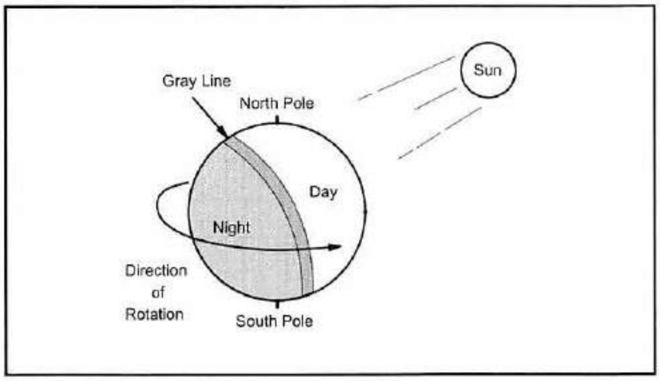


Fig 1-54—The gray line is a transition region between daylight and darkness. One side of the Earth is coming into sunrise while the other side is just past sunset.

Q I have not been operating for several years and I am looking forward to getting back on the air. I moved to North Florida and I would like to make regular contacts with friends 40 to 60 miles away. Would 10 meters be adequate for this purpose if I run a beam and 100 W?

A Ten meters is probably not the best band for your application. Depending on what the other stations are using for rigs and antennas, contact is probably possible, but the signals may be weak. You'd have better luck using 40 meters during the daytime and 80 or 160 meters at night.

2 The Station: Installation and Operation

Q **Isn't Amateur Radio an expensive hobby?**

A The answer depends on your perspective. While Amateur Radio certainly isn't as cheap as, say, rock collecting, it is not the most expensive hobby in the world. If you want to see how bad it can *really* get, talk to a private pilot who owns his or her own airplane. The cost of general aviation makes hamming look free by comparison!

There is a decent chance that you'll fork over $200 to $300 to get started in Amateur Radio. That's a lot of money for many people. (It annoys me how some folks attempt to trivialize the impact of "a few hundred dollars.")

You'll probably hear that you can save huge amounts of money by building your own gear from kits. This is true to a degree. Most transceiver kits are low-power HF rigs, although you'll find the occasional VHF or UHF kit. If you have sufficient technical experience to build a kit and fix it if something goes wrong, a kit is a viable cash-saving option.

But if you want a transceiver with sophisticated features and higher power output, and if your engineering skills are lacking, you're looking at new or used equipment. Now we're talking about potentially large price tags.

The good news is that you won't be shelling out the big bucks on a frequent basis. A new dual-band FM mobile transceiver can set you back about $700, but you probably won't buy another one for a *long* time. If you take good care of a transceiver, it can theoretically last a lifetime. There are hams today who are using transceivers manufactured in the 1960s. Those radios work just as well today as they did when they were new.

Set reasonable goals for yourself and you can save even more money. For example, forget about tall towers and huge antennas for now. They tend to be very expensive. Instead, fix your sights on less ambitious antennas that you can install on your roof or patio, in a nearby tree or wherever. If your passion is to operate on the HF bands, consider wire antennas. You'll have a blast with a wire *dipole*, at a cost of $25 or less.

When you see those photographs of elaborate, wall-to-wall ham stations and forests of steel towers, consider two things:

1. The ham in question might be rich. There's nothing wrong with wealth, but most of us don't have that advantage at the moment.

2. The gear may have been accumulated over a long period of time. This is what usually happens. You buy a radio. A couple of months or years later, you buy another. Perhaps you receive a couple of accessories as gifts. After a decade of purchasing and receiving gifts, you wind up with a station that would make the Voice of America jealous!

EQUIPMENT

Q **Which radio should I buy?**

A This, along with "Which is the best antenna?" has to be one of the *most* frequently asked questions. As with the antenna question the answer is not what you might expect. There is no way that *XYZ* radio is the one you should buy.

Let's think of the obvious. Are you going to be operating only VHF? Or will you be using mostly the HF bands? Will you be able to operate from your home? Or are you restricted to mobile operation? All these variables determine which is the best radio for *you*.

Let's take the first option first. Will you be looking for a new rig or a used one?

VHF

The simplicity and lower cost of VHF radios compel the purchase of a new rig. This is probably a wise choice. Most VHFers start with either a mobile radio or a hand-held. Either could be a good choice. If you live in a metropolitan area or a small city with a repeater nearby, an HT can be your first all-around radio. Used while meandering around town on foot or in the car with an external antenna or at home either by itself or with a small 20 or so watt amplifier and a modest antenna on the roof, this little, relatively inexpensive radio can be a lot of fun. One clear advantage is that as your requirements increase or you start wanting to operate on the HF bands, your first HT will not become obsolete—it will be with you for years to come. For this reason, HTs, in *really* good condition and still with their manuals, are rarer on the used market.

Mobile VHF radios do find their way onto the used market, but these can be a bit tattered by the time their owners place them on the auction block—hams tend to hang on to them as long as they are working.

A new mobile radio is a really nice choice for the VHFer if your pocketbook allows. These are often used as a mobile radio and then pulled out of the car to use at home with a dc power supply and an outside antenna. At 45 to 50 W output from most of these radios, you can really extend your range over the HT.

HF

Here the market is wide open. At any given time, there are dozens of new HF radios on the market. It's like shopping for a new car—as soon as someone provides a new feature, all the competition comes out with a new model to equal or top it.

With careful shopping such as reading the *QST* Product Reviews and in many cases the Expanded Test Report and discussions with your ham friends, you can find just the radio you want or need. Of course, new feature-laden HF full power (100 W) radios are quite pricey—ergo the proliferation of lower-priced QRP rigs on the market today.

While on the subject of QRP (low power operating—5 W or less), although this a very popular part of the hobby it is challenging and not recommended for just any beginner. There are basic skills required for QRP work that are better acquired first with the more forgiving full power station. But if there are operating constraints, with a little patience, QRP can be great fun and there are kits for $60 or even less.

The analogy of HF radios and cars goes further than stated above. Hams tend to trade or sell off their older rigs only because the new models are so alluring. As with cars, the used radio market abounds. Good used rigs can be found everywhere at very good prices.

Perfectly serviceable HF radios from the '80s, some in very good condition, can be had for less than $600. See **Fig 2-1** for two examples. Today, unless you have someone who can help you, you might stay away from the rigs from the late '70s. These fine examples, available for $200 to $300 are best left to the collector of vintage radios.

A very important point when buying a used radio is to make sure it comes with the manual. Photocopies of manuals can sometimes be found for the older rigs from dealers in these things, but this, at best, will add to the expense of the rig. Also if a fellow kept his manual, this tells you something of the character of the owner/seller.

Finally, unless you are very experienced, never purchase a used rig by a manufacturer that is no longer in the amateur business. Some of these have either gone out of business completely, or are currently manufacturing for the commercial market only. Support, parts, etc. will be very hard to come by.

Q Where do I find these used radios at bargain basement prices?

A They are all over. In classified ads in the ham magazines, on the Internet, at fleamarkets and hamfests, from local ham dealers, from the mail order houses, at the house of a friend from your local club, and on and on.

Probably the best place to buy a used rig is from someone you trust such as someone you know or a reputable dealer. Most ham radio stores and some of the large mail order houses have trade-ins. The advantage is that they probably stand behind what they sell. If you are looking at a rig at a local ham store, they may even put you in contact with the previous owner for more details on the radio. Some stores sell on consignment and will also give you the phone number of the owner. Most even have a fair return policy.

Next, and where you can probably find the best prices is at a hamfest. Here, however, *caveat emptor*—buyer beware. If you find what you are looking for here, make sure you can test the rig before turning over your cash. Even then, you can't be absolutely sure. But here are a few things to look for to tip the scales in your favor.

How does the radio look? Is it free from dents, dings and

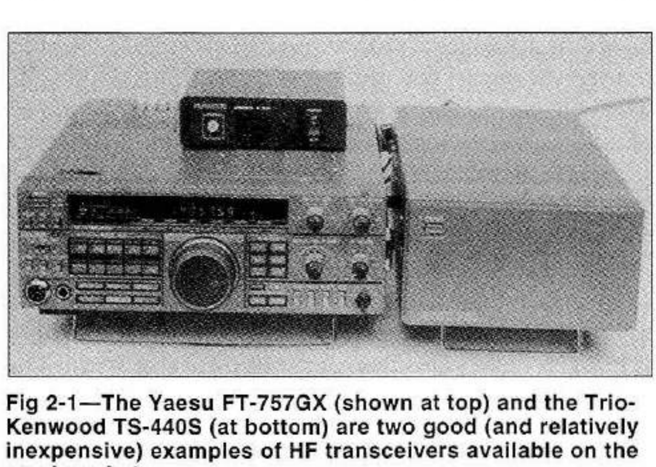


Fig 2-1—The Yaesu FT-757GX (shown at top) and the Trio-Kenwood TS-440S (at bottom) are two good (and relatively inexpensive) examples of HF transceivers available on the used market.

large scratches? These could be a dead giveaway that the equipment was abused.

Is it clean? Not only is it free of grease or coffee stains, but does it look like the owner took the trouble to clean up the radio for sale with Windex and a cloth to get the dust off. This tells you something about the personality of the fellow. Does he take care of his equipment?

Does he have the original manual, and what shape is it in? This also tells you something about the owner.

If it passes the above muster *and* he has the original carton, jump on it! You have found a proverbial creampuff. In fact, such a find is worth a premium so the price may be $25 or so higher than a similar unit and may well be worth it.

I will repeat that you should never buy a radio without the manual. These can be hard to come by and they contain important operating instructions that you must have—let alone the schematics should you ever need service.

Classified ads in the magazines or postings on the Internet are a good source because with their large coverage, you can probably find the exact radio, make and model, you are looking for. In these cases, however, let your best judgment be your guide. Also, making payment via Postal Money Order gives you some recourse.

Q When shopping for a radio, what features should I consider?

A Here are the major features that most hams consider important when selecting an HF transceiver:

IF Filters: Receiver filtering is often performed in the intermediate-frequency (IF) chain, usually with crystal filters. Many transceivers offer several IF filters according to the mode selected (a wide filter for SSB, a narrow filter for CW). Check which IF filters are available, and whether or not accessory filters are offered as well. For example, many SSB operators prefer to install 1.8-kHz IF filters in their rigs. CW operators often choose 500- or 250-Hz filters.

Audio Filters: Filtering can also be done in the audio stages of the radio. Many radios use audio filtering as a supplement to IF filtering. The main disadvantage of audio filtering is that it is usually done outside the AGC circuitry of the receiver. Strong signals that are filtered out by the audio filter may affect the volume level of the desired signal by pumping the AGC.

Notch Filtering: Notch filtering is usually performed in the IF, but it can also take place at audio frequencies. This feature gives you the ability to reject or "tune out" an undesired CW signal or other heterodyne. It may be implemented by an adjustable, analog notch-frequency control, or digital signal processing (DSP) technology. DSP notch filtering can be particularly useful because it can "seek and destroy" multiple carriers.

Passband tuning (PBT) and variable bandwidth tuning (VBT): PBT and VBT are two features that increase receiver flexibility in tuning signals on a crowded band. They work by shifting the receiver's passband to avoid an interfering signal, or by varying the width of the passband until the undesired signal is no longer heard. Both affect the fidelity of the desired signal, but it is usually better to endure muffled or "tinny" audio than to suffer interference from another station.

Two VFOs: Dual VFOs have become standard in modern radios. The primary advantage of a dual VFO is the ability to work split-frequency, transmitting on one VFO and receiving on the other. They also let you quickly bounce back and forth between two frequencies or bands.

Noise blanker: A good noise blanker can dramatically reduce impulse noise. Noise blankers generally work quite well on automotive ignition noise and will vary in effectiveness on other types of noise. FM has substantial inherent noise immunity, so noise blankers are not usually found in FM rigs.

Memories: Most modern radios also have memory channels into which you can program your favorite frequencies and modes. Memory features also "remember" the settings of filters and other controls, making it seem as if you had many separate radios at your fingertips!

Computer control: Most current transceivers include a computer control interface. This comes in handy for logging or contest software, satellite operating and other applications in which it is convenient or necessary to control the radio's features via computer.

General-coverage reception: This is a great feature for hams who want the ability to listen to international broadcasts and other signals in addition to Amateur Radio. The next time an international crisis flares up, you can listen to the action on your Amateur Radio rig!

Expanded frequency coverage: Now we're talking about expanded transmit and receive capability. For example, both the Kenwood TS-690 and the ICOM IC-729 transceivers include 6 meters. Some HF transceivers feature the ability to add internal or external transverters or modules that permit operation on VHF/UHF bands.

Antenna tuners: While antenna tuners are not required in every station, they sure make life easier! A well-designed antenna tuner will allow you to use antennas that aren't resonant at your desired frequency. You can put up a dipole for one band (40 meters, for instance) and operate on several other bands as long as you use a low-loss feed line.

A number of transceivers provide built-in antenna tuners that adjust themselves automatically. Many hams find it handy to have an antenna tuner right where they need it—in the radio.

Variety of modes: SSB and CW are standard in most rigs, but others add AM and FM, too. Yes, there is still AM activity on the amateur bands and FM flourishes on the high end of 10 meters. If you're a RTTY or AMTOR enthusiast, look for a rig with an FSK mode. You don't need FSK to operate RTTY or AMTOR, but rigs with FSK often provide narrower IF and/or audio filters when this mode is selected. Filtering makes a big difference when the RTTY/AMTOR subbands are crowded!

13.8-V dc operation: If you plan to operate mobile or portable, will the transceiver accept a 13.8-V power source? Some rigs feature an internal 13.8-V dc option while others offer a dc accessory supply.

Size: How big is the radio? Will it fit in your car? Will it fit on your operating desk? Transceiver sizes vary from tiny boxes to behemoths!

Q **How should I lay out my station?**

A Station layout is largely a matter of personal taste and needs. It will depend mostly on the amount of space available, the equipment involved and the types of operating to be done. With these factors in mind, some basic design considerations apply to all stations.

THE OPERATING TABLE

The operating table may be an office or computer desk, a kitchen table or a custom-made bench. What you use will depend on space, materials at hand and cost. The two most important considerations are height and size of the top. Most commercial desks are about 29 inches above the floor. This is a comfortable height for most adults. Heights much lower or higher than this may cause an awkward operating position.

The dimensions of the top are an important consideration. A deep (36 inches or more) top will allow plenty of room for equipment interconnections along the back, equipment about midway and room for writing toward the front. The length of the top will depend on the amount of equipment being used. An office or computer desk can make a good operating table. These are often about 36 inches deep and 60 inches wide.

STACKING EQUIPMENT

No matter how large your operating table is, some vertical stacking of equipment may be necessary to allow you to reach everything from your chair. Stacking pieces of equipment directly on top of one another is not a good idea because most amateur equipment needs air flow around it for cooling. A shelf like can improve equipment layout in many situations.

ARRANGING THE EQUIPMENT

When you have acquired the operating table and shelving for your station, the next task is arranging the equipment in a convenient, orderly manner. The first step is to provide power outlets and a good ground. You can't have too many outlets, radio equipment has a habit of accumulating with time, so plan for the future at the outset.

Fig 2-2 illustrates a sample station layout. The rear of the operating table is spaced about 18 inches from the wall to allow easy access to the rear of the equipment. This installation shows two separate operating positions, one for HF and one for VHF. When the operator is seated at the HF operating position, the keyer and transceiver controls are within easy reach. The keyer, keyer paddle and transceiver are the most-often adjusted pieces of equipment in the sta-

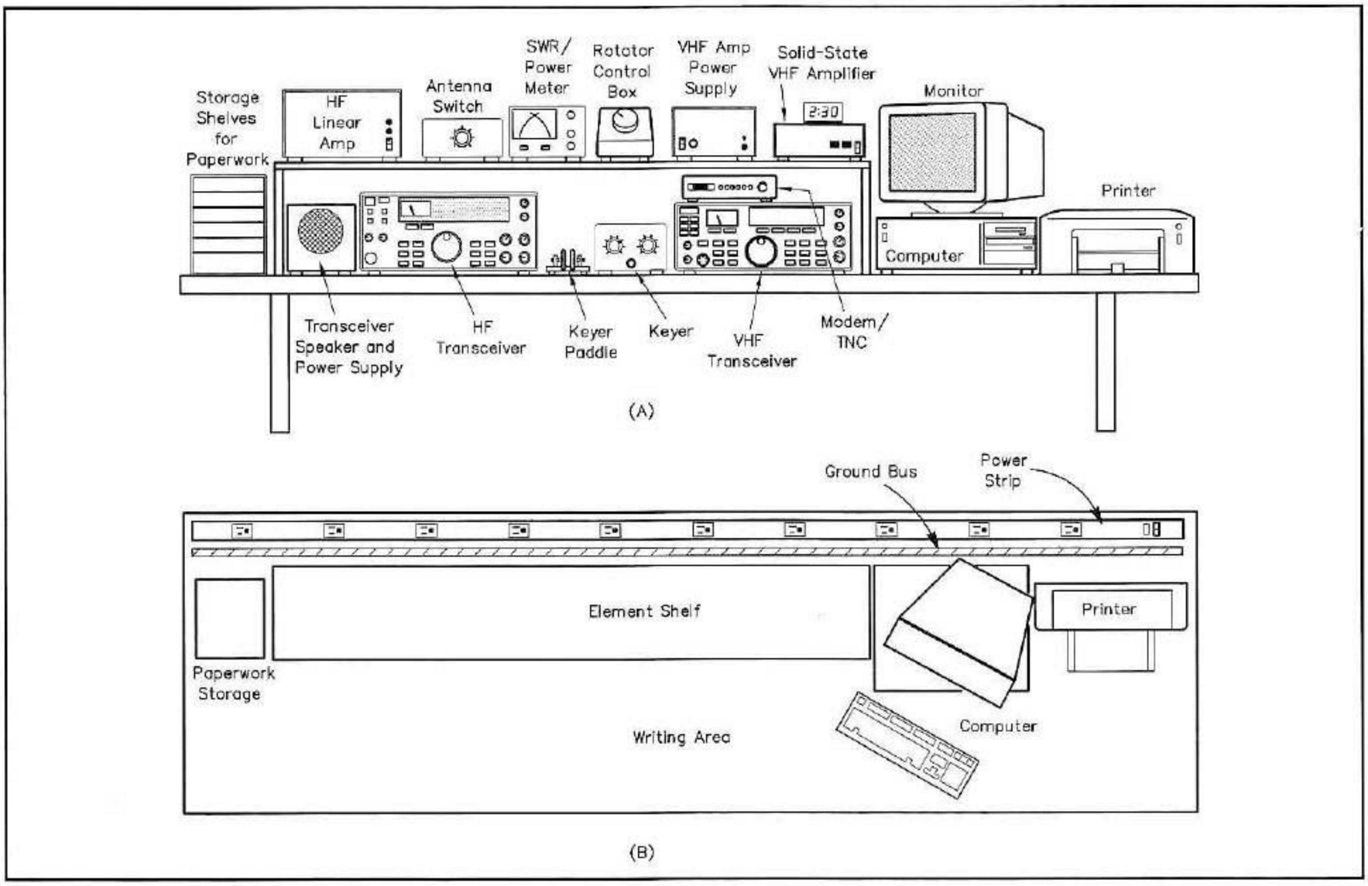


Fig 2-2—Example of how station layout can contribute to enjoyable operating. The equipment is spaced far enough apart so that air circulates on all sides of each cabinet.

tion. The speaker is positioned right in front of the operator for the best possible reception. Accessory equipment not often adjusted, including the amplifier, antenna switch and rotator control box, is located on the shelf above the transceiver. The SWR/power meter and clock, often consulted but rarely touched, are located where the operator can view them without head movement. All HF-related equipment can be reached without moving the chair.

This layout assumes that the operator is right-handed. The keyer paddle is operated with the right hand, and the keyer speed and transceiver controls are operated with the left hand. For best results during CW operation, the paddle should be weighted to keep it from "walking" across the table—a pad made from a computer mouse pad that has rubber on both sides works well. It should be oriented such that the operator's entire arm from wrist to elbow rests on the table top to prevent fatigue. The VHF operating position in this station is similar to the HF position. Remember to leave plenty of room for paperwork, even with a microphone and keyer paddle on the table.

Q What are the first few pieces of test equipment I should buy? I'm just getting started, and (of course) don't want to spend a lot of money.

A There are small digital multimeters (DMM) available for $100 or less. They have an accuracy of a few percent, and are needed around every ham shack. Voltage measurements, some current measurements and resistance or continuity measurements—you can do them all. Is there power at this ac outlet? Use your DMM. Want to make sure that coax connector you just soldered is not shorted? Use your DMM. Is that 9-V battery dead? Leave it in the circuit, and use your DMM. In addition, if you want to measure inductance and capacitance, there are small one-evening kits available for about $10 that attach to your DMM, turning it into a capacitance and inductance meter.

Q Why is it that when I increase my output power from 10 W to 100 W, the SWR reading on my meter changes?

A The change you're seeing is a function of the accuracy of the meter. The SWR actually remains the same, no matter how much power you're running.

Most SWR meters (and wattmeters) are less accurate when measuring low RF power on a higher-power scale (for example, measuring SWR and power at 10 W with the meter on the 100-W setting). To a certain extent, this inaccuracy is caused by the behavior of diodes in these meters at low power. All meters suffer from this problem to one degree or another. Trust the readings you get at the high end of whatever power scale you've chosen. They're the most accurate.

Q I was asked by a budding ham if there's a major difference in receiving capabilities between a good shortwave receiver and a comparable general-coverage ham transceiver. I couldn't answer her question! Is there?

A The answer pivots on the word "comparable." Most high-end shortwave radios offer performance that is equal or superior to ham transceivers in the same (or lower) price class. When you start talking about less expensive receivers (less than $800), most multiband ham transceivers have a clear advantage.

On a practical level, just about any shortwave receiver can do double duty as a ham receiver, depending on the application. For example, some hams enjoy casual, low-power CW operating using inexpensive portable shortwave receivers that can copy CW or SSB (see "A Portable Shortwave Receiver Roundup," Product Review, Aug 1997 *QST*). Quality becomes an issue when you enter the worlds of DXing or contesting. For these applications you need a receiver that is sensitive enough to hear weak signals, yet selective enough to keep interference at bay. In other words, you need a high-end radio.

Q I have someone who wants me to convert his 10-m radio to work on 11 m—and the person is not a ham. I feel that this isn't right but can't quite seem to prove it. Do you know what the technicalities of the situation are?

A This question is asked in many forms so I will try to cover all circumstances.

The following apply to the USA.

1. A radio that is used by anyone on the citizen band must be made/manufactured by a factory that has submitted a prototype to the FCC for Certification.

2. An Amateur Radio may not be operated on the citizen band by anyone.

3. No radio designed or Certified for use on any other band (including amateur bands) may be modified to operate on the citizen bands. (You may not modify a 10-meter radio to work on the citizen band. A radio amateur *may*, however, modify a CB radio to operate on 10 meters because Amateur Radio equipment does not fall under the Certification rules. Amateurs may design and build their own radios from whatever parts or equipment they wish as long as the finished radio operates within the limits set forth in the amateur rules. This is the **only** service so blessed.)

4. It is not illegal for a non-ham to own an Amateur Radio. He may not, however, *transmit* with the radio—he may listen all he wants.

"Is it illegal for a ham or non-ham to sell an Amateur Radio to a non-ham?" That's a trick question. Back in the 1970s, during the CB explosion, there was a proposal that radio dealers be required to see the license of the individual to whom they were selling Amateur Radio transmitting equipment. There was a lot of resistance by dealers to making this mandatory, and the proposal was dropped.

It is *not* illegal for a ham, or anyone, to sell an Amateur Radio to a non-ham. You will find that most sellers voluntarily ask for a call sign and usually put it on the sales slip, however.

All of the above rules are dropped in the face of a bona fide emergency.

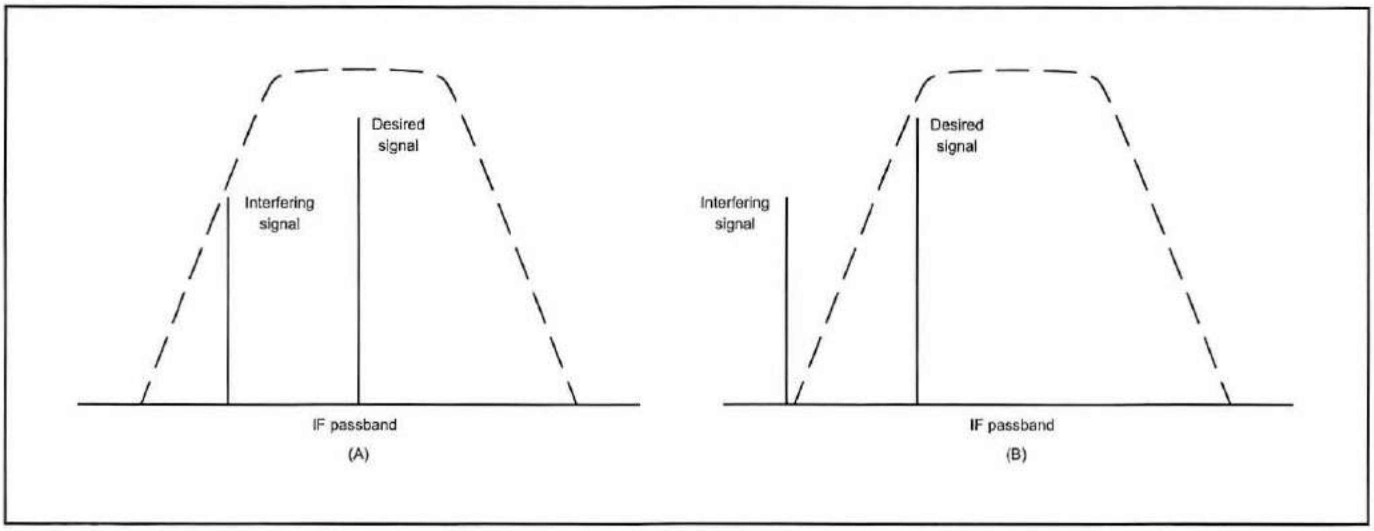


Fig 2-3—At (A) both the interfering signal and the desired signal fall within the IF passband. By using the IF SHIFT control you can effectively move the passband (B), shutting out the interfering signal while the desired signal remains.

Q I have an FT-747GX Yaesu and can't seem to get 100 W PEP on SSB from the rig. I can only get 45 to 50 W PEP out of it. It does 100 W on FM and CW, and I know that the meter is showing correct, because I have tried it on my other rig on SSB and it does 100 W on the PEP scale. The only way I can get 100 W PEP from the Yaesu is to whistle into the mic. Do you have any suggestions that might fix this problem?

A That is normal. The meter is an average power reading meter. On CW and FM the carrier being sent does not fluctuate from full power but on AM and SSB, the carrier fluctuates as it is modulated by the voice so only average power (50% is normal) shows up. The reason it is showing almost 100% when you whistle is because you are maintaining a constant amplitude.

Q What is "IF shift" and how does it work?

A IF shift (sometimes called "passband tuning") is a useful feature that you'll find on many transceivers. It helps reduce or eliminate interference by effectively changing the receiver passband frequency without changing the frequency to which the receiver is tuned.

Take a look at **Fig 2-3**. You can think of a receiver's IF passband as a kind of tunnel through which signals must pass. When you tune in a particular signal, it appears in the center of the IF passband. Another nearby signal may also appear within the passband. If it does, you'll hear both signals in your speaker or headphones. To get rid of the unwanted signal we could make the IF passband very narrow by switching in special IF filters or using IF digital signal processing. But a less expensive approach (albeit not always as effective) is to simply *move the entire passband*. When you twist your IF SHIFT control, you're shifting the whole passband. It's kind of like pulling the rug out from under the offending signal! IF shift isn't a panacea for interference problems (the quality of the signal you want often suffers when the passband is shifted), but it is a cost-effective approach, considering the alternatives.

Q I would like to know the standard for receiver S-unit measurements. Some say an increase of 3 dB amplified signal will produce 1 S-unit increase, as measured by the receiver. Others say 6 dB amplifier gain = 1 S-unit.

A There is no "official" standard, but since Collins meters used 6 dB per S unit, that is what most folks refer to.

Sometimes you will hear a rig's S-meter called a "Guessmeter"; having measured the S9 level of quite a few, I can say that is an accurate analogy indeed.

The Collins S-meters used a signal level of 50 microvolt for S9. Different modern rigs (save for the Ten-Tec Omni 6) indicate S9 anywhere from 1 microvolt up to a couple of hundred microvolt. I haven't recorded the variations in S-unit levels, but each rig is different in that respect as well.

The key to the trouble is the way S-meter circuits are designed. Almost always, they merely indicate the AGC voltage (the stronger the signal, the more the gain has to be reduced, so the higher the AGC voltage), but this varies directly with the components used in the receiver design.

It is possible to have a calibrated S-meter, but to get consistent performance across the entire HF band for all signal levels would require a more expensive circuit.

Q I recently purchased an old Heath SB-102 transceiver. It works, but the components inside are covered with a thick layer of dust. What's the best way to clean it up?

A You have a number of options, depending on the types of components involved, the type of dirt and grime, and your access to a vacuum cleaner.

For loose dust, try a small camel-hair brush. You can buy these dust brushes at department stores, but a paintbrush will also work. A vacuum cleaner with a hose attachment is worth a try, too. Either way you go, be careful not to disturb any of the components or adjustments during the cleaning process.

If the dust is mixed with grease, you may have trouble removing it without a solvent. A spray flux remover often works well, but you must be careful not to direct the spray into critical areas such as coils or the LMO. You might also try a *nonlubricating* tuner cleaner, especially if it's the type that doesn't leave a residue.

As nutty as this might sound, you can wash vacuum tubes in the kitchen sink with a little dish detergent. Be sure to give them a thorough rinse before drying them. One caveat, however, is that the tube label may wash away during cleaning. Be sure to have a secondary means to identify tubes once they are removed from the circuits.

Q I am 16 years old. I want to work ham with a tube set from the 40s or early 50s. I want to work code and 20 and 40 meters. I have access to Antique Radio Classified. What should I ask for as regards equipment?

A Good to hear that you want to operate vintage gear—as they say, "Real radios glow in the dark."

I would recommend, however, that you start with a radio from the mid to later 50s, the reason being that there are a lot of them around (price), and parts are pretty much available (repair).

On the receiver side, although the Collins 75 series or the National HRO 50 or 60 are probably the best, they are a bit pricey. A Hallicrafters SX-94 or SX-100 can be had for under $200. Also the Hammarlund HQ-100, 110, 150 and 160 can be had for between $100 and $200.

For a transmitter I would recommend either an E.F. Johnson Viking Ranger or Viking Valiant, or a Heathkit DX-100. These can be found for between $100 and $250.

There are a few hints to purchasing vintage equipment. It **MUST** have the manual. This is not only necessary for repairs, but is needed to properly hook the unit up to your station and properly use the features of the radio.

Check that it is in working condition. Manuals can be purchased from dealers but that is an added expense and repair by an individual who specializes in older tube equipment can be expensive. Incidentally, the advantage of a Heathkit is that the manual is also the construction manual, making it very convenient should repairs be needed.

Good used radios can be found at hamfests and ham radio flea markets. A fine idea is to contact a local ham radio club and find someone that will go shopping with you—he/she can be of great value in spotting the good from the bad. Here are a few Web sites you should visit:

Antique/Vintage Radio:
www.arrl.org/tis/info/antique.html
What Rig Should I Buy?:
www.arrl.org/tis/info/rigbuy.html
The Boneyard Radio Price Guide: **www.geocities.com/CapeCanaveral/Hall/8701/ham/boneyard.htm**

Q I enjoy operating CW on 20 and 40 meters with my Viking Ranger II and Hammarlund HQ-180 receiver. When I attempt to monitor my own signal on the Hammarlund, it sounds like I'm drifting. At other times I cannot hear the signal at all. Other stations report that I'm rock stable. What could be causing this?

A Chances are, the Ranger II is generating such a strong signal that it overloads your receiver, causing the audio output to drop to zero or disappear. This effect is often called "blocking." The coupling between two radios physically close together can occur via a number of different paths. For instance, ground leads aren't perfect, and can couple strong signals from one device into another. There may also be leakage through shields (or the lack thereof). Having a nice clean signal as monitored in the shack is a tough test—unless you build a special receiver to handle the very strong signals.

You may be able to cure the problem by better isolating the radios. Physical distance is a good start, though a great distance is obviously impractical. A better T/R switch or terminating the receiver input better is another possibility. Or, you might just mute the receiver and rely on an audio sidetone.

ACCESSORIES

Q I've just purchased my first 2-meter FM transceiver. I have enough cash left over to buy a VHF/UHF SWR/power meter or a base-station antenna, but not both. Which item should I purchase?

A I'd vote for the SWR/power meter. An accurate SWR/power meter will give you many years of service. You can use it to check the output of whatever VHF and UHF transceivers you own—now and in the future. You can also use it to evaluate various antenna systems you may buy or build.

As far as the base antenna is concerned, you can build one yourself for only a few dollars. Antennas will come and go, but a good piece of test equipment is a keeper.

Q I've just added an amplifier to my station. Where do I connect my SWR/power meter to measure the output while I am operating?

A The SWR/power meter should be connected between the output of the amplifier and the antenna. If you're using an antenna tuner without a built-in meter, connect the SWR/power meter between the amplifier and the tuner. Use the shortest cables possible. Also, make sure the meter is set to measure high power before you transmit! See **Fig 2-4**.

Q Can I use a 50-ohm, 10-W wire-wound resistor as a 2-meter dummy load? It seems perfect for the job.

A No. While the dc resistance is correct, there is so much inductance that hardly any energy is absorbed by the resistor. In fact, such a resistor barely works at 160 meters (1.7:1 SWR). A much better choice is to use metal-oxide resistors. You can solder together a pair of

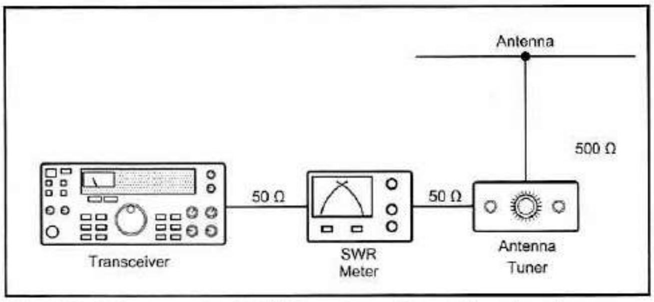


Fig 2-4—Placement of SWR meter with optional antenna tuner in the line.

100-ohm resistors (Radio Shack no. 271-152) in parallel to make a nice 2-W dummy load that works fine, even at 2 meters.

Q When working with an older HF transceiver, should you always tune it into a dummy load rather than the antenna?

A When tuning the finals of older equipment, tune first into a dummy load. In addition to providing a nice 50-ohm load, the dummy will prevent you from causing interference. When you switch to the antenna, a minor adjustment may be necessary to compensate for any mismatch. This should take seconds.

Listen before you attempt any on-air tweaking. Don't complete your tune up on an active frequency. When you find a clear spot, identify your station, listen again, then—if you hear nothing—proceed with the tune up.

When using manual antenna tuners with older equipment, first tune the transmitter into a dummy load. Then, switch to the antenna and adjust the antenna tuner controls for maximum received signal strength. Reduce the transmitter power to a minimum. Now listen. If the frequency is not being used, key the transmitter and make final antenna tuner adjustments. Keep these transmissions to a few seconds in duration, listening in between.

Q I want to put cooling fluid in my old Heath Cantenna oil cooled dummy load. What should I use?

A The oil in a dummy load functions as a coolant so it should have the following characteristics:

1. Low viscosity (for adequate cooling flow)

2. High flash point (to prevent the oil from igniting when hot). Heat transfer oils have flash points in the 230° to 250° range.

3. Low moisture absorbency (so that the above characteristics do not change).

There are better oils, but you won't find them available in small quantities. Do not use motor or transmission oils. They can be corrosive to the components of your dummy load (the resistors in particular).

MFJ sells this type of dummy load and will sell the oil separately through their parts department. There is no part number—just ask for the dummy load oil.

Q Does anyone make a device that will allow you to switch the microphone input of an FM mobile transceiver between a microphone and a packet TNC?

A This question comes up from time to time as hams try to get double duty from their FM rigs. If they do a fair amount of packet and voice operating, it's annoying to have to unplug the microphone, plug in the TNC cable and so on.

MFJ Enterprises makes a unit that performs the switching tasks you require. You plug the microphone into the box, then connect the box to your radio and packet TNC. Switching between the two audio sources is as easy as pushing a button (**Fig 2-5**).

Q I recently purchased a used headset and microphone at a flea market. There was no documentation. What is the best way to "characterize" the components? In other words, how do I go about determining the impedance of the earphones and microphone, and what the microphone needs to function properly?

A The best way to characterize headphones is to measure their impedance at several frequency points, but most hams don't own the necessary equipment. You can make a crude measurement with a simple voltmeter. Place a potentiometer in series with the headphones and feed an audio signal to them (preferably a 1-kHz continuous tone). With the voltmeter on the ac setting, measure the voltage across the headphone and across the potentiometer. Adjust the resistance of the potentiometer until the voltages are the same. Disconnect the potentiometer and measure its resistance. The result will be reasonably close to the impedance of the headphones—at least close enough for amateur work.

The microphone can be characterized by running it into a very high impedance audio amplifier, and then placing different loads across the microphone until the audio characteristics are optimized. The maximum volume may not correspond to the best audio characteristics. It is quite common for people to just "approximately" load the microphone and use an external equalizer. This allows more flexibility.

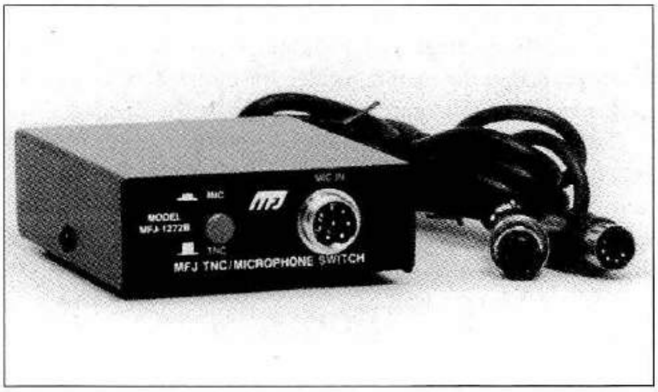


Fig 2-5—The MFJ-1272B switches the microphone input of your FM transceiver between your microphone and packet TNC.

Q **I want to build a crude signal generator for testing some of my little home-brew HF receivers. Can you suggest something that's quick and easy to build?**

A The crystal-controlled generator shown in **Fig 2-6** will function with crystals from 1 to 15 MHz, and provide useable harmonics up to 30 MHz. Bear in mind that an RF signal generator like this isn't suited for critical jobs such as receiver IF alignment, but it is good enough for a number of other test applications.

Q **How do I connect an amplifier to my exciter?**

A First, you need to read the instructions of the amplifier and exciter. Many amplifiers have been damaged by excessive input power. This is particularly true of solid state amplifiers, which can be destroyed by very short pulses. If a 100 W radio is turned down to 25 W, it is quite normal for them to transmit 100 W before the ALC circuitry does its job.

It may be necessary to install a resistive power attenuator between the amplifier and exciter.

Next, it is a good idea to figure out how the amplifier will be keyed on and off. RF sensing is possible at low power levels, but it isn't recommended, as you lose some of your transmit signal during the transition. Most amplifiers have a PTT, or push to talk connection for keying. Typically, grounding this input will turn a relay on, putting the amplifier into transmit. Older amplifiers often have relays that require a substantial amount of voltage and current, often exceeding the ratings of new transceivers. It is always a good idea to measure the voltage and current, and ascertain that no ratings have been exceeded.

Figs 2-7 and **2-8** are two circuits you can modify for your application.

Q **Can you please tell me what the "AT" stands for at the end of a model number?**

A AT after the model number of radios usually designates that it has the automatic Antenna Tuner.

Q **I was wondering if you could tell me the correct way of connecting an oscilloscope to a transceiver to observer station output. I have an RCAscope with vertical and horizontal inputs, but do not know where to hook it to the transceiver.**

A When connecting anything to a transmitter output, you need to first make sure the impedance (SWR) will not be affected. You also need to make sure the scope can handle the full voltage, but that is not usually a problem. The scope input is typically a very high resistance, but the probe (even if it is just a piece of coax) that you use to connect the scope to the rig will have some amount of capacitance.

In the ARRL Lab, to monitor a transmitter output, we use a power attenuator. The transmitter is connected to the input and the scope is connected to the attenuator output. Placing the scope on the output of the attenuator decreases

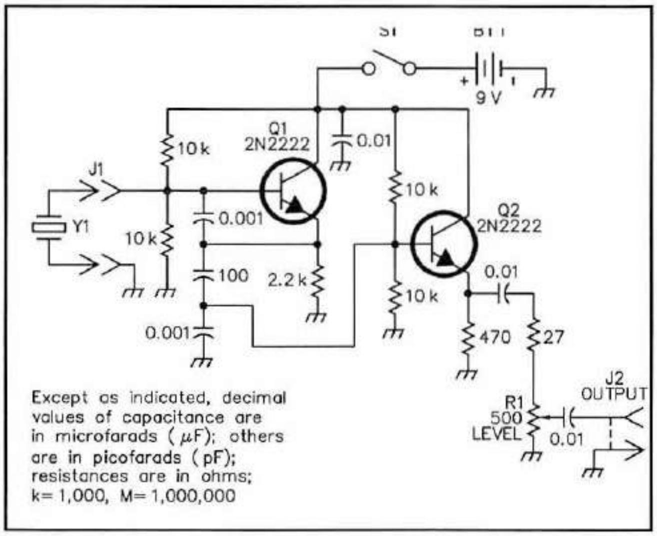


Fig 2-6—Schematic diagram of a crystal-controlled signal source. All resistors are ½ W, 5% carbon types, and all capacitors are disc ceramic.

BT1—9-V battery
J1—Crystal socket to match the crystal type used.
Q1, Q2—2N2222 transistor
R1—500-Ω potentiometer
S1—SPST toggle switch
Y1—1 to 15-MHz crystal

the effect it will have on the transmitter. While you could try using a SO-239 "T" adapter on the output of the transmitter, you may have an SWR problem with that method.

The other issue is that the scope will have to have a frequency rating higher than the transmit frequency. If you have a 5 MHz scope, you would only be able to use it on 160 and 80 meters (you might get a reduced sweep on 40 meters—how much would depend on the scope). In any case, you would use the vertical input.

Q **What is a Lissajous pattern? And who came up with the unusual name?**

A You can credit the name to French physicist Jules Antoine Lissajous. He originally used sounds at differing frequencies to vibrate a mirror and trace patterns with a beam of reflected light.

In electronic applications we can generate Lissajous patterns by applying different signals to the horizontal and vertical inputs of an oscilloscope. In fact, this technique was often used to measure frequencies in the days before frequency meters. A signal of a known frequency was applied to the horizontal input and the signal to be measured was applied to the vertical input. The resulting pattern was a function of the ratio of the two frequencies. For example, if you put a 1-Hz 1-V signal on the vertical input and the same on the horizontal, a circle will appear on the screen. If you change the horizontal input to 2 Hz, you will get a horizontal figure 8—showing that the horizontal to vertical ratio is 2:1. By observing the patterns you can interpret the ratio, which tells you the frequency of the signal you're attempting to measure.

If you have a Web browser that supports Java, check out

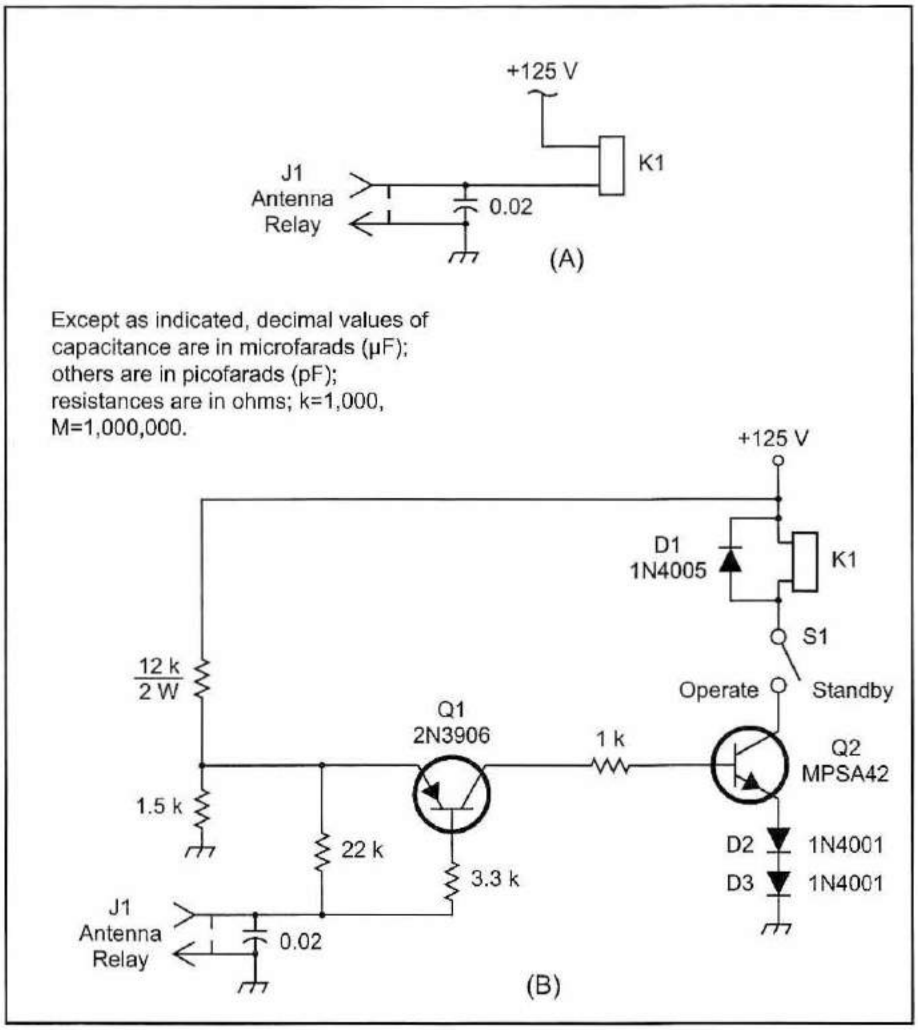


Fig 2-7—James Hebert, K8SS' SB-220 modification lowers the voltage at the ANT RLY jack, J1, from 125 at A to approximately 12 at B. Short-circuit current through J1 is reduced from 25 mA in the unmodified circuit to 2 mA in the circuit shown at B. JI, K1 and the 0.02-μF capacitor are SB-220 parts. Resistors are ¼-W, carbon-film units unless designated otherwise.

D1—1-A, 600-PIV diode.
D2, D3—11A 50-PIV diode.
Q1—General-purpose transistor.
Q2—High-voltage switching transistor, V_{ceo} =300. ECG287 also suitable.
S1—SPST toggle.

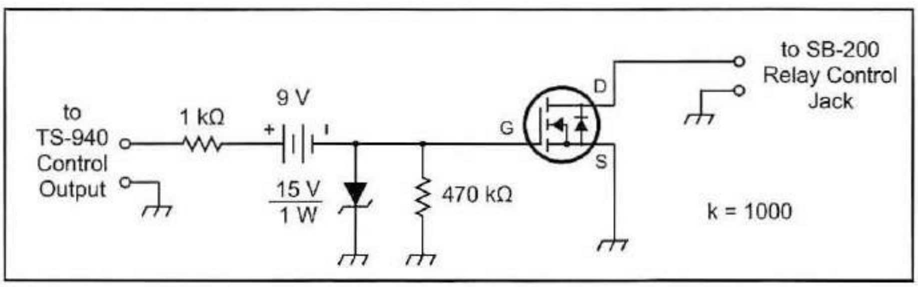


Fig 2-8—Richard Jaeger, K4IQJ's solid-state transceiver-to-amplifier interface uses a power MOSFET instead of a relay for amplifier control. For amplifiers that use a *positive* relay-control voltage, reverse the polarity of the Zener diode and battery, and use an IRF612 N-channel MOSFET instead of the IRF9612.

the "Lissajous Lab" at **http://ovpserv4.rug.ac.be/toegepfysica/Applets/Lissajous4/index.htm**. You can plug in the frequencies of your choice and view the resulting Lissajous patterns (see **Fig 2-9**).

POWER SUPPLIES

Q The power cube that came with my CW keyer seems to have burned out. I have another cube, about the same physical size, but it says 6 V ac and the old one said 7.2 V ac. But when I measure the new one, my voltmeter reads 8.5 V. Do you think I can use the new one?

A As you might guess, not all power cubes are created equal, but some come very close. The voltage is just one of several things to check. First, did the old cube contain a diode, and therefore supply rectified ac? Some cubes supply ac; some, rectified ac; and some, dc. Next, is the power capability of the new cube high enough? The keyer might require 6 V at 20 mA, and the new one could supply the 6 V, but not at the required load current. The volt-ampere rating might give you a clue.

Assuming your keyer uses an internal voltage regulator, the actual input voltage is not critical as long as it is not over a volt or two from the original cube. But some cubes, when overloaded, get very hot, so I don't suggest you push it!

Finally, be very careful of the plug. There is no real standard, and if you wire the plug's output polarity backward you could damage your keyer. If the cube supplies just ac,

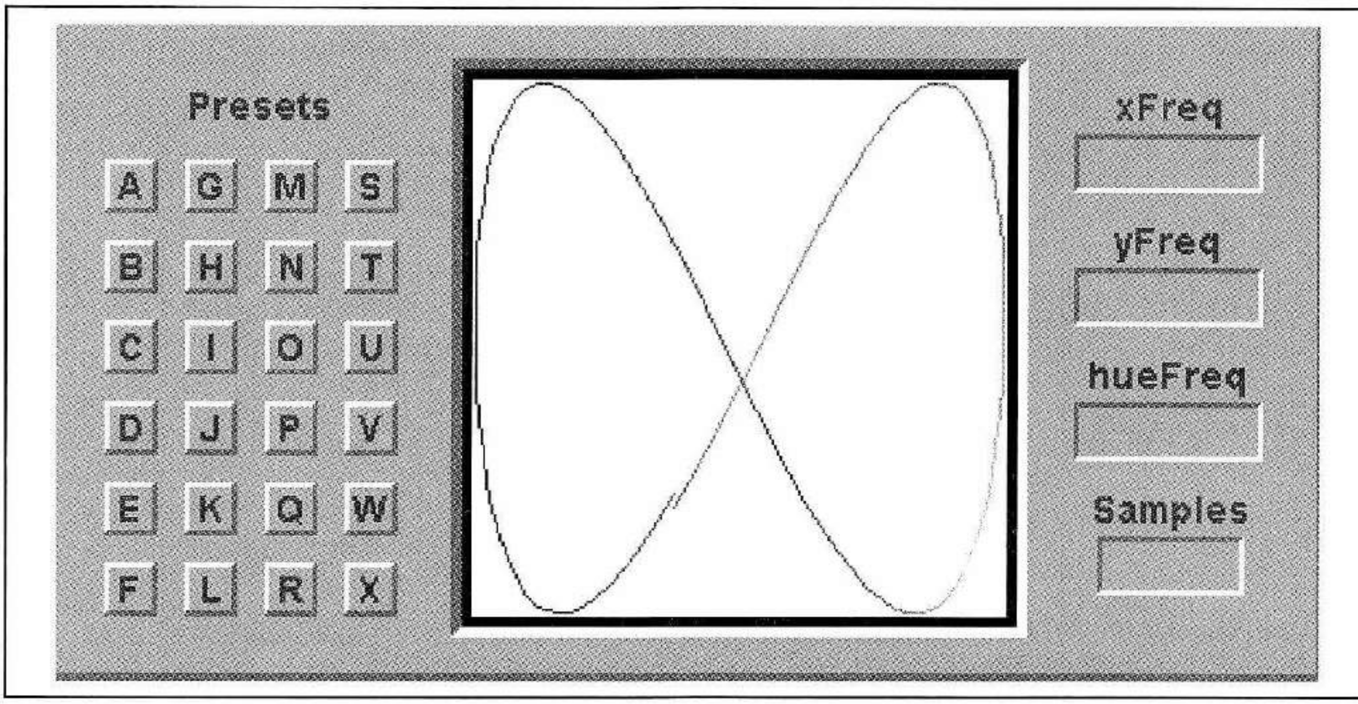


Fig 2-9—Check out the "Lissajous Lab" on the Web at ovpserv4.rug.ac.be/toegepfysica/Applets/Lissajous4/index.htm.

then this is not a problem.

Q The power supply I'm building has a transformer wired through a switch and fuse to the ac line. Does it make any difference to what pin on the ac wall plug I wire each side of the line cord?

A The standard, for safety, connects the hot lead to the narrower flat pin, and the other lead to the wide pin (called the *neutral* lead). For your power supply, the line switch and the fuse should be in series with the hot lead, although I prefer to switch both leads with a DPDT line switch. The round pin on the ac plug goes to the power supply chassis. Does it make any difference? Well, if anyone ever wants to work on your power supply (and you don't remember how you built it), you can prevent a nasty accident by wiring the supply as the safety standard suggests.

Q I often see power transformers for sale at hamfest flea markets. Most of the time, however, I have no idea which leads belong to which windings. Is there a way to find out?

A Flea markets are great places to find cheap transformers. Despite the fact the transformer you've spotted is lying at the bottom of a dingy cardboard box, there is a good possibility that it's still useable. The problem is to determine what voltages and currents the transformer can supply. First consider the possibility that you're really looking at an audio transformer or other impedance-matching device rather than a power transformer. If you aren't sure, don't connect it to ac power!

If the transformer has color-coded leads, you're in luck. There is a standard for transformer lead color-coding (see **Table 2-1**). Where two colors are listed, the first one is the main color of the insulation; the second is the color of the stripe.

Check the transformer windings with an ohmmeter to determine that there are no shorted (or open) windings. The primary winding usually has a resistance higher than a filament winding and lower than a high-voltage winding.

If your mystery transformer isn't blessed with color-coded leads, I suggest that you check out Chapter 11 in the *ARRL Handbook*. Figure 11.2 shows a neat little test setup.

Table 2-1
Power-Transformer Color Codes

Function	*Color*
Nontapped primary leads	Black
Tapped primary leads	Black
Primary center tap	Black/yellow striped
High-voltage plate winding	Red
High-voltage center tap	Red/yellow striped
Rectifier filament winding	Yellow
Rectifier filament center tap	Yellow/blue striped
Filament winding 1	Green
Filament winding 1 center tap	Green/yellow striped
Filament winding 2	Brown
Filament winding 2 center tap	Brown/yellow striped
Filament winding 3:	Slate
Filament winding 3 center tap	Slate/yellow striped

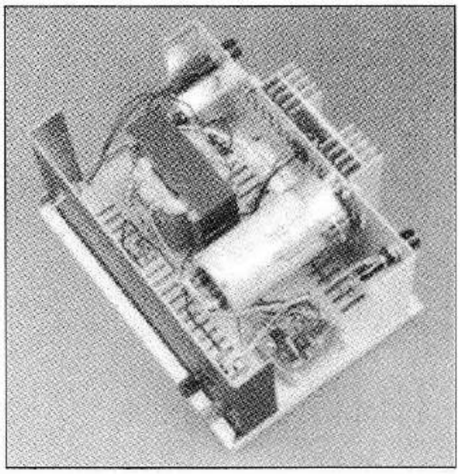


Fig 2-10—You can build this 13.8-V, 5-A dc power supply from details provided in the *1997 ARRL Handbook.*

Q Can I upgrade my old Micronta 1-A power supply to 5 A by just changing the filter capacitor?

A No. In fact, the capacitor is one item you *wouldn't* need to change. Upgrading from 1 A to 5 A is a big increase. You'd have to replace the transformer, the rectifier diodes and most of the regulator circuitry itself to withstand the higher current demand. In other words, you would have to rebuild the power supply from the ground up. You'd be better off buying a new high-current supply, or building one from scratch using designs in *The ARRL Handbook* (see **Fig 2-10**). Building a simple, low-voltage power supply is relatively easy and very rewarding!

Q I need to measure the amount of current my radio is drawing from my power supply when it's in the receive mode. I don't own an ammeter, though. All I have is a cheap volt/ohmmeter (VOM). Do you have any tricks up your sleeve to solve this problem?

A Indeed I do! Just use your cheap volt/ohmmeter, a small resistor and a pinch of Ohm's Law.

The trick is to use a very small resistance in series with the positive voltage line from the power supply. A 0.47-Ω, 5-W resistor, such as a Radio Shack 271-131, will do nicely. As the current flows through the resistor, it creates a voltage drop that you can measure with your VOM. Once you have this number, you can plug it into Ohm's Law to determine the current. Let's say that you're using the 0.47-Ω resistor and you measure a voltage drop of 1 V across it. To calculate the current (I), just run the numbers:

I = E (voltage) ÷ R (resistance), or I = 1 ÷ 0.47
The answer is 2.13 A

Of course, this method is not as accurate as using a meter, but it is usually good enough for ballpark work. Note that this method is best for smaller currents. Even though the resistance and resulting voltage drop are low, there is enough power being dissipated to generate a substantial amount of heat in the resistor. In our example, the 5-W resistor will be dissipating more than 2 W, which is well within its rating. But if you were going to measure much larger currents (like the kind your radio probably draws when it's transmitting), you'd need a much higher wattage resistor. In that case it is best to seek out a used ammeter. You'll occasionally find them lurking in boxes at the larger hamfest flea markets.

Q What is a switching power supply and how does it differ from a normal power supply?

A In a linear power supply, the line voltage goes directly into a low-frequency transformer where it is stepped down to the appropriate low voltage before rectification, filtering and regulation. In a switching power supply, the line voltage is directly rectified and filtered to produce a high dc voltage. This voltage is then "switched" at a high frequency rate (not RF, but certainly higher than audio–perhaps 50 kHz for example) by switching transistors. It is then fed into a high frequency transformer and the output is rectified and filtered. Regulation can be done in the output stage, but more typically, the regulation is done at the switching transistor to allow the amount of energy fed to the transformer to be adjusted as needed.

One advantage is that higher frequency components are much smaller and lighter weight for the same power capability than their low frequency counterparts. Another advantage is that, since the transformer is the least efficient part of the supply, controlling its input power can provide much better efficiency. The power lost as heat in a linear supply is typically 40-60% of the output power. In a switching supply, that typically drops to 10-20%.

The disadvantages of a switching supply are the increased complexity (more likelihood of a component failure), increased cost (many more parts) and tendency to created radiated RF (the switching waveform is usually pretty close to a square wave, so it contains a lot of harmonics). This last item has been the main one that has kept switching supplies out of the ham market until recently. Current designs use an extensive amount of filtering and radiation suppression techniques to greatly reduce unwanted RF.

Adding filtering and regulation to a linear supply is a simple matter. Information on calculating filter component values for a particular desired ripple can be found in the *ARRL Handbook* chapter on Power Supplies. However, regulation will come at a cost in reduced output capacity–if you have an unregulated supply that puts out 15 V, you probably won't be able to get more than 13 V from a regulator system attached to it.

All switching supplies have some kind of regulation, although some designs are quite crude and could use improvement. However, I don't suggest trying to modify a switching supply unless you have studied switching power supply design extensively.

Q I have solar panels that supply 14 Vdc @500 mA. My HW-8 requires 13 Vdc @ 480 mA (xmit). I have used gel cells to power the rig but wonder if the solar panels can run the rig directly. Here in SE Florida

the beach and Atlantic Ocean are a few minutes away and sunshine without clouds is no problem. Can I run the rig directly off the solar panels?

A Yes you can. I have run my HW-9 directly from the solar panel many times. Of course when a cloud goes by you might get a report of QSB on your signal and it does limit your operation to daylight hours.

TROUBLESHOOTING

Q During the blizzard last winter, I attempted to attach the feed line from my coax-fed dipole to my transceiver. As I moved the connector near the rig, I saw a large spark! What could cause this?

A High winds and precipitation can cause substantial static buildup on antennas especially large ones. The effect is similar to rubbing your shoes on a dry carpet and then touching a door knob. The static electricity on your body discharges through your fingertips (sometimes painfully). In your case, when you brought the connector close to the rig, the static electricity on the antenna suddenly discharged to ground.

This is another good reason to disconnect your antenna feed line when bad weather threatens. Many hams don't realize that it doesn't take a thunderstorm to build a sizable electric charge on an antenna. Imagine applying a several-hundred-volt charge to the sensitive input of a solid-state receiver (they're more accustomed to dealing with potentials in the *microvolt* range!). As you can see, it doesn't take a lightning strike to cause very serious damage.

If you're reluctant to disconnect your cables, consider installing a static-discharge device such as those advertised in *QST*. Most of these products include tiny tubes filled with gas. When the static electricity in the antenna system reaches a preset level, the gas suddenly conducts and discharges the electricity to ground. The discharge takes only a few *nanoseconds* (billionths of a second), short-circuiting the energy before it can damage your radio

Another option is to use an antenna switch that grounds the antennas that are not in use They're not adequate for a direct lightning hit but are fine for static buildup.

In extreme weather conditions such as blizzards and thunderstorms, I'd still recommend that you disconnect your feed line and avoid operating until calmer weather returns. A discharge unit may protect your investment—or it may not. Why take a chance?

Q The plate on the back of my new rig says "117 Volts, 50-60 Hz." I measured my line voltage and the meter read 119 V. Is this a problem?

A Not with today's rigs. Most of them contain a power supply with regulators, and line voltages from 110 to 125 V are usually acceptable. This was a real problem with older vacuum-tube rigs. They used transformers to supply the filament voltages to the tubes, usually without regulation. Often, the tube life was shortened by high filament voltages. Many of the better tube rigs had sets of taps on their power transformers, and you would have to pick the tap for your line voltage—110, 112, 115, 130 V or whatever.

Many newer rigs do have two tap settings—for 117 or 220 V. This allows you to operate the transceiver in many countries that do not use the North American standard of 117 V. Usually, rigs shipped to a particular country have the correct tap connected at the factory, but it doesn't hurt to check before you plug a new radio into the wall socket!

Q I have a Yaesu FT-7 transceiver that seems to generate the proper output, but the receiver is behaving strangely. Sometimes it seems to die altogether. When I jostle the rear cabling and PL-259 it comes back in full force. Gently tapping the radio provides similar results. I've checked the coax and it is fine; so is the PL-259 connection. This has occurred on different antennas and cables, so I know it's not the cable system. Have you heard of such a problem before?"

A This is a common problem on older radios. There are three possible causes:

(1) Oxidation on the connectors (using a contact cleaner would help here).

(2) Fatigue of the contact "fingers" on the center receptacle of the SO-239 coaxial connector. After repeated connects/disconnects, the sides of the center part of the SO-239 are often bent outward, resulting in poor contact with the pin on the PL-259. You can sometimes take a sharp probe and bend them *slightly* inward to correct this. If the connector doesn't look too difficult to replace with a new one, you might want to consider that approach.

(3) Cold/fatigued solder joint on the inside of the radio at the SO-239 connector.

Q I have my crank-up tower down and over now for antenna repair. I have heard a variety of local opinions regarding lubrication of raising cables. One is to leave them dry and the other is to wet a cloth with WD-40 or CRC 5-56 and wipe the cables with this to provide lubrication and rust protection. Any opinion or recommendations?

A As the young people would say, WD-40 **NOT!** WD-40 is not a lubricant—it is (this is true) the 40^{th} Water Displacement formula (WD-40) that NASA tried for some application or other.

What you want to use is a "good" grease—check with your local auto mechanic; he should know what's available.

Q A friend of mine and I were doing some tests on 75 meters recently. I wanted to see if I could hear his signal over the 600 miles that separated us. It was a frustrating exercise because I could hear him pretty well while he was tuning up, but when he switched to SSB, he was very weak. Why?

A When your buddy was operating his rig in the TUNE mode, he was concentrating all of his RF power in a very narrow bandwidth. When he jumped to SSB, his RF was suddenly spread over nearly 3 kHz of spectrum. Without getting into heavy-duty analysis, we'll suffice to say that his RF was "watered down"—no longer packed into a tight space.

You've stumbled upon the reason why CW is often audible when no other type of signal can be heard. The RF energy in a CW signal is concentrated in just 100 Hz or so of bandwidth. That's why low power (QRP) operators prefer CW. They can run just a watt of power and still be heard hundreds and even thousands of miles away. It's easy to understand why moonbouncers prefer CW, too. They operate at higher power levels—typically more than 500 W—and the narrow bandwidth of CW allows their signals to be audible even after traveling to the Moon and back!

Q I'm teaching an Amateur Extra course and the term "common mode" has come up in our discussions of interference. Unfortunately, the definitions in the *License Manual* and in *The ARRL Handbook* fail to explain it in easily understandable language. Can you provide a brief explanation?

A The best definition of "common mode" appears in the new *ARRL RFI Book*. Basically, common mode is a situation where a given signal appears equally on more than one conductor in a cable, with the same voltage and the same current flowing in the same direction relative to a particular device (see **Fig 2-11**). The return path of the signal is typically outside of the affected cable.

A good example is RFI to a telephone via the line cord. The 4 (or 6 or 8, depending upon the phone system) conductors act as a multiconductor, end-fed antenna.

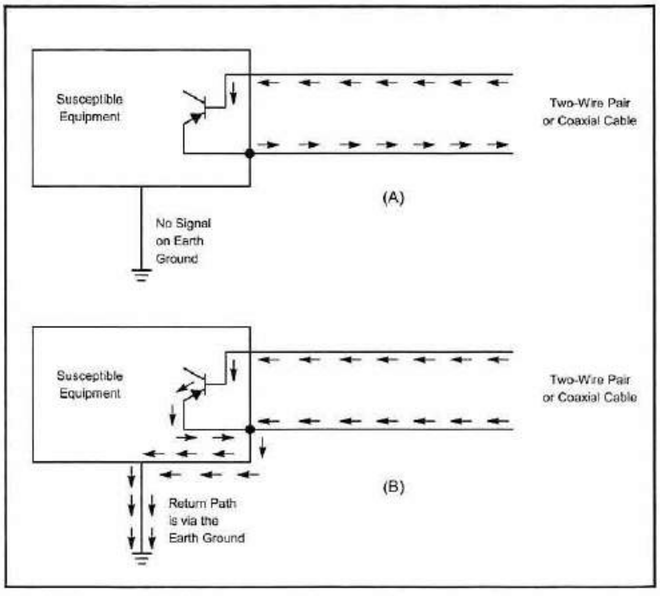


Fig 2-11—In (A) there are differential-mode signals conducted between two wires of a pair. This signal is independent from earth ground. In contrast, a common-mode signal (B) is in phase on all wires that form the conductor (this includes coaxial cable). All wires act as if they are one wire. The ground forms the return path.

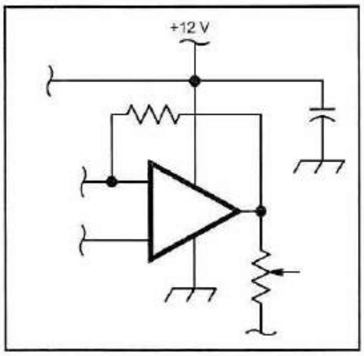


Fig 2-12—A straight line ending in a wavy line indicates that the circuit path continues elsewhere. In this case, it's a connection to a 12-V power source.

CONSTRUCTION

Q I'm building a kit for the first time and I am a little confused by the schematic diagram. It shows circuit paths that just end in wavy lines. I assume this means that the circuit continues, but I'm not sure. Can you help?

A Schematic diagrams can indeed be confusing if you're not accustomed to the symbols. Your guess is correct. The symbol (**Fig 2-12**) indicates that the circuit continues, but the continuation isn't shown. Why not? In this case it's because the continued circuit is a power connection. When you have several of these with the same voltages indicated, it means they all share the same power source. It's much easier for you to read the schematic if the connections are shown this way, rather than having a bunch of individual lines snaking their way back to the power supply circuit.

You'll see this technique used often—especially in complicated schematics. If you need to show that one part of a circuit connects to another, it's far simpler to use this type of symbol. Whenever you see the symbol, just think "goes to" or "connects to" and you'll never fail.

Q I'm debating whether to buy or build my own equipment. Can you offer any guidance?

A Making two-way radio contacts with a radio you've built yourself is a wonderful experience for radio amateurs. Most people do this with low-power (QRP) Morse code (CW) transceivers. A number of companies make kits just for this purpose. You can probably get on the air with a serviceable home-built station for under $100. Experts can do it for much less by taking advantage of bargains found at flea markets that specialize in Amateur Radio components.

Pushing the state of the art is another great reason to build your own gear. There are bands and modes that aren't popular yet, so that little is available in the way of affordable equipment. The Wright brothers had to build their own airplane. They couldn't have been first in flight if they'd waited for someone to produce a commercial product!

But are there valid reasons not to build? Economics is probably the major factor. Generally speaking, you can't build complicated electronic gear for less than you can buy it. Often, the money spent on home-brew gear can't easily be recovered. In other words, you may have a tough time

Fig 2-13—The Elecraft K1 transceiver is one popular transceiver kit. There are several others to choose from as well.

selling your home-brew equipment in the future. In contrast, the resale value for commercial Amateur Radio gear is surprisingly high, even for relatively old equipment.

If you decide to roll your own, start with simple projects. Build simple things, like antennas or electronic keyers. Assembling a modern all-band all-mode radio is more difficult than trying to build your own computer! (And modern radios often have a computer inside that coordinates everything!) **Fig 2-13** shows an example of a popular transceiver kit.

Q I was recently talking to some electronics techs who "insisted" upon using silver solder (not rosin-core) for their project. Is there a difference in the application or finished work that makes one type the right choice over the other? What are the differences in preparation work or soldering practices when using rosin-core or non-rosin-core solder?

A First, I should note that there are different kinds of silver solder: acid core for plumbing work and rosin core for electronics work. The latter is preferable because the acid can cause corrosion in certain circumstances. On the other hand, acid flux generally does a better job of penetrating oxidation than rosin does—that's why plumbers use it.

The silver in silver solder also tends to adhere better when it is oxidized than regular tin-lead. That's the main reason hams prefer silvered PL-259s—they are far easier to install than the nickel plate ones. Long-term conductivity may be better too.

Silver solder is also useful for preventing metal from leaching out of electronic components such as chip capacitors. Some terminal strips would also leach metal if ordinary tin lead solder was used—it was often essential to use silver solder when repairing old Tek scopes. It doesn't matter with some chip parts—there are chip caps with a protective nickel barrier plated with gold to virtually eliminate this problem.

There is little evidence to show that silver plating is worthwhile at VHF in terms of reducing circuit losses—polished copper is superior. Most people can't obtain the type of silver plating that is useful, as the cyanide used is heavily regulated.

COMPONENTS

Q What is the correct method for tightening UHF and/or N-type connectors and adapters after you attach them to your equipment?

A Marc Abramson, KC9VW, of Cable X-perts provides the answer ...

After properly mating any connector and/or adapter, the correct way in which to secure it is to hand tighten *only*. This will provide sufficient electrical and mechanical connector integrity. Using a mechanical tool for mating connectors (such as a wrench or locking pliers) will likely cause overtightening and breakage. Just tighten the connectors with your fingers and that will do the job. Of course, don't forget to weatherproof any connectors used outdoors.

Q What is a BNC connector and what does "BNC" stand for?

A BNC is a "quick connect/disconnect" coaxial cable connector (see **Fig 2-14**). Unlike common PL-259 or male N connectors that require several rotations of their shells to secure them, a BNC latches with a single twist. According to Press "The Wireman" Jones, N8UG, "BNC" is an abbreviation for "Bayonet Neill Concelman." The word "bayonet" refers to the connector's style and Paul Neill and Carl Concelman were Bell Labs engineers who developed it. BNC connectors can be used well into the microwave range and can tolerate as much as 500 V peak-to-peak.

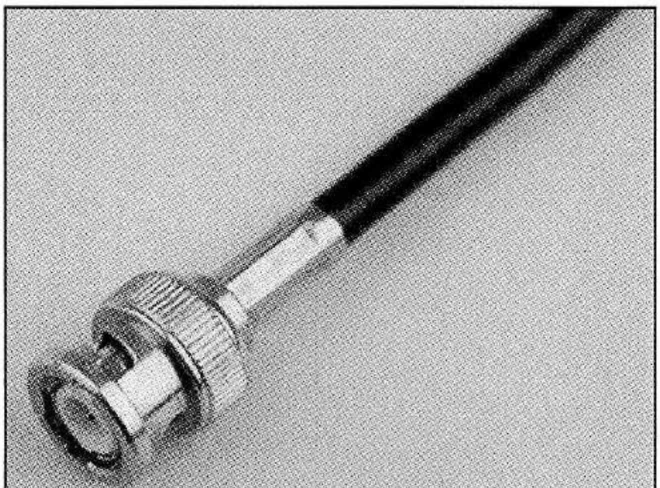


Fig 2-14—A typical BNC connector.

Table 2-2
Connector Loss at Various Frequencies

Frequency (MHz)	*N Loss (dB)*	*UHF Loss (dB)*
1.8	0	0
30	0	0
100	0	0
150	0	0.01
200	0	0.015
450	0	0.09
600	0	0.13
900	0	0.33
1000	0.025	0.4
1300	0.05	0.43
1600	0.025	0.25
2000	0.025	0.01

Q I often hear about losses in RF connectors. For example, everyone says that so-called UHF connectors are terribly lossy even at VHF! Has anyone actually measured connector loss at various frequencies?

A Using an HP8753 RF network analyzer and a test setup to contrast the losses of the lowly UHF connector to the highly respected N connector, these are the results.

The UHF connector's insertion loss increases until about 1200 MHz, and then starts to decrease until it is almost zero for the UHF connector at 2 GHz! At this frequency, both connectors are about 1/4 wavelength long.

Bottom line: UHF connectors work fine through the VHF range, and are not too bad even on the 420 MHz band if you can stand about 0.1 dB mismatch loss per connector.

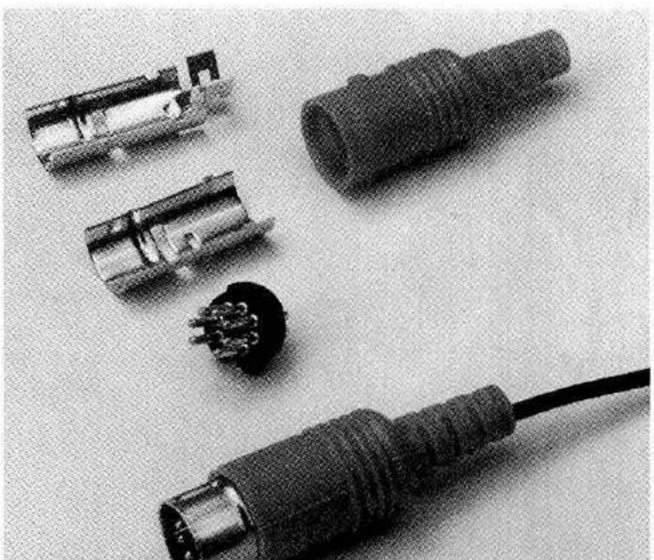


Fig 2-15—The ubiquitous DIN connector.

Q What is the meaning of DIN, the infamous multi-pin plug?

A DIN is an acronym for Deutsches Institut für Normung, the standards-setting organization for Germany. A DIN connector (see **Fig 2-15**) is a connector that conforms to one of the many standards defined by DIN. There are many types of DIN connectors in addition to the familiar multi-pin circular types.

Q My Kenwood TS-570D has 13 pin receptacle for accessories. They provide a 13 pin DIN plug with the set. This plug has 13 stubs on the wiring side that do not appear to be meant for soldering. If soldered to there would have to be a butt joint which is not a very good idea. Question: Are there sleeves available to facilitate use of these plugs? No supplier contacted so far has any knowledge of the subject and someone somewhere has the answer. Perhaps your Lab technicians can help. The pins are approximately .032 inches in diameter.

A Through the years, I have encountered DIN plugs like the ones you describe. There seems to be no adapter so care is required.

If the wire is thin enough and you are not connecting to adjacent pins you can form a small loop at the tip of the wire, bend it 90 degrees and slide it onto the pin for soldering. More often than not you are forced to "tack" solder the wire on and when you are done, pot the connector—auto windshield sealer or bathtub sealer will do the job. See **Fig 2-16**.

Q Radios, antennas and other products made for UHF and above often use Type-N feed line connectors. Why?

A One of the primary tasks of any coaxial connector is to maintain a constant impedance at the point where the cable joins the radio, antenna or whatever. If the impedance changes at the connector, you have what some call an *impedance bump*. This translates to an elevated SWR and increased signal loss (transmit and receive).

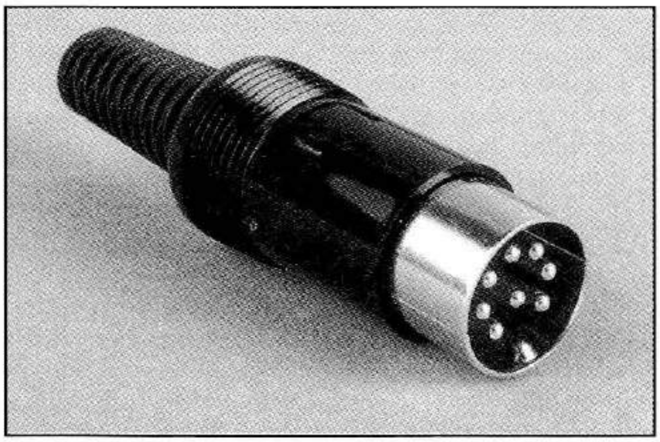


Fig 2-16—The type of DIN plug used with the Kenwood TS-570D transceiver.

The connector found on most HF and VHF transceivers is the so-called "UHF" connector (one of the worst misnomers in radio!). Although a UHF connector isn't the best choice for providing a constant impedance, any loss it causes at HF and VHF frequencies isn't worth worrying about. When you start dealing with frequencies above the 222-MHz band, however, the loss caused by a UHF connector can become significant. This is especially true if you're involved in weak-signal work or similar activities, where you need every bit of signal energy you can get.

Type N connectors are far superior when it comes to maintaining a constant impedance. That's why they're preferred among hams who operate at 420 MHz and above. Type Ns have an added advantage over UHF connectors: they make watertight connections.

Q Is there a shelf life for crystals? I have an old Collins radio that features a crystal-controlled local oscillator for each band. Ten-meter reception is nonexistent and the crystal for that band seems to be dead. Did it simply expire from old age?

A Provided crystals are properly cared for, they normally don't exhibit a shelf life. Assuming all the tuned circuits associated with your troublesome crystals are still in proper adjustment—and that's the most likely problem—here are several other factors to consider. For example, overdriving (or overloading) a crystal can cause it to crack and render it useless. Impurities such as dirt or moisture can cause reduced crystal output and possibly shift its frequency as well.

If your crystal has a holder that facilitates easy removal, such as the FT-243, I suggest that you try cleaning the crystal element. Crystals in hermetically sealed holders are obviously not eligible for this treatment. I've used denatured alcohol to clean my crystals, with excellent results. (Do not use rubbing alcohol. It may contain additives that can leave residue on the crystal.) Be sure not to touch the crystal directly with your fingers. Treat them gently and minimize handling them in general.

Once the holder is opened, be sure to inspect the crystal contacts. These are the small metal plates between which the crystal is sandwiched. Be sure there are no dust or dirt particles in the holder.

Q I recently bought some radio crystals. Most are removed from 1940s Navy radios. When I was young my father had some of these, and I wanted to take them apart to see what was inside. He wouldn't see to this. Now I have some to play with. Can you explain how they work, keeping it as simple as possible.

A A number of crystalline substances found in nature have the ability to transform mechanical strain (movement) into an electrical charge, and vice versa (think of a tuning fork or a church bell which can transform mechanical strain into sound). This property in crystals is known as the *piezoelectric effect*. A small plate or bar cut in the proper way from a quartz crystal and placed between two conducting electrodes will be mechanically strained when the electrodes are connected to a source of voltage. Conversely, if the crystal is squeezed between two electrodes a voltage will be developed between the electrodes.

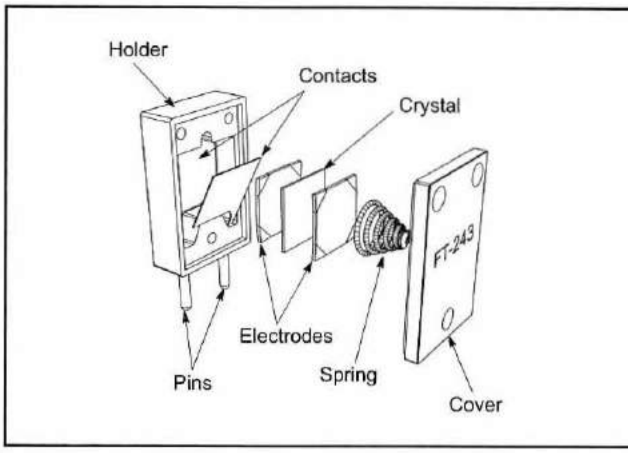


Fig 2-17—A cutaway view of a crystal shows its internal structure.

Crystalline plates also are mechanical resonators that have natural frequencies of vibration ranging from a few thousand cycles to tens of megacycles per second. The vibration frequency depends on the kind of crystal, the way the plate is cut from the natural crystal, and on the dimensions of the plate (like the tuning fork and the bell). The thing that makes the crystal resonator valuable is that it has extremely high Q, ranging from 5 to 10 times the Qs obtainable with good LC resonant circuits.

Since the crystal has a definite resonant frequency controlled by the crystal lattice, it can be used to "regulate" an oscillator to a high degree of accuracy. See **Fig 2-17**.

Q I enjoy restoring old rigs, many of which use relays. Can you give me some general service tips on working with these devices?

A Although relays have been replaced by semiconductor switching in low-power circuits, they are still used extensively in high-power Amateur Radio equipment. They may develop any of several problems: Relay action may become sluggish. ac relays can buzz (with adjustment becoming impossible). A binding armature or weak springs can cause intermittent switching. Excessive use or hot switching ruins contacts and shortens relay life.

You can test relays with a voltmeter by jumpering across contacts with a test lead (power on, in circuit) or with an ohmmeter (out of circuit). Look for erratic readings across the contacts, open or short circuits at contacts or an open circuit at the coil.

Most failures of simple relays can be repaired by a thorough cleaning. Clean the contacts and mechanical parts with a residue-free cleaner. Keep it away from the coil and plastic parts that may be damaged. Dry the contacts with lint-free paper, such as a business card; then burnish them with a smooth steel blade. Do not use a file to clean contacts.

Replacement relays should match or exceed the original specifications for voltage, current, switching time and stray impedance (impedance is significant only in RF circuits). Many relays used in transceivers are specially made for the manufacturer. Substitutes may not be available from any other source.

Before replacing a multicontact relay, make a drawing of the relay, its position, the leads and their routings through the surrounding parts. This drawing allows you to complete the installation properly, even if you are distracted in the middle of the operation.

Q I've heard of a phenomenon call the "skin effect." What is the "skin effect"? Does it take place only at RF frequencies?

A The skin effect is a fascinating phenomenon, and it takes place at all signal frequencies. The resistance of a conductor to ac is different than its resistance for dc. A consequence of Maxwell's equations is that thick, near-perfect conductors (such as metals) conduct ac only to a certain depth that is proportional to the wavelength of the signal. This decreases the effective cross section of the conductor at high frequencies, and thus increases its resistance.

At low audio frequencies, the increase in resistance called, *skin effect*, is insignificant, but at radio frequencies above about 1 MHz, the skin effect is so pronounced that practically all of the current flows within a few thousandths of an inch of a copper conductor's surface. The depth of this skin layer decreases by a factor of 10 for every 100-fold increase in frequency. Above 10 MHz, only about the outer 0.0008 inch of the surface is used, and above 100 MHz the depth is less than 0.0003 inch.

This explains why at RF a hollow tube and a solid tube of the same diameter and made of the same metal will have the same resistance.

Q I recently acquired a dual-band H-T that I would like to use on 2 meters with my MFJ-1796 vertical antenna. As you may know, this antenna covers several HF bands along with 6 and 2 meters. I'm feeding the antenna with 40 feet of RG-58 coax. My friend says that I'd have to replace this feed line if I wanted to use my H-T because the loss at 2 meters is too great. Is this true? If so, is there a common, affordable replacement that would solve the problem?

A Your friend is correct concerning the loss in your 40 feet of RG-58 at 2 meters. And remember that the loss works both ways—it reduces your transmitted signal and attenuates received signals.

Assuming that your antenna presents a 1:1 SWR on 2 meters, you can expect to see a loss of 2.6 dB (about 45%) at 146 MHz with 40 feet of "typical" RG-58 coax. In other words, nearly half of your transmit power will be lost, along with a comparable reduction in received signals.

But even replacing the RG-58 with commonly available *foam* RG-8 coax will provide a substantial improvement. Now your matched loss at 146 MHz would drop to a much more acceptable 0.8 dB, or about 17%. Of course, losses will be reduced on the lower bands as well.

Q I sometimes hear the term "Q" in conversation, especially when the subject is antenna tuners. What is "Q"?

A Components that store energy, such as capacitors and inductors, can be compared in terms of *quality* or *Q*. The Q of any such component is the ratio of its ability to store energy to the sum total of all energy losses within the component. In practical terms, this ratio reduces to the formula:

$$Q = X/R$$

where:

- Q = figure of merit or quality (no units),
- X = X_L (inductive reactance) for inductors and X_C (capacitive reactance) for capacitors (in ohms), and
- R = the sum of all resistances associated with the energy losses in the component (in ohms).

Most capacitors have fairly high Qs because of their ability to store charges for considerable time periods. Good quality ceramic and mica capacitors may have Q values of 1200 or more. On the other hand, microwave capacitors can have poor Q values; 10 or less at 10 GHz and higher frequencies.

Inductors are subject to many types of electrical energy losses, such as wire resistance and core losses. All electrical conductors have some resistance through which electrical energy is lost as heat. As a result, inductor Q rarely approaches capacitor Q.

An antenna tuner is a tuned-circuit device where inductors and capacitors are working together. In this situation you can wind up with extremely high Qs, depending on the load (antenna system). Even if you're running very low power levels, the high Q in the tuner can create a substantial charge—enough to arc, in some cases!

Q I know this is an awfully basic question, but could you please review the fundamentals of identifying resistor values?

A Don't feel bad. Everyone needs brushing up on the basics now and then.

Take a look at **Fig 2-18**. Most resistors are marked with bands of specific colors. By "decoding" the colors in the proper order, you can determine the value of the resistor.

Numerical values for first and second bands:

0 = Black
1 = Brown
2 = Red
3 = Orange
4 = Yellow
5 = Green
6 = Blue
7 = Violet
8 = Grey
9 = White

Numerical values for third band:

0.01 = Silver 0.1 = Gold
1 = Black

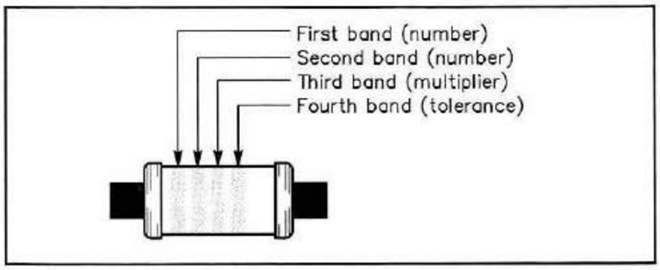


Fig 2-18—Resistors are often marked with bands of color to identify their values.

10 = Brown
100 = Red
1000 = Orange
10000 = Yellow
100000 = Green
1000000 = Blue

Numerical values for fourth band:

5% = Gold
10% = Silver
20% = No color

The third band is normally a "multiplier" band. Some resistors, such as 1% tolerance components, require a fifth band. In this case, the first three bands will have numerical values and the fourth band will be the multiplier.

Let's say that you have a resistor with the following color bands (reading from left to right): red—red—orange—silver.

It decodes like this:

red = 2
orange = multiply×1000
silver = 10%

What do you have? A 22,000 ohm, 10% tolerance resistor!

Q Can you provide a list of the diameters of various wire gauges and their resistances per 1000 feet?

A Absolutely! See **Table 2-3**.

Table 2-3

A Comparison of Wire Gauges

Gauge	*Diameter (inches)*	*Resistance (in Ω) per 1000 feet*
0000	0.460	0.04906
000	0.40964	0.06186
00	0.3648	0.07801
0	0.32486	0.09831
1	0.2893	0.12404
2	0.25763	0.1563
3	0.22942	0.19723
4	0.20431	0.24869
5	0.18194	0.31361
6	0.16202	0.39546
7	0.14428	0.49871
8	0.12849	0.6529
9	0.11443	0.7892
10	0.10189	0.8441
11	0.090742	1.254
12	0.080808	1.580
13	0.071961	1.995
14	0.064084	2.504
15	0.057068	3.172
16	0.05082	4.001
17	0.045257	5.04
18	0.040303	6.36
19	0.03589	8.25
20	0.031961	10.12
21	0.028462	12.76
22	0.025347	16.25
23	0.022571	20.30
24	0.0201	25.60
25	0.0179	32.2
26	0.01594	40.7
27	0.014195	51.3
28	0.012641	64.8
29	0.011257	81.6
30	0.010025	103
31	0.008928	130
32	0.00795	164
33	0.00708	206
34	0.006304	260
35	0.005614	328
36	0.005000	414
37	0.004453	523
38	0.003965	660
39	0.003531	832
40	0.003144	1049

HF

Q I'm compiling a list of the things I might need for my new HF station. Besides the transceiver and the antenna system, can you give me a brief rundown of important accessories?

A There are many accessory items you could buy—enough to keep you shopping for a long time. Let's keep it simple and discuss only the basics....

SWR Meter

SWR meters provide visual indications of the impedance match between your transceiver and your antenna system. They measure the magnitude of forward and reflected power, displaying the result as a *standing wave ratio* (SWR). Generally speaking, an SWR of 2:1 or less is acceptable to modern solid-state transceivers. At SWRs greater than 2:1, most transceivers activate a "foldback" circuit to prevent damage to the output transistors. The foldback curtails the RF output power, dropping it precipitously, depending on the severity of the SWR.

Many rigs include an SWR meter. Make sure yours doesn't before you make an extra purchase! And if you intend to buy an antenna tuner, you'll be pleased to know that most tuners include their own SWR meters.

Antenna Tuner

Consider this an adjustable impedance matcher between your antenna system and your transceiver. An antenna tuner doesn't really "tune" the antenna in a literal sense.

Antenna tuners come in all sizes, according to how much RF power they can handle and the designs of their matching circuits. Prices range from about $80 to well over $1000. If you're using the typical 100-W transceiver, you should be able to find an adequate tuner in the $120 to $200 price range.

Tuners often make life easier if you're using an antenna fed with ladder line, or a random-wire antenna. If the SWR at your operating frequency is less than 2:1 on a coax-fed antenna, you don't need a tuner. (Besides, some HF transceivers feature built-in tuners.)

Keys and Keyers

If you want to operate CW, you'll need a CW key. So-called "straight" keys can be yours for a minimal price in some cases, but they're tiring to operate during long conversations (or contests). "Paddle" keys are used with electronic keyers. The keyers automatically generate the dits and dahs, according to which paddle you're pressing at the time. With a paddle key and keyer at your side, you can send copious amounts of code with slight movements of your thumb and index finger. Electronic keyers are considered required equipment these days by serious contesters and DXers. See **Fig 2-19**.

Headphones and Headphone/Microphone Combos

A set of headphones is a blessing to any ham who lives with someone, or has crabby neighbors. Radio noises are music to our ears, but they often drive others up the nearest walls. A good set of headphones is a terrific investment for domestic tranquillity. They're also wonderful aids when working those weak stations you can barely hear. You'll be amazed at how much more you can copy with the audio output of your radio in both ears.

If you want to enjoy the luxury of hands-free voice operating, consider a headphone/microphone combination. The microphone is mounted on a small boom attached to one of the earpieces. The boom is adjustable, allowing you to position it right in front of your lips. DXers and contesters love these gadgets! They can rack up the contacts and keep their hands free to type, write, eat, wave their fists in the air, or whatever.

Logs

Although FCC logging requirements are a quaint memory, hams still enjoy keeping track of their contacts. A well-maintained log is like a diary—it allows you to step back in time and rehash some memorable conversations. Logs have more practical uses, too. If someone accuses you of interfering with their television, for example, you can consult your log and see if you were actually on the air at the time. Logs can also help you get a handle on how your antenna system is performing. Do most of your contacts seem to come from particular areas of the country? If so, perhaps your antenna radiates your signal most strongly into those areas.

Personal computers are ideal machines for logging. Check the pages of *QST* and you'll find software that maintains your log, prints QSL address labels, and just about everything else except brew your coffee.

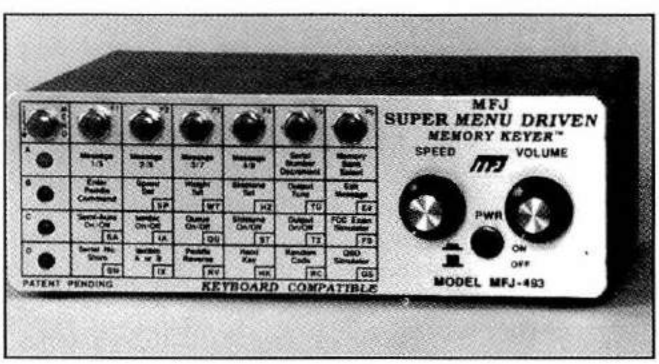


Fig 2-19—The MFJ-493 is an electronic CW keyer that allows you to store messages and play them back (such as contest CQs).

QSL Cards

A QSL card is written verification of a contact. It contains all the vital information, such as the time of the contact, the frequency, signal reports and so forth. QSLs are primarily used by hams who are chasing various awards. They need QSLs to prove that the contacts were genuine. Even if you're not seeking certificates to hang on your wall, it's a good idea to keep a stock of cards at hand. After all, *you* may be the contact someone needs to clinch *their* award! You'll find plenty of QSL printers advertising in Ham Ads and the back pages of *QST* magazine. Most will send you samples of their work for a small fee.

Q My SSB transceiver has a button labeled PROC. The manual says I can use this feature to boost my "talk power." What is PROC? Will it really increase my output?

A PROC is a shortened form of the word "Processor." The PROC switch activates your transceiver's speech-processing circuitry.

During SSB operation, your radio produces maximum RF output during your highest voice peaks. If you look at the pattern in **Fig 2-20A**, however, you'll see that these peaks don't occur often-and they last only a split second. This means that the actual RF output of your transceiver is the average of the peaks and valleys (minimum and maximum amplitudes). That average is much lower than your highest peak output.

The idea of speech processing is to increase average RF output by keeping the signal level as constant as possible (see **Fig 2-20B**). Several approaches can be used—too many to discuss here. For example, some transceivers employ compression using a kind of automatic gain control that follows the signal fluctuations and attempts to keep them smooth. Speech clipping works by chopping off the highest peaks and leaving a waveform with a higher average-to-peak power ratio.

Whichever method your radio uses, the result is indeed greater overall output. Studies have shown that speech processing can make a substantial difference in the readability of a signal under certain conditions. So why not use it all the time? There are at least two reasons to use speech processing sparingly: (1) Improperly adjusted, it can distort your signal, making you sound as though you're talking from

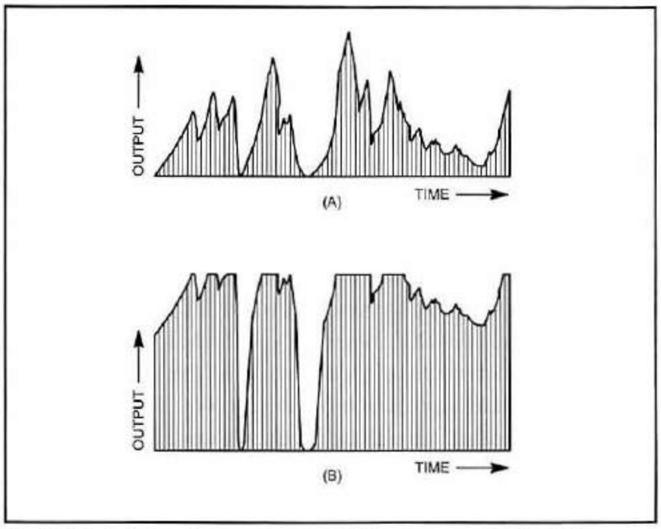


Fig 2-20—The pattern shown at (A) represents the RF output of an SSB transceiver without processing. Note the sharp peaks and valleys. The average output isn't very high. In (B) we've added speech processing. Many of the sharp fluctuations have disappeared. The average output is now much higher.

deep inside a cavern. (2) The higher sustained output level may cause your transceiver to overheat.

Q I have a friend who wants to sell one of those low-power 10-meter transceivers. The price looks good, but I'm worried about wasting my money. The band is pretty dead between sunspot cycles, after all. What do you think?

A If the price is right, I'd grab it. First of all, 10 meters is not entirely dead between cycles. You can always chat with other locals on the band. In fact, many clubs hold 10-meter nets year round, just to keep in touch. Hams can still enjoy sporadic E contacts over hundreds of miles or more. It's just a matter of listening for openings and calling CQ—even when the band seems quiet. And then, when the cycle swings up again, you'll be glad you nabbed this bargain.

Ten-meter transceivers are also good platforms for working VHF and UHF. If you can find a way to reduce their output to a low enough power to feed the transverter you have selected, you can use the radio to drive the transverter to put your signal on 144, 222 or 430 MHz. For example, in the January 1995 issue of *QST* you'll find an article that describes how to modify a Uniden HR-2510 for transverter use. See **Fig 2-21**.

Fig 2-21—The Uniden HR2510 is a 10-meter only transceiver.

Q Why do we use lower sideband (LSB) on 40 and 80 meters, but upper sideband (USB) on 20 meters and up?

A SSB rigs typically use *heterodyning* to achieve the desired output frequency. Heterodyning involves the mixing of two signals. When you mix two original signals, you end up with two new signals: one is the *sum* of the originals and the other is the *difference*.

The early home-brew SSB rigs of this kind used 5.0 to 5.5-MHz VFOs. Why? Because surplus World War II *Command* transmitters were readily available. Their VFOs were ideal for ham applications. Thanks to the heterodyne process, when a signal from a Command VFO was mixed with the output of a 9.0-MHz SSB generator, the result was a transmitter with coverage from 14.0 to 14.5 MHz and 3.5 to 4.0 MHz. ($9 - 5 = 4$ and $9 + 5 = 14$). This allowed coverage of the two most popular phone bands without the need for further heterodyning.

There was only one problem, though. This scheme resulted in the sideband being *inverted* when switching between the two bands (for the same reason there is sideband inversion when using some of the OSCAR satellite transponders). If you were transmitting USB on 20 meters and suddenly switched to 75 meters, you wound up transmitting LSB.

Rather than force people to build additional circuitry simply so they could maintain the same sideband at all times, the convention developed that USB would be used on 20 meters and LSB on 75 meters. As SSB spread to other bands, the convention was extended to the bands below 9 MHz being LSB and above, USB. Of course, there is no longer any real reason for this convention to be followed, but old habits die hard!

Q When I'm listening to an upper-sideband (USB) signal, the audio is received on the lower side of the signal. You would think that the opposite would be true! Why is this?

A An ordinary AM signal consists of three parts: the carrier, the upper sideband and the lower sideband. The upper sideband is higher in frequency than the lower sideband, and the carrier frequency is between the two sideband frequencies. The two sidebands are mirror images of each other (more or less).

In the case of a single-sideband signal, the carrier is suppressed along with one of the sidebands. In fact, the frequency of an SSB signal is defined by its *suppressed carrier frequency*. Since the upper sideband is higher in frequency (that's why we call it the *upper* sideband), the frequency where the carrier would appear—had we not essentially killed it in the transmitter—is *lower*. To convert the Donald Duck squawking to human speech, you must adjust your radio's controls to replace the missing carrier at the correct frequency *below the upper sideband*.

This is what happens whenever you use your VFO to tune in an upper-sideband transmission. Your receiver simply replaces the missing carrier signal, allowing you to make sense of the audio. Reception of lower sideband is similar, but you must insert the carrier *above* the sideband signal.

Q I am a new ham and when shopping for radios, I keep seeing the terms: WARC and MARS. Can you elaborate? What are they and do I use them when using my radios?

A WARC stands for World Administrative Radio Conference. The term "WARC bands" refers to the 30, 17 and 12 meter bands (10.100 to 10.150, 18.068 to 18.168, and 24.890 to 24.990 MHz, respectively). They're often called the "WARC bands" because they were made available to amateurs as a result of the 1979 World Administrative Radio Conference. Access to the new bands wasn't immediate, though. For example, 17 meters was not available for amateur use in the US until 1989.

Amateur Radio gear before 1979 was not capable of operating in these new bands. However, modification kits did come out for some radios, such as the Yaesu FT-101 series, that allowed one to install the circuits and modify the band switches for the WARC bands. Throughout the decade that followed WARC 79, hams continued to discuss whether a particular radio, amplifier or antenna was "WARC capable." That is, could it operate on the new bands, or at least be modified to do so? The term "WARC" was used so often in this context, it became part of the ham vocabulary.

Today the new bands are no longer new. Virtually all multiband HF transceivers and amplifiers include the so-called WARC bands, and a number of multiband commercial antennas include these bands as well. Even so, the term persists, especially among hams licensed prior to the early '90s.

The WARC bands offer some interesting opportunities for the curious. American hams on the 30-meter band are limited to a maximum output of 200 W with CW or digital modes *only*. Having almost the same global propagation characteristics as 20 meters, this makes 30 meters an ideal low-power (QRP) experimenter's band. The 17-meter band is also excellent for DX, especially at the height of the solar cycle. Even when we are wallowing at the bottom of the cycle, you can always find a few signals on 17 meters. The 12-meter band has very little activity during solar slumps. As the sunspots increase, however, 12 meters can become a daytime DX powerhouse.

MARS stands for Military Affiliate Radio System (sometimes erroneously called the Military *Amateur* Radio System or Service) . This is an quasi-military organization that runs traffic nets on designated military frequencies just above or below most Amateur Radio bands. MARS stations also run phone patches from troops overseas—this was very popular during the Viet Nam and Gulf Wars. Most military bases have MARS stations, and civilians are welcome to join MARS and volunteer their time and stations for this worthy cause.

Most radios in the past were manufactured so that the tuning circuits would work well slightly above and below the amateur bands allowing them to run on MARS frequencies. Today's solid state transceivers are capable of operating across the whole HF spectrum and are locked out by the microprocessor from operating outside the amateur bands. A procedure must be performed to "open up" the MARS frequencies. Military personnel at a military installation may operate using only the MARS license, but civilian volunteers must have *both* an Amateur Radio license and a MARS authorization and special call sign for use on MARS frequencies.

Q I have always done CW, until I went mobile. As I drive a stick shift, it is hard to do CW while driving the hills of Pennsylvania (although it can be done). I thought that I would give SSB a chance, but am having trouble tuning the signals for clarity. I think I am also not tuning right as I have trouble getting a signal that I can understand and when I do, I turn out to be way off their receive freq. I'm not sure that what I have just typed is clear. I guess the question is how best to tune a SSB signal? Can you give me some pointers?

A The best tuning of an SSB signal is accomplished by tuning from the high pitch to the low. I'll explain. As you know, on 160, 80 and 40 meters, lower sideband is used and on the higher bands, upper sideband is used. Let's use 20 meters as an example.

Set your rig for 20 meters and Upper Sideband. Go to the lower end of the 20 meter band and SLOWLY tune UP in frequency. You will soon hear a very high pitched squeaky voice. Keep tuning very slowly and you will hear the pitch become lower and lower. Soon it will become intelligible but still too high. Keep on tuning UP and the voice will sound natural. There, you've done it!

If you continue tuning up, the voice will become lower and lower until it sounds like a 45 RPM record played at 33¹/₃—then down to where it is unintelligible again..

On the bands that use Lower Sideband the process is reversed. You start at the UPPER portion of the band and tune DOWN slowly. The voice will go from the squeaky sound down to intelligible speech.

SSB tuning in a mobile takes just one little trick. Steady your hand against the panel while tuning with two fingers, thumb and index finger. Hold the side of your palm against the panel of the radio while tuning. If your installation does not allow for this, then try placing your three unused fingers spread out on the panel. This will steady your hand and will minimize the bumps in the road from bouncing your arm all over the place.

Q Since I've been listening to the 10-meter band, I have heard a lot of conversation about 10-10 numbers. What's this all about?

A The 10-10 International Net is the group that assigns the ever-popular 10-10 numbers. The purpose of 10-10 is to encourage interest and activity on 10 meters. There are regular 10-10 meetings on the air (*nets*) as well as contests sponsored by 10-10 International. In addition to the main organization, there are more than 220 local chapters that hold their own regular meetings.

By collecting the 10-10 numbers of other members, you can earn a variety of awards. That's why you'll often hear hams swapping their 10-10 numbers on the air. At times you'll even hear DX stations calling, "CQ DX 10-10." This means they want to contact 10-10 members *only*.

So how do you get your own 10-10 number? You talk to at least ten 10-10 members and submit the log data (date, time, frequency, etc) to 10-10 International. With more than 65,000 members, you shouldn't have a difficult time finding 10 of them on the air! Once your application is confirmed, you'll be assigned your own 10-10 number.

For complete information about 10-10 International, send $1, two First-Class stamps and an address label to Chuck Imsande, W6YLJ, 18130 Bromley St, Tarzana, CA 91356.

Q Where can I find a simple explanation of frequency hopping as it applies to spread spectrum communication?

A The answer is as near as the *ARRL Handbook*. Here is a small sample to whet your appetite ...

"Two obstacles to sending greater amounts of information are bandwidth and frequency congestion. *Spread spectrum* implies the use of a wide bandwidth, and that's correct, in a way. It doesn't mean that a station transmits a single 'wide' signal, but that it slices a whole band into a belt of frequencies that it can use virtually simultaneously. Although a signal is actually present only on one frequency at a time, the effect is that of having a whole band to operate within.

"The bandwidth of an amateur emission is restricted by FCC specifications. A signal may only take up a given amount of space. If so much information is to be carried that the transmitted signal becomes too broad, it reduces the number of stations that can use a band. If several stations wish to transmit simultaneously on one part of a band, one of two things happens: They interfere with each other or they must take turns, thereby reducing the total amount of information that can go through each RF circuit over a period of time.

"On the other hand, what if a station could transmit information over a wide range of radio frequencies, but use only one at a time? Assuming the transmitter and receiver were synchronized, a signal could jump from one frequency to another in a matter of milliseconds. Each 'hop' would last a mere blink of an eye (or actually, much less time than it takes a human to blink an eye). Now several stations could occupy the same bandwidth at the same time, as long as their respective hops didn't coincide too often. With the proper electronic processing (computer hardware and/or software), each pair of stations could have the equivalent of a whole band to themselves. And several pairs of stations could see almost the same 'free space' on a band because the only time they would be aware of each other would be if a random hop happened to coincide.

"Mathematical formulas can be used to minimize the odds of frequent 'collisions' and a list of specific 'plug-in' frequency schedules could be used to allow outsiders to monitor a frequency-hopping QSO or to locate and respond to a CQ. (In fact, the FCC has stated that hams may use only a narrow range of spread-spectrum schemes. This makes it possible to monitor such operations. It also precludes hams from using protocols that might effectively amount to data encryption.)"

Q I'm considering the purchase of a low-power (QRP) transceiver. I can only afford a single-band rig, so I face the dilemma of which band to choose. Can you help?

A That's a tough question because the answer depends on your personal preferences. Consider your lifestyle, for example. If you have work and family commitments, and find that your hamming is confined to the nighttime hours, I'd suggest a 40 or 80-meter transceiver. Both of these bands are open and active at night. But if most of your free time takes place while the sun shines, consider 30, 20 or 17 meters. (At low points in the solar cycle, the bands above 17 meters are poor choices for QRP work.)

How much room do you have for an antenna? If space is at a premium, try 20 meters. A 20-meter wire dipole antenna is only about 33 feet long. If you can find about 66 feet to stretch out a 40-meter dipole, 40 is an excellent band for QRP. Unlike the other bands we've discussed, 40 meters is active day *and* night.

If you have access to Internet e-mail, consider joining the QRP-L mailing list. You'll receive as many as 50 messages per day on topics ranging from equipment modifications to propagation—and no shortage of helpful advice. To join the list, send a message to **listserv@Lehigh.edu**. You can type anything you want in the SUBJECT line; it will be ignored. In the body of your message, enter the following:

SUBSCRIBE QRP-L <first name><last name>
<call sign>

where <first name> is your first name, and so on.

Q I just built a low-power CW transceiver from a kit. It works well, but I hear noises whenever I tap on the cabinet. It's as though the sounds of the bumps and taps are being conducted right into my headphones. Is this common with low-power transceivers?

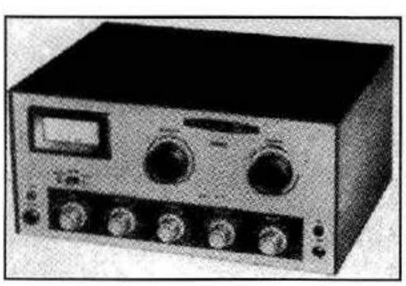
A With some designs, yes. You didn't mention the manufacturer or model, but I'll wager that your rig uses a direct-conversion receiver. In a *direct-conversion* design, the incoming signal is mixed with a signal from a local oscillator. The frequency of the local-oscillator is nearly the same as the signal you want to receive. They differ by only a few hundred hertz or so. In the mixing process, they combine and the result is a very weak audio-frequency signal. So, the incoming RF is converted directly to audio–*direct* conversion. The audio signal is passed to a high-gain amplifier that boosts it to a level sufficient to drive your headphones. A direct-conversion receiver relies on this audio amplifier to provide all or most of the gain. This being the case, the audio amplifier must increase the signal level by a huge amount. The gain is so great, the circuitry can function like a microphone, picking up vibrations in wires and components and translating them into electrical impulses. When you tap on your transceiver's enclosure, you hear it in your headphones. The circuit is said to be "microphonic."

Most direct-conversion receivers suffer from this problem to one degree or another.

Even so, they provide excellent sensitivity. They're relatively easy to build and adjust, which makes it possible for the manufacturers to offer these kits at affordable prices.

Q I have an old Heathkit DX-60B transmitter that I want to convert to a QRP (low power) rig. I've removed the final amplifier tube and I'd like to adapt the matching network to accommodate the 6CL6 driver tube instead. In addition, I need to find a way to adjust the driver output down to 5 W. Can you help?

A There are a number of ways you can get 5 to 10 W out of your DX-60. Perhaps the easiest is to turn down the drive control until you reach the 5-W point. You'll see it as R7 on your schematic.



Believe it or not, you can reconnect the final output matching network directly to the 6CL6 driver. While this is not an ideal situation, it will work well enough to achieve reasonable output power. You'll have to change the dc voltage to the network, though. Don't apply the 600 V originally intended for the final output tube to the 6CL6! Consult your schematic and you'll find a way to pass the proper voltage through the network to the plate of the 6CL6. You'll probably want about 140 V on the plate for 5 W output.

Obviously, there are some dangerous voltages running around inside your DX-60. If you're uncertain of your technical abilities, find someone else to do the modification for you.

Q I have a CW keyer that is designed strictly for grid-block keying. Its output keying line goes negative to switch the transmitter. The problem is that my transmitter uses a *positive* keying line. Is there any way I can interface the two?

A The simple circuit shown in **Fig 2-22** should do the trick. It uses an inexpensive power MOSFET to allow your positive transmitter keying line to be actuated by the negative-only switching output of your keyer.

Q I just got my license and want to operate CW. Should I start with a straight key, keyer, "bug," paddles? Should I learn code on a simply key and transition to those paddles, or should I begin learning on the paddles so that I only need to learn one thing?

A The "straight key" is a simple device and capable of responding to code sent at any speed. For all but the most proficient, though, it becomes awkward to operate at speeds above 20 WPM. Hence the *bugs* and *paddles*.

The bug, which has been around a long time, uses a swinging side to side motion which seems to be more comfortable compared with the up-and-down motion of the straight key. It is still a mechanical device, however, and takes some practice to master.

The paddles in conjunction with an electronic keyer help

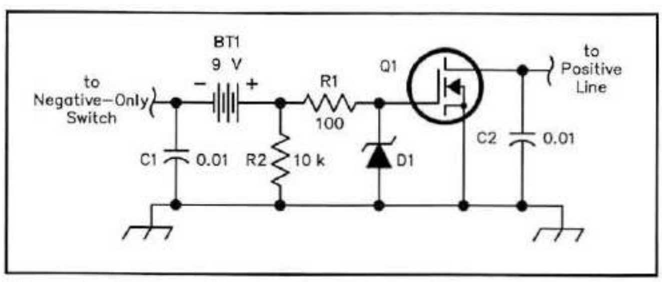
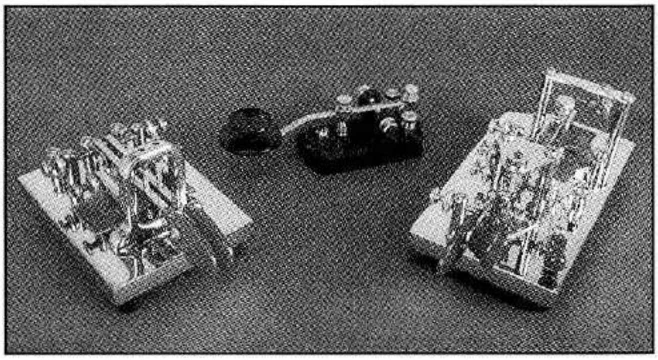


Fig 2-22—A level-shifting circuit that allows a negative-only switch to key a positive line.

BT1—9-V transistor radio battery
C1, C2—0.01-μF ceramic disc capacitors
D1—15-V, 1-W Zener diode (1N4744)
Q1—IRF620 MOSFET (available from Mouser Electronics, tel 800-346-6873; part no. 511-IRF620)
R1—100 Ω, 1/4 W resistor
R2—10 kΩ, 1/4 W resistor



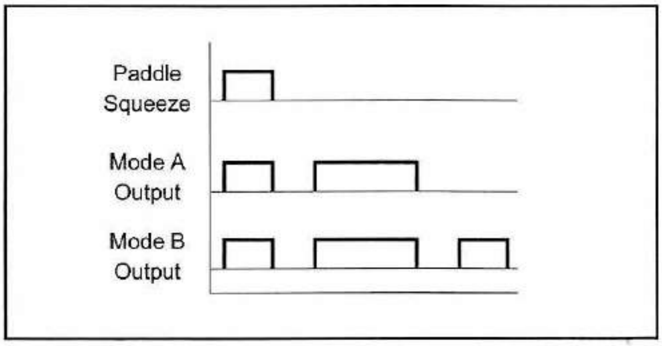


Fig 2-23—Here we show that the paddles have been squeezed together so that the *dit* paddle makes first contact and then both are released simultaneously. Note that the release can take place at any time before the keyer completes sending the last element of the set; in other words, in this example, the completion of the *dah* in mode A or the second *dit* in mode B. If the paddles are held beyond the end of the last element, a second set will be sent.

the operator send near perfect code when operated properly. The side to side motion is intuitive and comfortable and with just a little practice it can be mastered by almost anyone. The problem is that it is somewhat awkward to operate at very slow speeds, under 13 WPM.

I highly recommend you learn Morse code using an inexpensive straight key and only when your speed approaches 13 WPM you invest in keyer and paddles. The process is not like unlearning one method and learning another; the transition is smooth. Remember, the hard part is learning the code and gaining speed in *copying*, not so much sending. Once you learn the rhythm of sending code on one device, it stays with you onto the other device.

Q Is there an advantage to using an electronic CW keyer instead of a bug or a straight key?

A Bugs, straight keys and electronic keyers all have advantages and disadvantages. It's usually a matter of personal preference. For example, you can easily send clean, readable CW with an electronic keyer—if you use it properly. Although keyers will maintain the correct lengths of your dits and dahs, you're still responsible for controlling the spaces that create characters and words (although some keyers help with these, too). However esoteric the keyer, there's plenty of opportunity for sloppiness if you're not careful. Once you've mastered an electronic keyer, it's usually easier to increase your sending speed substantially.

Electronic keyers often include memory features that allow you to store certain words that you send often (such as your call sign). Sending the stored text is as easy as pressing a single button.

Bugs—semiautomatic keys that make dits mechanically with you providing the dashes—require more dexterity on the part of the operator. They're capable of very high speeds in the right hands, but few operators these days have the time or patience to master them. Straight keys are the least expensive and certainly the easiest to learn. However, high-speed sending is more difficult and using one for long periods can be very tiring.

In terms of quality, I've heard outstanding code generated by all three. It isn't so much the mechanism as the person who is using it. As someone once said, "Keys don't send code—*people* send code."

Q My new rig can be set up for Iambic-A or Iambic-B keying modes. I am familiar with iambic keying but can't find anything in the literature available to me on the two keying modes and how they differ. How are they different?

A That difference is *very* subtle! It relates to the sequence of dit/dahs generated by simultaneous releasing of both paddles. The difference is best discovered by performing this test:

1. Set your rig's keyer speed to minimum.
2. Carefully (but quickly) grab both paddles and release them at the same exact time.

With Mode A keying, you will get either a DIT-DAH or a DAH-DIT sequence. With Mode B keying, you will get either a DIT-DAH-DIT or a DAH-DIT-DAH sequence. The starting element can be controlled by squeezing in such a manner that either one or the other paddle makes contact first—thus the skill required to operate paddles.

Mode B is designed to add an extra "opposite element" to the end of alternating keying sequences. The result is a slight reduction in the amount of paddle-pressing needed to form some characters. The differences are shown in **Fig 2-23**.

Q I see the new hams in my radio club using two different conventions with their keyer paddles—some use the thumb for dots and others use the thumb for dashes. Which is the "correct" way?

A The normal convention is that dashes are sent with the forefinger and dots with the thumb (of the right hand). This follows from the days of the semiautomatic key (bug), since the greater dexterity of the forefinger made it easier to manually key dashes than would be possible with the thumb. There is no "correct" way with keyer paddles, but it is advisable for all hams (whether right- or left-handed) to use the same convention—the right-hand thumb, or the left-hand forefinger, sends dots. This allows anyone to use another ham's paddles when visiting another station, during Field Day, etc.

Q What is the Farnsworth method of learning Morse code?

A For decades hams have been searching for various methods to make it easier to learn Morse code. The Farnsworth method is one of the more successful attempts, which is why you hear it used on so many code-practice tapes—including those sold by the ARRL. Development of the technique is credited to Donald (Russ) Farnsworth, but its true origins are veiled in mystery. No matter who discovered it first, everyone calls it the "Farnsworth method."

Basically, it involves sending characters (letters, numbers and punctuation) at higher speeds with longer gaps of silence between characters. For example, the dits and dahs that comprise the letter Z (dahdahdidit) are sent at, say, 13 wpm, while the silence between the Z and the next letter is equivalent to what you'd hear at a sending speed of 5 wpm. Once you've learned the sounds of the characters at your "goal" speed in the Farnsworth format, it's usually easy to increase your copying speed since you have already trained yourself to recognize the rhythm of the characters and only have to quicken pause in-between.

Q I'm just getting my feet wet with CW and I'm a little confused by all the abbreviations. Can you help?

A The reason CW operators often use abbreviations is to speed the conversation. Exchanges would be long indeed if every word had to be spelled in its entirety. Here is a list of some of the most common abbreviations in use:

73	Good luck.
88	Love and kisses.
AGN	Again
ANT	Antenna
BK	Back, as in "Back to you."
CPY	Copy
DE	From. For example, W1RFI DE WA1PIX
ES	And
FB	Fine business. The ham equivalent of "great!"
FER	For
GUD	Good
HR	Here
HW	How
LID	A poor operator.
OM	Old Man. Any male regardless of age.
PWR	Power
R	Received. Usually sent as "RRR"
RX	Receiver
SRI	Sorry
TNX	Thanks
TX	Transceiver
UR	Your
WUD	Would
WX	Weather
XCVR	Transceiver
XYL	A married woman.
YL	Traditionally, an unmarried woman, but can be used to mean any woman.

Also, there are *procedural signals* written as two letters with a line drawn over them (**overscore**) and sent together with no break. Some of the more common ones include:

$\overline{\text{AR}}$—end of message
$\overline{\text{BT}}$—break
$\overline{\text{CL}}$—clear
$\overline{\text{KN}}$—over to you *only*
$\overline{\text{SK}}$—end of work (end of contact)

Q What is coherent CW?

A To the untrained ear, coherent CW sounds identical to "normal" CW—except that the characters are sent in a very precise manner. The Morse is sent and received by computer and, because of the synchronized nature of the mode, can be "understood" in less-than-optimal conditions. As with other digital modes, the text appears on the computer monitor as it is decoded.

The standard speed for coherent CW adopted by Ray Petit, W7GHM, when he designed the system was 12 WPM. Ray specified the dot length as 100 ms, an element space at 100 ms, a dash and character space at 300 ms and all other spaces as multiples of 100 ms. This timing is still in use today.

Coherent CW depends entirely on accurate timing based on the element length. Imagine two square waves, both identical in timing but derived from separate oscillators and having the mark length equal to the space length and both these equal to 100 milliseconds. If started together, they will stay in step indefinitely if the clocks generating them are perfectly stable. The original hardware coherent CW system was based on this principle and highly stable oscillators and transceivers were required. This is the main reason why coherent CW never generated much enthusiasm in the ham community when it was first introduced.

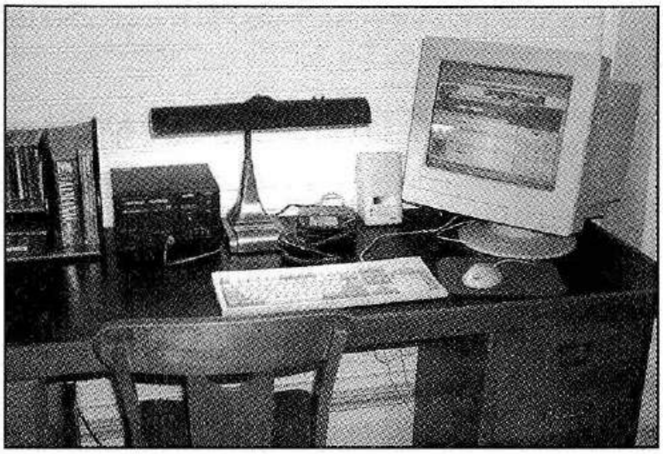
Thanks to the evolution of personal computers and software, coherent CW is now possible with most modern commercial transceivers. The rigs are reasonably stable and software can be used to generate precisely timed code (and compensate for drift as well).

Despite the fact that it's easier than ever before to run coherent CW, there is very little activity. The few coherent operators on the air are usually found about 20 kHz up from the bottom ends of the bands. (Watch for stations calling "CQ CCW.") Coherent CW has been superseded by more advanced digital communication schemes such as CLOVER and PACTOR II. Still, coherent CW may be the only synchronized digital mode that is decodable by both the human brain and computer!

VHF

Q Is it okay to use my mobile rig (VHF/HF) in my house? What do I do for power?

A Yes, mobile rigs will work just fine inside a house. You should use a regulated 12-V supply, making sure that it will deliver the maximum current required by the radio.



It is also possible to run a radio off 12-V batteries—surplus sealed gel cell batteries are quite popular for this purpose. Used automobile batteries will work in an emergency, but are a poor choice, as they are quite messy and are not designed to be deeply discharged. A few deep discharges will often kill an automobile battery.

Q Can I hook up a mobile Amateur Radio to an outside roof antenna and operate the radio safely without problems?

A Yes you can use a mobile radio with any antenna so long as you follow procedures as with any other base radio, such as proper antenna, feed line and grounding.

Any 20-A power supply will power your radio nicely.

Q I use a power supply to operate my mobile radio in the house. It receives fine but when I transmit the lights dim and the frequency display goes wild. I can't even get into my local repeater. What's the problem?

A It sounds like you're demanding too much from your power supply. When your mobile radio is receiving, it isn't drawing much current—probably around 500 mA. When you transmit, however, the current flow can jump to 6 A or more—depending on the output of your rig. The more power your rig puts out, the more current you need from the power supply.

Check the current rating of your radio (in the transmit mode) and your power supply. You'll find this information in the manuals or stamped on the equipment. If your radio needs 6 A in the transmit mode and your power supply can supply only 1, you've got a problem! Whenever you transmit, you're overloading the power supply. This causes the voltage to drop below the level your radio needs to operate. You might even blow a fuse or pop a circuit breaker.

The solution? If your radio has a low-power mode, try it. Perhaps the current drain will be low enough for your power supply to handle. The alternative is to build or buy a new power supply with a higher current rating. If your power supply rating is adequate, check the size and length of the wire between the power supply and the radio. Too much voltage drop could cause the problem, and might be a fire hazard.

Q Can you explain the FM "capture effect"?

A Sure. *Capture effect* is what happens in FM reception when the strongest signal on a channel totally suppresses all the other signals on the channel. You've probably heard this while receiving FM stations on your car radio: Stations abruptly pop in and out instead of smoothly blending with each other, as cochannel AM broadcasters do when they fade in and out at night.

The capture effect occurs as a result of an FM receiving system's ability to suppress AM interference sources like static, ignition noise and alternator whine. Once an FM signal has "captured" an FM receiver's *limiter* circuitry (the circuitry that does away with AM noises), the receiver tends to respond to weaker FM signals as though they are AM noise and entirely suppresses them.

Q What is the best way to work 6 meters from a hardware standpoint? Do I have to invest in a tower and a beam antenna? How about an amplifier?

A The "best" way to work 6 meters depends on what you hope to accomplish. If you want to fully exploit the long-range modes such as sporadic E, meteor scatter and aurora, a beam antenna atop a roof or tower is ideal. (Of course, you must make sure to feed the beam with low-loss coaxial cable.) The addition of an RF power amplifier (150 W or more) would also help—especially for meteor scatter and aurora.

Having said that, it is important to point out that many hams enjoy 6 meters with very modest stations. During a recent spectacular series of sporadic-E openings, hams with 6-meter wire dipoles in their attics were getting in on the fun. Even mobile stations were able to participate. When the sunspot numbers are high, you'll hear these same stations working the world.

So, if you can afford the beam, tower and amplifier, by all means go for it. You'll have an optimal 6-meter station that will give you a lifetime of enjoyment. But don't forgo the band just because you have to settle for something less.

Q I'd like to operate my H-T from an external power supply such as one of those "wall cubes." I notice, however, that my H-T requires 13.8 V while the wall cubes only supply 12 V. Can I still use them?

A If your H-T will operate on 13.8-V dc in your car, it should work fine with 12-V dc in your home. A 1.8-V difference is well within most tolerances. You can check with the manufacturer to be sure. Many H-Ts have battery voltage options for various output levels.

The real question with using a wall cube power supply concerns its current capabilities and filtering. Be sure the wall cube is rated for the load (your H-T). It must also provide sufficient filtering to keep the ac components at acceptably low levels. And make absolutely certain that you are not reversing the polarity when you connect it to your H-T. Doing so can cause permanent damage to the radio.

Q When I read advertisements for hand-held transceivers I often see mentions of "memory cloning." What is it?

A Memory cloning refers to a rig's ability to transfer the contents of its memory channels to another radio of the same model. Some transceivers accomplish this feat through the use of special cables, while others do it over the airwaves via coded signals.

Memory cloning is convenient if you travel frequently. Rather than enter all the repeater frequencies for a new destination by hand, you can simply "clone" the contents of a local ham's radio after your arrival. Of course, this assumes that you can find a "native" who owns the same type of H-T and who is willing to allow you to copy its memories.

Another application of memory cloning is public service. In an emergency operation you can use memory cloning to quickly set a new volunteer's radio to the same frequencies used by everyone else. Again, however, this presumes that the cloning function on his or her H-T is compatible with yours.

Q What audio frequencies do DTMF "Touch Tones" use for which numbers? What are the A, B, C and D keys?

A The DTMF Touch-Tone system uses pairs of audio tones to represent various keys. There is a "low tone" and a "high tone" associated with each button (0 through 9, plus * (star) and # (octothorpe or pound symbol). The low tones vary according to which horizontal row the tone button is in, while the high tones correspond to the vertical columns. See **Fig 2-24**. The tones and assignments are as follows:

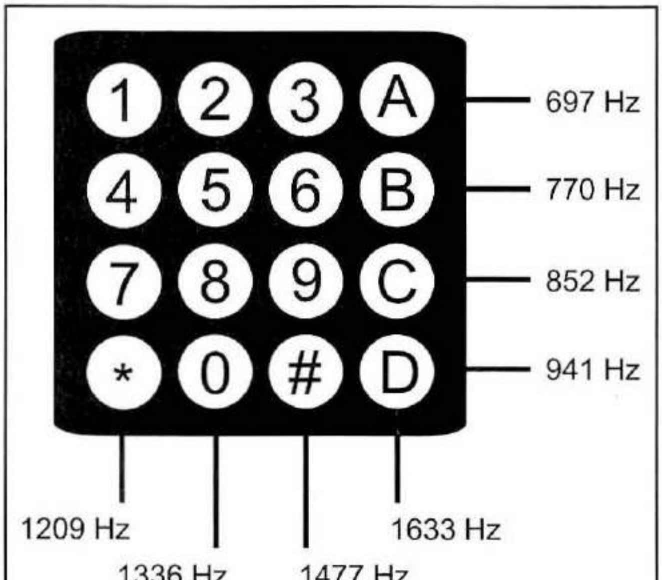


Fig 2-24—The high and low tones associated with DTMF Touch Tones.

When the 4 button is pressed, the 770 Hz and 1209 Hz tones are sent together. The telephone central office will then decode the number from this pair of tones. (Or your repeater will decode the pair to activate a particular function.)

The tone frequencies were designed to avoid harmonics and other problems that could arise when two tones are sent and received. Accurate transmission from the phone or transceiver, and accurate decoding on the telephone company or receiver end, are critical.

The tone frequencies should all be ±1.5% of nominal. The high frequency tone should be at least as loud, and preferably louder than the low frequency. It may be as much as 4 dB louder. This factor is referred to as "twist." If a DTMF signal has +3 dB of twist, then the high frequency is 3 dB louder than the low frequency. Negative twist is when the low frequency is louder.

The A, B, C and D buttons are extensions that originated with the US military's *Autovon* phone network. The original names of these keys were FO (Flash Override), F (Flash), I (Immediate), and P (Priority) which represented priority levels that could establish a phone connection with varying degrees of immediacy, killing other conversations on the network if necessary with FO being the highest priority. All four extension pairs use 1633 Hz as their high tone.

Q Could you please give me a rough estimate of the cost factors involved in setting up a 2-meter FM repeater?

A This is a very difficult question to answer because so many variables are involved. A few *QST* advertisers sell prepackaged repeater systems that will set you back from $1000 to $2500, but you could also put one together from used or surplus components. A repeater is, after all, just a receiver and a transmitter connected together and placed in an advantageous (read "high") spot to rebroadcast what is received.

There are many other cost factors to consider beyond the price of a transmitter and receiver. To name a few...

Duplexer: If you intend to transmit and receive from the same antenna (or from two antennas at the same site), you need a cavity filter—known as a duplexer—to keep the transmitted signal from blocking the receiver. Duplexers are precision devices and typically cost several hundred dollars.

Antenna(s): Although any omnidirectional antenna will do, you'll get better performance from well-designed "gain" models.

Coaxial cable: You'll need the more expensive, low-loss cable.

Controller: This is the device that routes the audio from the receiver to the transmitter, controls transmitter keying, toggles the CW or voice identifier and more.

Site costs: This includes any rental fees to house your repeater and utility charges.

But before you spend the first dollar, you must obtain an input and output frequency pair coordinated by your local

Fig 2-25—A repeater can be an expensive proposition, but using surplus or homebrew components reduces the cost.

frequency coordination group. Some people just pick a pair and go on the air, and you can imagine what kind of havoc this causes. You'll find a list of frequency coordinators in any recent copy of the *ARRL Repeater Directory*. (Also see "Anatomy of a Repeater," *QST*, May 1995, pp 69-71, or on the *TIS Web Pages* at **www.arrl.org/**.) **Fig 2-25** shows a repeater installation that uses some surplus and homebrew parts.

Q OK, I'm no *rocket scientist*. Can you please explain the features of today's complex handheld VHF radios?

A Twenty years of fierce competition in the 2 meter market has resulted in feature laden HTs and mobiles. All of the modern rigs have more features than most hams will ever use, but there are a few common ones that you need to know about:

1. All HTs made today have programmable memories. These memories are where you would keep information about each of the repeaters you use. The memories are used so you do not have to set up the radio each time you change repeaters. Although some early HTs had 10 memories or fewer (or none), all the modern models boast between 20 and 100 memories. 20 is more than adequate for most folks, unless you travel a lot to another area of the country and want to keep track of all of the repeaters there as well as at home.

2. All HTs made today also have CTCSS encoders. CTCSS stands for Continuous Tone Coded Squelch System (also known as PL, which stands for "Private Line"). What that means in plain English is that the HT has to transmit a steady tone along with the transmit audio to activate the repeater. The tone is in the range of 60 to 200 Hz and is filtered out of receiving rigs. This feature is used on many repeater systems (each repeater has a unique tone) to prevent it from being activated by a faraway station. As an example, you might find two repeater systems 50 miles apart on the same frequency. If they did not use CTCSS, a strong signal located between them would activate both.

3. DTMF—DTMF stands for Dual-Tone, Multi-Frequency. In essence, it is exactly the same thing in a radio as in a telephone—when you press any key on your DTMF, it generates 2 simultaneous audio tones: one that corresponds to the "row" of the key and another that corresponds to the "column."

DTMF is used with most repeaters to access the telephone autopatch system (which is simply a connection between the repeater and telephone system). However, on some repeaters, the repeater controller circuitry allows DTMF tones to do other special functions as well, such as measure and report received signal strength. Autopatch control varies from repeater to repeater, so you'll have to consult your other local repeater users to determine how to access a particular repeater's autopatch.

CTCSS stands for Continuous Tone Coded Squelch System. These "subaudible" tones (80-255 Hz—called "subaudible" because they are filtered out of most repeater audio passbands) are used to control the repeater's squelch.

When the tone is enabled for a particular repeater, your HT or mobile includes the tone as part of your every transmission (hence the "continuous" label).

Some HTs and mobiles have the ability to use CTCSS to control their squelch as well. In most rigs, the board (a CTCSS "decoder" or "paging" or simply "tone squelch" board) is an option you have to buy, but some rigs include this option right from the factory.

4. Auto-offset. All repeaters transmit and receive on different frequencies. (The frequency displayed on the transceiver is always the frequency it is receiving on). In the 2-meter band, some repeaters transmit below their receive frequencies and some transmit above their receive frequencies. There is a quasi-standard that determines which one should be used depending on the frequency (ie, from 147.0 MHz to 147.3, most repeaters use a "+" offset, etc.). Many modern HTs automatically switch offset when a new frequency is entered. This means that you don't always have to look up the offset in a book somewhere to use a repeater for the first time. This is especially handy when traveling.

5. Tone Squelch. This is actually not used very often, but

it is often touted in advertising copy, so I thought I should explain it. Many HTs have the ability to decode CTCSS tones as well as transmit them. What that means in practical terms is that you can set your HT to receive only folks who transmit the same tones you select to receive. This is used mainly by folks at large hamfests so that a group of hams can talk among themselves without having to listen to other hams on the same frequency. It is also used by local emergency support groups who leave their HT on always and wait to be notified of a pending emergency. There is also a system similar to this using DTMF tones.

I would have to write you a small book to explain every possible feature, but as I said at the start, most hams will never use all of them.

Q I'm a Technician, so I'm limited to the bands above 50 MHz. Assuming that I can get my hands on some SSB or CW equipment and a good antenna system, what can I expect in terms of long-distance (DX) communication?

A *Limited* to the bands above 50 MHz? Some limitation! Compared to the HF bands, you have more frequencies, less interference and fewer regulatory restrictions on the VHF, UHF and microwave bands. For many hams, this "limitation" is very liberating.

But what about DX? Long-distance communication above 50 MHz is certainly possible—and there are many ways to go about it.

• *Tropospheric—or simply "tropo"—openings.* Tropo is the most common form of DX-producing propagation on the bands above 144 MHz. It comes in several forms, depending on local and regional weather patterns. Tropo may cover only a few hundred miles, or it may include huge areas of the country at once. The best times of year for tropo propagation are from spring to fall, although they can occur anytime.

• *Sporadic E* (abbreviated Es) propagation is one of the most spectacular DX producers on the 50-MHz band. Where it may occur almost every day during late June, July and early August. A short Es season also occurs during December and January—just in time for the January VHF Sweepstakes! Sporadic E is more common in mid-morning and again around sunset during the summer months, but it can occur at any time and any date. Es also pops up at least once or twice a year on 2 meters in most areas. Es results from small patches of ionization in the ionosphere's E layer. Es signals are usually strong, but they may fade away without warning.

• *Meteor scatter* communication uses the ionized trails meteors leave as they pass through the atmosphere. VHF radio signals can be bent (refracted) by these high-altitude meteor trails and return to Earth hundreds or even thousands of miles away. This ionization lasts only a second or so. It's so intense, though, that even 432-MHz signals can sometimes be refracted. Most meteor-scatter contacts are made on 6 and 2 meters.

Meteor-scatter contacts are possible at any time of year. Activity is greatest during the major meteor showers, especially the Perseids, which occurs in August. If you're running about 150 W to a single 8 or 11-element Yagi antenna, give meteor scatter a try.

• *Aurora* (abbreviated Au) openings occur when the auroras are sufficiently ionized to refract radio signals. Auroras are caused by the Earth intercepting a massive number of charged particles from the Sun. Earth's magnetic field funnels these particles into the polar regions. The charged particles often interact with the upper atmosphere enough to make the air glow. Then we can see a visual aurora. The particles also provide an irregular, moving curtain of ionization that can propagate signals for many hundreds of miles.

Aurora-reflected signals have an unmistakable ghostly sound. CW signals sound hissy, SSB signals sound like a harsh whisper. FM signals refracted by an aurora are unreadable.

• *EME, or Earth-Moon-Earth* (often called *Moonbounce*) is the ultimate VHF/UHF DX medium. Moonbouncers use the Moon as a reflector for their signals, and the contact distance is limited only by the diameter of the Earth (both stations must have line of sight to the Moon). As you've probably guessed, Moonbouncers have a particular obsession about knowing where the Moon is, especially when they can't see it because of cloud cover.

Moonbounce conversations between the USA and Europe or Japan are commonplace—at frequencies from 50 to 10,368 MHz. That's true DX! Hundreds of EME-capable stations are now active, some with gigantic antenna arrays. Their antenna systems make it possible for stations running 150 W and one or two Yagi antennas to work them. Activity is constantly increasing. In fact, the ARRL sponsors an EME contest, in which moonbouncers compete on an international scale.

• *Satellites*: The low-orbiting birds such as RS-10, RS-12, RS-15 and OSCAR 20 can relay your signals over distances over hundreds of miles or more. Better yet, OSCARs 10 and 40 offer *hemispheric* coverage.

Q I want to take advantage of those elusive band openings on 6 meters, but I have family obligations that keep me away from the radio. How can I catch the hot openings without parking myself in front of the rig for hours on end?

A Ah, the VHFer's dilemma! When will the band be open? First, there is the statistical method. Sporadic-E band openings can happen any time, but they often peak at 10 to 11 AM local time, and again between 5 and 7 PM. So if you have limited operating times, these periods will yield 80% of the openings.

Second is the visual method. If you have an outdoor TV antenna and a television that isn't in frequent use, switch the TV to channel 2 (without sound) and leave it there. Just glance at the box from time to time. If you suddenly see images from distant stations, 6 meters is sure to be open.

The third method is to simply park your radio on the calling frequency (50.125 MHz), crank up the volume, then increase the squelch until the noise stops. Now go about your normal routine. If you hear sounds from your radio room, it may mean that a band opening is in progress.

If your rig has scanning functions, you may want to set it up to scan from 50.125 to about 50.150 MHz. When the band opens, the activity isn't necessarily on the calling frequency! You can also try scanning for beacons between 50.020 and 50.080 MHz.

Finally, there is the *DX PacketCluster* network. If you have a 2-meter FM rig, a packet TNC and a computer (or terminal), you can connect to your local network. Some *PacketCluster* systems specialize in HF spotting only, but most others include VHF and UHF spots. As with the TV approach, just glance at your monitor from time to time and see if anyone has posted a 6-meter alert. You can also access *PacketClusters* via the Internet, but long-term monitoring in this fashion can get expensive!

Q What does "simplex frequency" mean on FM listings?

A To define simplex, let's first define duplex and full duplex.

Full duplex is what we do on the telephone—the line is open both ways simultaneously and we may, as in an argument, both speak at the same time and hear each other at the same time.

Half duplex is what is done with a repeater system. The repeater itself is operating in full duplex mode, that is it is receiving and (re)transmitting simultaneously but the two users of the repeater can only speak or listen when it is his turn.

Simplex is when two operators are using the same frequency (no repeater) to communicate with each other directly. One may speak and the other must listen—taking turns. The advantage is that unlike the repeater, which uses two frequencies to accomplish its magic, the simplex operators are using only half as much spectrum.

This type of simplex communication is used for local contacts that do not need the help of the repeater in covering great distances. Simplex is therefore used at public service events such as small walk-a-thons and such—also by mobile stations when traveling where they are unfamiliar with where the repeats are located.

In Amateur Radio circles it is considered impolite to tie up a repeater (duplex) when simplex operation will do nicely. By convention certain frequencies are set aside for simplex operation, ensuring that no one will construct and operate a repeater on these frequencies.

Q What are the 2-meter simplex frequencies?

A The most common is 146.52 with 146.55 a close second. Available in most areas (although these may be repeater frequencies in your area) are 146.40 to 146.58 and 147.42 to 147.57.

Q I work as a pharmacist, which means I'm confined to the store all day. I'd like to use my 2-meter H-T to relieve the boredom, but I can't reach any repeaters. It's frustrating to watch customers with portable cellular telephones. They never seem to have any trouble making calls from inside the store! What's the solution?

A It's not uncommon to have difficulty transmitting from inside a commercial building on 2 meters with a hand-held transceiver (H-T). The metal structure attenuates the signal substantially. When you consider that you're only running a few watts, it doesn't take much attenuation to render your signal inaudible to all but the nearest, most sensitive repeaters.

Cellular telephones have the advantage because they operate on much higher frequencies. The shorter wavelengths of their signals are better able to escape through windows and other openings to the outside world. You would get similar results with 33 or 23-cm amateur gear, but you wouldn't have many people to talk to.

If you can afford to make the investment, one solution would be to purchase a dual-band 2-meter/70-centimeter mobile transceiver that offers duplex "crossband" operation. You could leave the radio in your car and use a 70-cm H-T as your link while you're in the store. The dual-band rig would hear your H-T's signal and retransmit it on the 2-meter frequency of your choice. It would also relay 2-meter signals back to you on 70 centimeters.

This is essentially an auxiliary station operation and there are some FCC rules you must take into account. Pick up a copy of *The FCC Rule Book* from your favorite dealer or ARRL Headquarters for complete details.

Q I am having quite a bit of trouble trying to use the local repeater in my area. The machine is only about three miles away, but I have already been told I don't get into its main input well enough to be heard clearly. I have an ICOM IC-T22A handheld, which is the only radio I can use in my apartment (lease restrictions absolutely forbid outside antennas of any kind).

I have been advised that I may have to use some sort of antenna (other than the rubber duck on my HT) to reach the local repeater from here, which I find a bit difficult to believe. If I were trying to hit machine 35-45 miles away from my present QTH) I could see it, but to hit a repeater just three miles distant? I cannot construct any sort of antenna either, since I have no tools at my present location (left them all behind when I moved last year).

Is there any hope of my being able to use the local repeater without going to a lot of trouble (and without having to use an outside antenna)? I am a member of the club which sponsors it and would like to participate in their weekly 2-meter net.

A Have you tried using another radio, perhaps borrowed from a club member, to ensure that your HT is working properly. That is the first thing you should do. Once you have determined that the rig is OK—your friend's radio can't get in either—proceed with a new antenna.

It is possible that a rubber ducky antenna will not "get into" a repeater 3 miles a way. There may be an obstacle in the way, or the frame or covering of your house (aluminum siding, foil backed insulation) may be blocking the signal.

A rubber ducky is a very, very inefficient antenna—not much better than a dummy load.

If you can't build a simple ground plane (see the antenna section of this book), then get a mobile mag-mount antenna and place it on a metal surface like the frig, the stove, filing cabinet or even a metal TV tray. This will be a great improvement.

Once you have determined you have a working system and a clear path but the capture of the repeater is still only marginal, a small amplifier of about 35 W might be in order—these are available in the $90 price range.

Q What is my "grid square"?

A Grid squares—also known as "Maidenhead" grid squares, since they were developed by an international group in Maidenhead, England—are a way of dividing up the surface of the earth. They are a shorthand means of describing your general location anywhere on the planet. For example, W1AW in Newington, Connecticut, is located in grid square FN31pq.

Grid squares are based on a station's latitude and longitude. They are coded with a 2-letter/2-number/2-letter code (such as FN31pq). Since no two stations can have the exact grid square (unless they were located right next to each other), this designator uniquely identifies a station.

There are a number of ways to determine your grid square. Maps of the continental US and parts of Canada are available from the ARRL. You can also find your grid square on the World Wide Web. There are also a variety of online lookups that use your latitude and longitude coordinates to determine the grid square. **Fig 2-26** is a grid square map that is available from the ARRL.

Q I believe that my station is right on the border between two grid squares. How do I determine which grid square identifier to use?

A The rule is that after determining your coordinates to the *best of your ability*, you can use either (or any) of the grid squares upon which you border.

Q What does the "limiter" limit in an FM receiver?

A The limiter stage of an FM receiver has the task of chopping most of the noise and amplitude modulation from an incoming signal. In most FM receivers the limiter immediately precedes the detector stage, known as the *discriminator* (see **Fig 2-27**).

Although discriminators are designed to respond to variations in frequency (which is how an FM signal is modulated—by varying the frequency), they will also respond to changes in signal voltage, or *amplitude*. Noise shows up on signals as variations in amplitude. So, to avoid detection of the noise component, you have to reduce or eliminate any variations in amplitude.

Limiter circuits are basically amplifiers, but with an interesting catch. When the input signal increases beyond a predetermined point, the limiter overloads and stops amplifying. In this way the limiter limits variations in amplitude. Take a look at the "before and after" photographs in **Fig 2-28**.

When sufficient signal arrives at the receiver to start the limiting action, the radio *quiets*—that is, the background noise disappears. When you hear someone on the air say, "I'm receiving the repeater full quieting," they mean the signal is so strong that the limiting action is removing every trace of noise. By the way, the sensitivity of an FM receiver is rated in terms of the amount of signal required to produce a given amount of quieting, usually about 20 dB.

SATELLITES

Q What are all those numbers in the ARRL Keplerian Bulletin and what do I do with them?

A *A German astronomer and mathematician, Johannes Kepler, 1571-1630 is considered the founder of modern astronomy. He formulated three laws that explain how the planets revolve around the sun (the beginning of orbital mechanics).*

All of the current crop of computer programs that are used to compute the position of a satellite and determine the corresponding antenna pointing angles use a basic set of numerical constants as inputs. These input constants are derived from classical astronomical motions and are called the primary Keplerian elements.

Here is a basic description of some of the terms associated with orbital mechanics. These descriptions will provide most of the known identification references to the specific element, so that you will recognize the term no matter how it is declared. These element descriptions will also be presented in the same order as they are commonly listed and used, so that sequential associations will also be recognized. Mathematical references will also be avoided.

Epoch, TØ: A fancy name for a specific reference time. This is the UTC date and time for which the Keplerian elements are defined. Epoch values may be stated in conventional dating methods of day, month and year (ddmmyyyy) followed by UTC clock time. Internally, all computer programs use a numeric day-of-year date reference, and many of us are more accustomed to stating the Epoch in this manner. For instance, 11 November 1987 is day number 315 of 1987, and most programs will accept the compound number of 85315.458333 for 1100 UTC on that date. The decimal portion of the number, .458333, is that fraction of the 24-hour period corresponding to the clock time of 1100 hours of day 315.

Inclination, IØ (degrees): Satellite orbits are best described as an elliptical motion within a flat plane in inertial space. The tilt of this plane with regard to the Earth's equator is the angle called Inclination. If IØ is zero degrees, then the orbit is in the equatorial plane, typical for most geostationary communications satellites, while a value of 90 degrees describes a polar orbit. See **Fig 2-29**.

Right Ascension of the Ascending Node (RAAN), OØ (degrees): This angle describes the location, with respect to the Earth's longitude coordinates, of the tilted orbital plane.

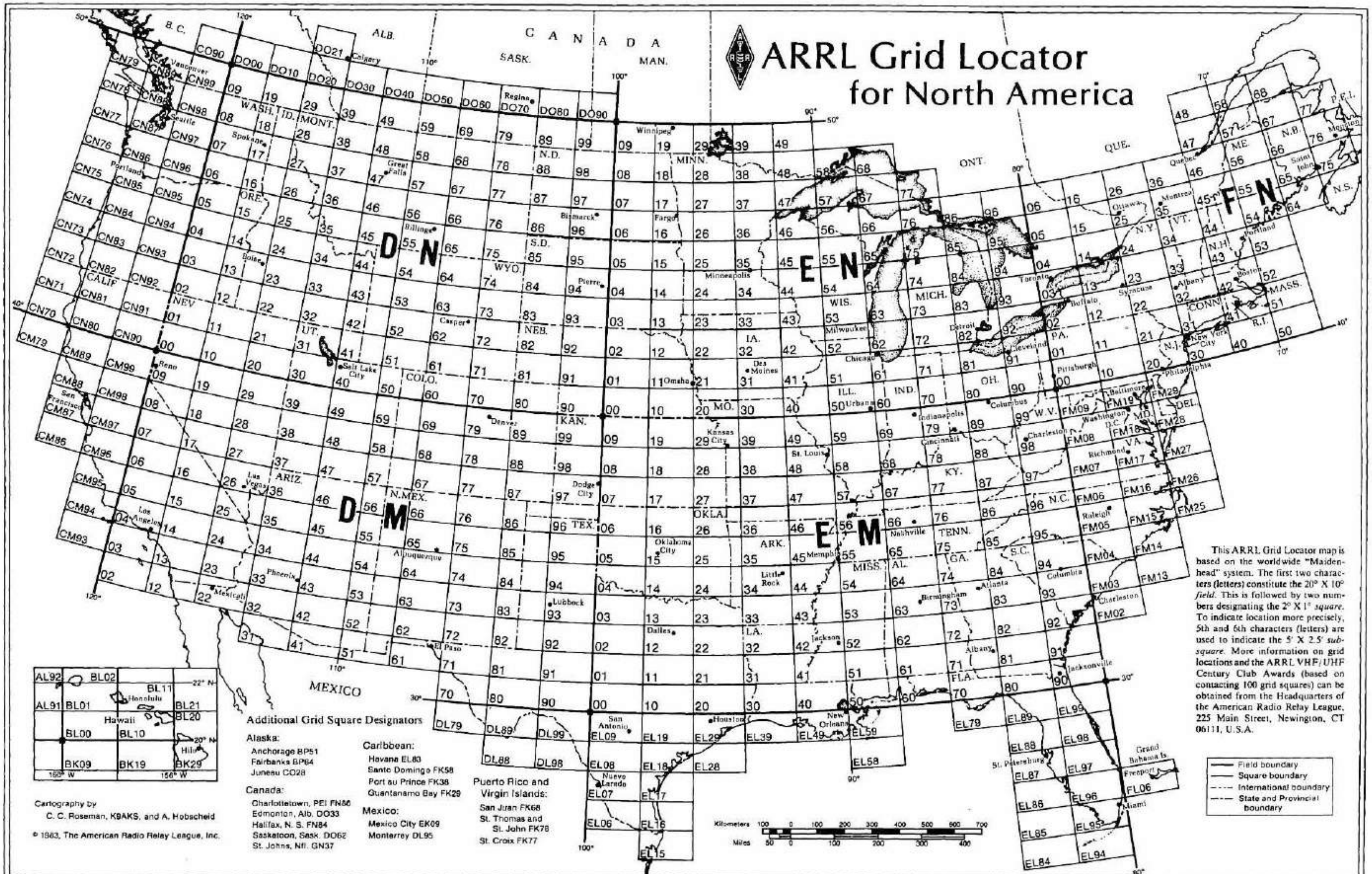


Fig 2-26—The ARRL Grid Locator Map is available in large size (and at reasonable cost) from ARRL Headquarters.

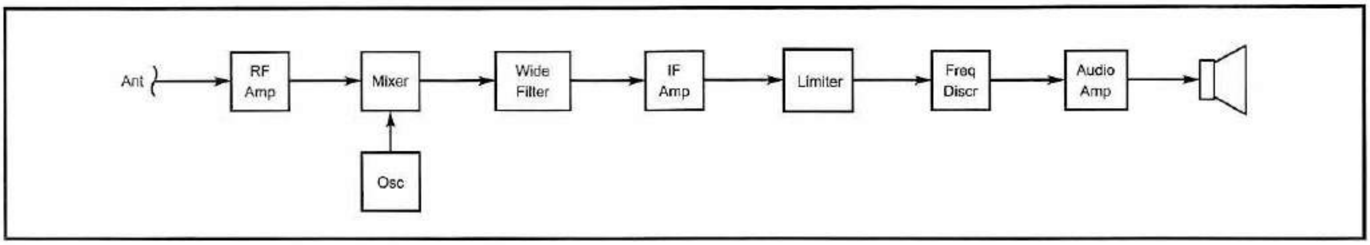
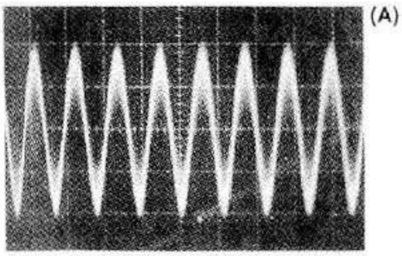


Fig 2-27—Block diagram of a typical FM receiver.



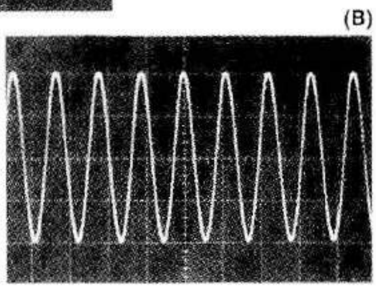


Fig 2-28—At (A) the input waveform to the limiter stage shows amplitude modulation (AM) and noise. At (B) the same signal after passing through two limiter stages. Notice that the AM components are gone.

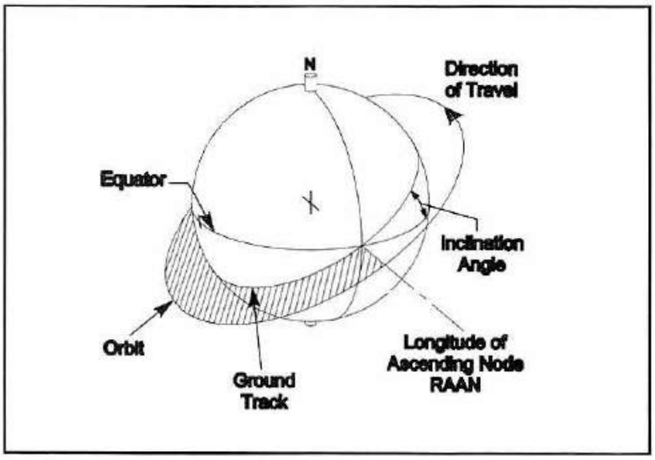


Fig 2-29—Inclination and RAAN.

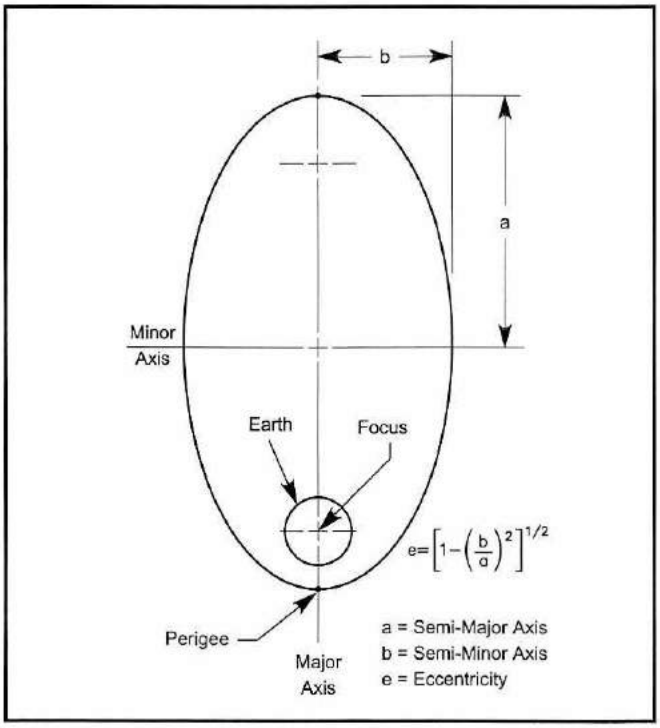


Fig 2-30—Eccentricity and semi-major axis.

Convention places the OØ at that point on the Earth's longitude scale (degrees west longitude) that the satellite track crosses the equator while traveling from the Southern Hemisphere to the Northern Hemisphere.

Eccentricity, EØ: A dimensionless number that describes the shape of an ellipse. All orbits are elliptical motions of which the circle is only a special case. Since ellipses can vary in shape, we need to know the "flatness" of the orbit. If the orbit is truly circular, then EØ = 0, but if the orbit is very flat, the value goes to EØ = 1.0, which is a straight line. Beyond this point, the "elliptical" orbit is no longer elliptical, but is either parabolic or hyperbolic and is no longer a closed, or periodic, orbit. See **Fig 2-30.**

Argument of Perigee, WØ (degrees): This awkward title is merely a statement of the position of the perigee, or lowest altitude point of the orbit, with respect to the RAAN. Measuring orbital position, in degrees, about the center of the Earth, starting from the ascending node crossing of the equator around to the perigee position, then, is the value of WØ. You can then reason that a value of WØ = 270 degrees means that the high point of the orbit, the apogee, will be at the most northerly latitude. Conversely, a value of WØ = 90 degrees places the apogee at the most southerly latitude. See **Fig 2-31.**

Mean Anomaly, MA, MØ (degrees): Another "strange" term, but if you read "anomaly" to be identical to "angle," it then starts to have meaning. MA is merely a statement of the angular position of the satellite in its orbit at the very moment of the reference time is set for the Keplerian elements. MØ is expressed in degrees centered on the Earth's center, starting from the perigee. Another use of MA is in the AO-10 computer for keeping track of time, since the orbital period is a constant time unit. The computer takes the full orbital revolution, from one perigee to the next perigee, and divides that

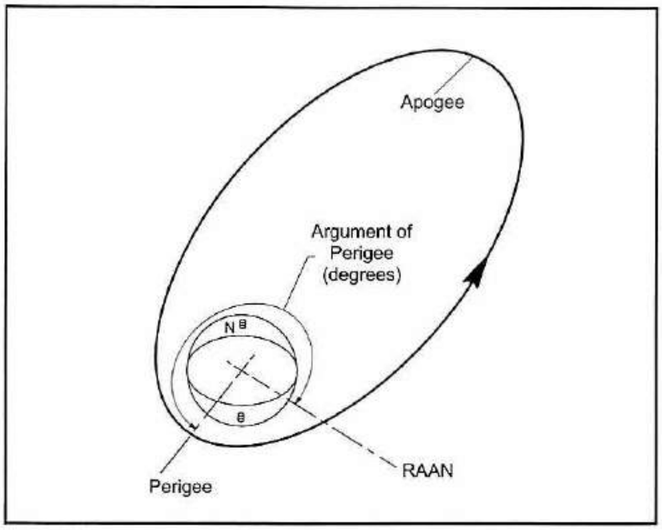


Fig 2-31—Argument of perigee.

time into a computer-usable number of 256 parts, rather than the conventional angular measurement of 360 degrees. AO-10 scheduling is done in increments of this version of MA, sometimes called "Phase."

Mean *Motion, NØ* (orbits per day): This is a very simple notation that merely expresses the number of orbits a satellite completes around the Earth for each UTC day. Orbital period can be easily derived from NØ by dividing 24 hours by NØ.

Semi-Major Axis, SMA, AØ (kilometers): The SMA is a dimensional measurement of one half of the total "length" of the longest axis of an ellipse. In Earth orbits, if the NØ is stated, the use of the SMA is not necessary as they are numerically related in a very direct manner. Most programs will accept either NØ or SMA as input but only use one or the other. The SMA is commonly not stated in lists of Keplerian elements for OSCAR satellites. See Fig 2-30.

Decay Rate, Drag Factor, N1 (orbits/day/day): These two separate names describe the same quantity, which is the first derivative of the Mean Motion. It is, as the name states, the rate of slowing down of an orbit. This factor has been a relatively recent addition to the orbital computations and assists greatly with prediction precision. For those satellites in low orbits, N1 becomes a rather high number, and its impact rather apparent.

Q After installing my satellite tracking program I encountered the following problem. Latitude and longitude are entered in degrees. (Not degrees: minutes: seconds) since all I have is the longitude and latitude. What is the conversion formula to degrees?

A The process for converting appears in the section on operating. However, for satellite work you don't need to be too exact. If your program uses fractions of degrees instead of minutes, etc., forget about seconds, but for minutes each minute is .0166 degrees.

5 min is .08 deg
10 min is .17 deg
15 min is .25 deg
20 min in .33
30 min is .5 deg
40 min is .66
45 min is .75 deg
50 min is .83 deg
Enter your numbers thus:
+71.5 deg

Q I'm interested in monitoring transmissions from weather satellites. Where can I find their signals?

A The frequency range of interest is fairly narrow, with all polar-orbiting satellite transmissions within the 137 to 138 MHz range. US TIROS/NOAA transmissions are made on 137.50 and 137.62 MHz. Each of the two operational spacecraft uses one of these frequencies. NOAA-10, for example, uses 137.50 MHz, while NOAA-11 uses 137.62 MHz.

Russian METEOR/COSMOS weather satellite transmissions occur on a wider variety of frequencies. In the past, 137.15 and 137.30 MHz were the two prime frequencies. There still appears to be an operational METEOR spacecraft, and often more than one, on 137.30 MHz most of the time. In recent years, 137.85 MHz has been used quite regularly, and 137.40 MHz has been placed into service just recently. In any case, your receiver must cover 137.50 and 137.62 MHz, and 137.30 and 137.85 MHz are desirable options. For more information, see the fifth edition of *The Weather Satellite Handbook* by Ralph Taggart, WB8DQT. It's available from your dealer or directly from the ARRL.

Reception of geostationary WEFAX transmissions on 1691 and 1694.5 MHz (the latter used only by the European METEOSAT) is usually accomplished by using a converter ahead of the basic VHF FM satellite receiver. Such converters are designed so that the desired signal comes out at one of the standard VHF satellite frequencies (usually 137.50 MHz).

Q Can you explain the Doppler effect as it applies to satellites?

A If you have ever waited at a railroad crossing for train to go by at a respectable speed, you may have noticed that as the train was traveling away from you, the pitch is much lower than it was when it was approaching. This is called the Doppler effect.

In exactly the same way, the frequencies of satellite signals are affected by relative motion because all satellites are constantly moving relative to each other and to you. As a satellite approaches you its downlink frequency increases. As it passes your position and moves away, the frequency decreases.

Let's say that you are listening for a satellite beacon that has a published frequency of 435.700 MHz. That's the frequency you would listen to if you and the satellite were moving at the same speed relative to each other. The satellite is moving thousands of miles per hour faster, however, so you must tune your receiver to a higher frequency as the satellite appears above your horizon. You'd have to begin listening about 8 kHz higher, or 435.708 MHz. (The Doppler effect is less pronounced, by the way, at lower frequencies.) You'll notice right away that the frequency of the beacon signal is sliding steadily downward. When the satellite is at its closest point relative to your station, directly overhead in this example, you will be receiving its beacon on 435.700 MHz, the published frequency. Enjoy it while you can because the frequency will continue shifting downward! By the time the satellite vanishes below your horizon, you'll be listening at 435.692 MHz.

The Doppler effect is a vivid illustration of the fact that everything is in motion—and we're not just talking about satellites. The Earth rotates on its axis at approximately 1100 MPH. The Earth orbits the Sun at about 67,000 MPH. The sun circles the Milky Way at a speed of 486,000 MPH. And every object in the universe is moving away from every other object as the Universe expands at a constantly accelerating rate. In absolute terms, you're never "standing still"!

Q I've heard there are satellites I can work using just my dual-band FM HT.

A At present, there are at least two amateur satellites that allow for Mode J (2 meter uplink/70 cm downlink) FM operation: AO-27 and UO-14. While there has been some limited success using an HT with just a "rubber duck," better results can be had by using a higher gain antenna, such as a dual-band J-pole, or the commercially manufactured Arrow crossed-Yagi antenna (see **Fig 2-32**). A rubber duck may work only if the satellite were high enough in the horizon to avoid apparent obstacles, such as tall buildings or hilly terrain.

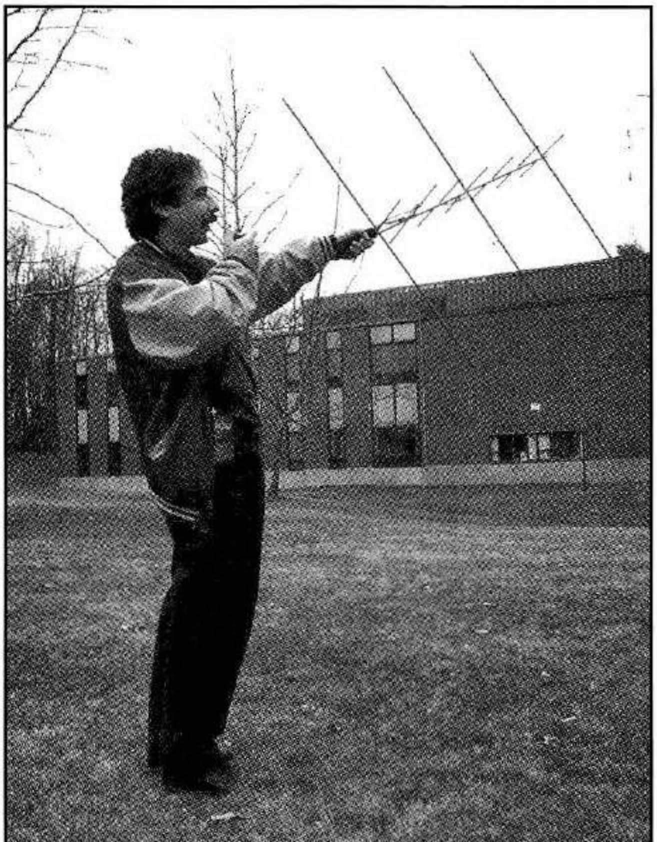


Fig 2-32—*QST* Product Review Editor Joe Bottiglieri, AA1GW, makes a contact through UoSAT-OSCAR 14 with the Arrow II antenna.

Q I understand that when a satellite passes overhead, it is very quick. What do I say to other hams in such little time?

A Most amateur satellites do not allow for casual QSOs given that their time overhead is brief. While conversing through a satellite with a ham 1000+ miles away is quite tempting, it can be discourteous since there are many other hams wanting to also use that satellite. Too many signals can overload the bird, causing signal collisions, or worse. If the satellite pass is brief, it's acceptable if you gave just your name, QTH and grid square.

Q What do you mean by "Mode J"?

A There are a number of amateur satellites currently orbiting the earth. Each one operates on its own set of frequencies and modes (such as FM or CW/SSB). The frequency and mode have been given designators, or MODES. For example, if a satellite is said to operate using "Mode A," this means that it has an uplink frequency on 2 meters, and a downlink frequency on 10 meters (usually near 29 MHz). Its mode could be either CW, SSB, and in some instances, DIGITAL. So as previously mentioned, "Mode J" means that the uplink frequency is on 2 meters, and the downlink frequency is on 70 cm.

There are variations to mode designators, however. For example, AO-27 and UO-14 use Mode JA, but are considered "FM" satellites. This is because the average ham would use FM on these birds. Other satellites, such as FO-20 and FO-29, are also categorized as Mode J, but use SSB on their uplink/downlink frequencies. The letter "A" merely indicates that this is an "analog" satellite. If the letter were "D," then this means that digital signals (such as FSK) can be used.

It should be noted that these designators may soon be retired. With the technology always changing, new satellites are being launched that offer many different modes of operation to amateurs. To keep up with these changes, the mode designators should change as well. For example, the "old" Mode A is also now called "Mode V/T." The uplink/downlink frequencies may stay within the same bands, but the capabilities of the satellite using this mode have changed.

Q Do I have to track the satellite?

A In a word, yes. Most amateur satellites are not considered geostationary. In other words, their orbits are such that they are NOT above a certain location on the globe at any given time. So to make use of any particular satellite, you need to know when that satellite will be above your horizon, and where it's located. (If it's below your horizon, the satellite will probably not receive your signal.) The only way to know its location would be to track it.

There are quite a few satellite tracking programs available. Most of them are shareware, although there are a few freeware programs that are just as good. If you have web access, you should visit the AMSAT Web page (**www.amsat.org/**). There you will find a number of tracking programs. All these programs use Keplerian elements to determine a satellite's position.

Q What license class should I hold to work satellites?

A Given the current crop of amateur satellites, anyone who holds a Technician class or higher can use the birds. The reason for this is that most of the uplink frequencies (whether HF or V/UHF) are outside the Novice class allocations. Since anyone can "listen" however, only the uplink, or transmitting, frequency is the defining factor as to who can use the satellites.

For example, UO-14 has an uplink frequency of 2 meters (with a downlink of 70 cm). A Technician class license holder has operating privileges on 2 meters. A Novice class does not. This should not dissuade a Novice from listening in, however.

Q Do I have to run a lot of power, given that the satellites use V/UHF frequencies and are so far away?

A In many instances, no. There are satellites that will even shut down if they sense too much input power. Unlike operating through a repeater—where you may have to deal with ground-based objects interfering with your signal—satellites generally do not have that problem.

A satellite is clear of the tallest of any and all ground-based objects.* Also, communications are usually conducted via line-of-sight. In other words, the satellite antenna is usually pointed toward the earth station, and the earth station's antenna is pointed directly at the satellite. Communications using as little as 5 W can be realized, as long as conditions are right.

DIGITAL

Q I recently obtained a working Heathkit H-19 terminal for possible use with digital communications. I was wondering if this terminal would work. If so, what TNC would be optimal, and how would I hook up the connections?

A Any TNC should work with a "dumb-terminal" for rudimentary work (packet only) *if* you have a compatible RS-232 connection on the terminal. It is possible that you have a TTL connection there. Heath computers and terminals were all proprietary back then—only Heath components and programming worked.

Q What are the differences between RTTY and packet? Do these modes require special radios? Can you operate RTTY or packet over telephone lines?

A There are a number of differences between radioteletype (RTTY) and packet. The principal ones are:

RTTY sends information in a continuous stream of data. Packet sends information in bits and pieces (no pun intended!) known as *frames*.

Packet has the ability to detect errors and request retransmissions of damaged frames. Generally speaking, you see only error-free text on your monitor. RTTY has no error-detection scheme. Whatever makes it through the noise and interference, plus whatever the noise and interference fools your demodulator into thinking it has received, is what you get.

Packet supports the complete ASCII character set, including upper- and lower-case letters. RTTY uses a truncated character set that allows only upper-case letters and limited punctuation.

To converse in packet you must establish a *connection* with another station according to the AX.25 packet protocol. This involves certain timing parameters, the exchange of particular data frames and so on. Your packet terminal node controller (TNC) does this for you automatically. RTTY doesn't require such an elaborate connection. You simply key the transmitter and start typing.

Packet requires reasonably strong, stable signals to maintain connections. RTTY is useable under all conditions—as long as you don't mind some very fragmented copy when the going gets rough.

RTTY is favored among HF digital contest operators because of the ease with which quick contacts can be made. You'll also see it used frequently by DX operators for similar reasons. Although packet is used on HF, it is best on VHF and UHF where noise, fading and interference are not as common.

Just about any transceiver can be used for RTTY or packet. RTTY is a 100% duty-cycle mode (continuous full-power transmissions). If the radio you're using for RTTY is not rated for 100% duty cycle operating, you'll need to reduce the output, perhaps by as much as 50%, to avoid damage.

Power isn't a consideration for packet, but the radio must be able to switch rapidly from transmit to receive. When your radio transmits a packet frame, for example, it must jump to receive immediately to hear the response from the other station.

Because both RTTY and packet rely on audio tones to send information, you could certainly operate over telephone lines, but it wouldn't be nearly as much fun!

Q I have two questions about HF packet. My Kenwood TS-830S manual states that I must reduce my output by about half when I operate RTTY. Is the same true for packet? Also, are there any packet BBSs on the HF digital subbands?

*One caveat is the satellite's apparent height above the horizon. If a satellite is but a few degrees above one's horizon, ground-based obstacles, such as tall buildings or mountainous terrain, can interfere with a signal.

A RTTY and packet both drive your TS-830S transceiver to maximum output for the duration of each transmission. The difference is that a RTTY transmission can be several minutes long, while a packet transmission is usually one or two *seconds* in length.

Running your TS-830S at full output for minutes at a time is hard on the final amplifier circuitry. That's why the manual suggests that you reduce output by 50% when operating RTTY. With packet, however, the transmissions are so short that your TS-830S will hardly break a sweat. (This is true of most transceivers, by the way.)

Most HF packet activity consists of traffic handling between automated stations. If you look carefully, however, you will find a few BBSs here and there. A number of these systems are in the Caribbean, as well as Central America. The majority of HF BBS operators elsewhere in the world (including the US) have long ago abandoned packet for PACTOR or CLOVER.

Q Do packet contacts count for the Worked All States or Worked All Continents awards?

A They certainly do! The catch, however, is that packet contacts through nodes or digipeaters *do not* count. You must make the contact directly with the other station (except for satellite awards).

Q I want to put together a computer for my station, but it is a frustrating process. Many of the computer retailers sell "custom" PCs that they will assemble to your specifications, but when I talk to them about my ham requirements, they are utterly clueless. This is particularly true when it comes to the number of COM ports that I need. Can you give me some advice?

A The problem with buying a computer for other than traditional applications such as word processing, spreadsheets, Internet connection, etc., is that there are usually only 16 IRQs, 2 COM (serial) ports, one printer (parallel) port and a finite number of card slots on the motherboard.

Motherboards come with different quantities of card slots depending on the manufacturer's design and marketing needs. There are also different types of slots. Today, the most common is the PCI slot—motherboards may have mostly, if not all, this type. Something to consider in managing your slots is that different cards require different type of slots. If your were to choose a motherboard that has an AGP slot, purchasing an AGP video card, could free up a needed PCI slot. Also, if you have a favorite card, such as a sound card or an SSTV card that is of the older 16 bit ISA standard, be sure your motherboard has an appropriate slot. Also keep in mind that the ISA and PSI slots that are adjacent to each other on the motherboard share the same hole in the back of the cabinet so only one of the slots may be populated. In other words, the motherboard may have 7 slots, but only 6 can be used.

There is nothing that can be easily done about the IRQs (Interrupt ReQuest). These are channels that exist for devices to tell the microprocessor that it needs some processing time to perform a task. Some of these are: putting the characters and figures on the screen, recognize that you have pressed a key on the keyboard, getting data from your hard drive, printing a document, activating the telephone modem, updating the system clock, and on, and on, and on. About half of the IRQs are used for the barebones computer to run itself. The rest are for you to do with as you wish...almost.

The company that is putting your computer together for you also has some favorite IRQ robbing devices that they believe you can't live without. Just about every computer today sports the latest 56k modem as a selling feature but if you never intend to use a telephone with this machine, it is robbing you of a valuable IRQ! The average "we can build one for you" computer has two IRQs still available when you get it. Believe it or not, the first Dell 500 MHz, Pentium III, multimedia, CD-ROM burning, DVD, mouth-watering, machine on the market had *zero* IRQs left for other applications! Nice machine, but not for ham radio.

Now, IRQs can be shared if the sharing devices are "friendly," however, divining which IRQs can be shared is voodoo magic. *Windows* gives it the old college try, but it's not perfect. Sharing is also somewhat possible for COM and printer ports.

COM ports are somewhat easier to deal with. Most computers today come with a PS2 mouse so COM 1 is now left free. This leaves two COM ports for you to use. The COM ports are where you will want to connect your TNC, your rig's computer interface adapter, and most other peripherals for ham radio, such as the GPS unit for APRS, etc. If it looks like you will be needing more than 2 COM ports, there are cards available that will supply you with up to four COM ports, provided you have a motherboard card slot and a couple of IRQs free. Are you starting to get the picture?

So, before you visit the dealer, you need to determine the number of COM ports, IRQs and card slots you are going to need for your ham applications in the foreseeable future. When you show up at the store be sure to ask, "After all the components and software are installed, how many IRQs, COM ports and card slots do I have left for myself?" Let their answers to that question, and your budget, guide your choice.

If you feel up to the challenge, consider assembling your own shack PC from components you purchase yourself, either on line or from a local outlet—it really isn't that difficult. You can throw together a bare-bones PC that will leave you with five or more IRQs, three or four card slots, and both COM ports free. A capable ham computer with a 500-MHz Pentium II microprocessor, a 10 Gbyte hard drive, a CD-ROM, sound and video cards and a mouse can be slapped together for about $500. Perfectly serviceable used monitors can be had for about $100; new, just a little more. Take a look on the Web at Pricewatch at **www.pricewatch.com/** and you'll find a huge collection of component and system bargains. See **Fig 2-33**.

Keep in mind that for most Amateur Radio applications, processor speed, hard drive speed/capacity and whiz-bang technologies are not necessary. Even something as "primi-

Fig 2-33—The Pricewatch site at www.pricewatch.com collects current retail pricing on computer systems and components from dozens of dealers.

tive" as a P75 or even a 486-DX2/66 machine with a 500 Mbyte drive will be fine. You can pick up one of those PCs for less than $100 used.

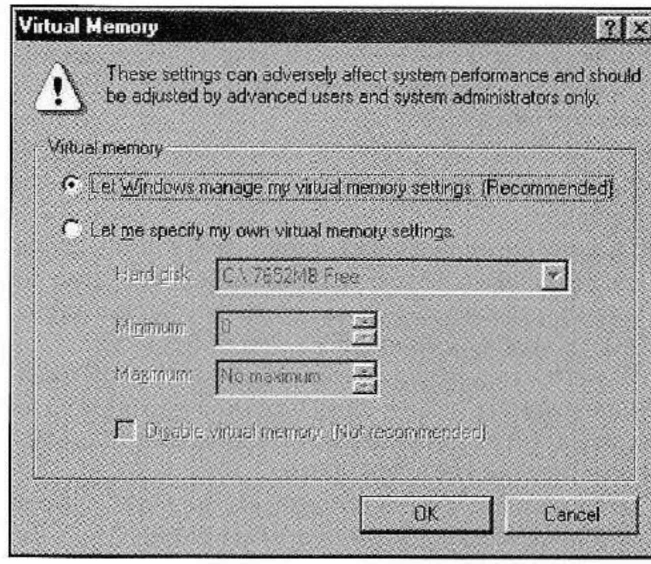
Update: Today with additional avenues of communication between peripherals and the computer, such as USB and FireWire, there may be more options for the ham.

Q This computer of mine runs so slow. I'm running a 166 Pentium with a 56k modem. When I log on to a program it seems to take forever to come up. Any hints would be very much welcome.

A There are three possibilities that come to mind right off the bat. The first and easiest is that your hard drive has become fragmented over time. Assuming you are using Windows 95/98, to defragment:

1. close all open programs
2. click Start
3. go to Programs/Accessories/System Tools/Disk Defragmenter
4. make sure your C drive is indicated and click OK
5. Go watch TV; this will take a while

This should be done every 6 months or so.



The second is check Virtual Memory

1. close all open programs
2. click Start
3. go to Settings/Control Panel
4. Click System
5. Click Performance
6. Click Virtual Memory
7. Make sure that "Let Windows manage my Virtual Memory settings" is selected.

The third possibility is that your hard drive is becoming too full. Windows needs some empty space for the Virtual Memory I mentioned and if space is cramped, this can slow your computer down considerably. Either delete unneeded programs/files or get a larger drive.

Q I want to use a computer in my shack, but I've heard that it can cause interference to my station receiver. Will *any* computer cause interference, or are some better than others?

A Unfortunately, all computer systems have the potential to cause interference. Computers are classified as *unintentional radiators* under Part 15 of the FCC regulations. Part 15 contains provisions that limit the amount of interference caused by computer systems, but they're talking about truly obnoxious interference (like when your neighbor can't watch television when you operate your computer). Interference to sensitive Amateur Radio receivers at close range (in the same room) is a different matter entirely. According to the FCC, you're essentially on your own!

The ARRL RFI desk receives occasional reports of interference from computer devices; unfortunately, most of those complaints don't include computer model numbers. We know even less about which computers don't have interference problems. After all, hams don't usually call to say, "I am *not* having an interference problem!"

Part 15 has more stringent regulations for computers marketed for use in the home (Class B computing devices) than it does for computers made for industrial use (Class A). You need to make sure you are buying a Class B device.

There are a few simple steps you can take to minimize computer interference:

- Use shielded cables for all of your computer connections.
- Locate your station antenna well away from the computer.
- Operate the computer in its original case, with all internal shields in place. If you've taken the computer apart for any reason, make sure you put back all of the case screws; even a small crack can radiate a lot of RF energy.

If you have a portable shortwave radio and/or VHF hand-held transceiver, bring it along when you are shopping for a computer. You can use it to get a relative indication of the amount each model might radiate.

If these simple steps are not enough, the ARRL publication *Radio Frequency Interference* has a chapter devoted to computer interference.

Q I don't want the Digital Revolution to pass me by. Exactly what *is* the difference between *digital* and *analog*?

A In their basic nature, all electronic signals are actually "analog." What this means is that the voltage can vary continuously with respect to time. The 60-Hz sine wave that powers most electrical equipment here in the US is analog. Audio frequency signals are analog, as are radio frequency ones. Sound and light are both analog, but that is getting away from the discussion of electronics just a bit. DC is generally considered analog, but only because the level doesn't carry any information associated with it.

The advantages of analog electronics are that the signals are very easy to generate and the exact signal levels can vary a fair amount in most (but not all) applications with very little problems being encountered.

For logic problems and control circuitry, analog signals aren't as useful. When the desired application is switching something 'on' or 'off' or when a set of conditions or events are used to control an action, analog circuits aren't the best choice. Circuit states of "on" or "off" can be equated to binary arithmetic (a number system that uses only 0s and 1s instead of 0-9 as "digits") and Boolean logic (a way of interpreting multiple events/conditions to arrive at one required action). This makes it easier to figure out complex systems using relatively simple formulas.

Now, the term "digits" comes from finger-counting. The reason each character in a regular number has ten possible values (0-9) is because we have 10 fingers (it is called the "decimal" system because "deci" is Greek for 10). So why are electronic circuits that are based upon values of only 1 and 0 referred to as "digital"? It's because each "place" is also called a "digit."

In the decimal system, 365 is a value of 3 in the "hundreds digit," 6 in the "tens digit" and 5 in the "ones" digit. In the binary system, the number 1101 is a 1 in the "ones digit," a 0 in the "twos digit," a 1 in the "fours digit" and a 1 in the "eights" digit (so the decimal equivalent would be 8 + 4 + 1 = 13).

As I mentioned at the start, all electronics is actually analog in nature, with varying voltage levels. If you took a single voltage level (say, 5 V) and called it a "1" and took another voltage (say, 0 V) and called it a "0" then this wouldn't be very useful because the first time a load was added to the 5 V source, it might drop down to 4.9 V and then no longer count as a "1." Neither would it be a "0."

So, is done is to define some reasonable voltage ranges. For TTL (transistor-transistor logic) circuits, a "1" is defined as a level of anywhere between 2.4 V and 5 V. A "0" is defined as anywhere between 0.4 V and 0 V. Note that some "gap" is required between the voltages so as to ensure that a "1" is not incorrectly misinterpreted as a "0" if a small additional voltage drop occurs. In practice, the voltage never enters the "gap" unless there is a problem with the circuit design or malfunction.

So what is a practical example? Take a home security system. You want to sound an alarm if any window breaks, if a door is forced open or if a fire starts, etc., etc. Each event is an all-or-nothing prospect. If a window breaks, you don't need to know the amount of the damage to know that an alarm must be sounded. In this type of system, everything is tied together by "OR" logic. If <window 1 breaks> OR <window 2 breaks> OR <door is open> OR <fire starts> then <alarm is sounded>. It doesn't matter if more than 1 event takes place.

If window 1 breaks, the Boolean equivalent of what happens to the system is:

1 OR 0 OR 0 OR 0 = 1

If two windows break, you have:

1 OR 1 OR 0 OR 0 = 1

and any other combination of 1s and 0s will give you that same result (sound the alarm). Only if all is quiet:

0 OR 0 OR 0 OR 0 = 0

do you get the "digital" result of having the alarm off. If you simply wired all the sensor circuits together, the voltage output from one would be loaded down by the others and you couldn't make a "logical" decision about what is going on.

The other form of logic is the AND condition. Take starting your car. Only if <the battery is charged> AND <if there is gas in the tank> AND <if the key is turned> will <the car start>. The Boolean logic equivalent for this is:

1 AND 1 AND 1 = 1

Now, it is important here not to get confused with the "and" of addition. In this case, we are *comparing* conditions to determine whether or not to proceed.

If any one of the conditions is not true (say we are out of gas), then the car will not start:

1 AND 0 AND 1 = 0

Likewise, if we have gas, but the battery is dead:

0 AND 1 AND 1 = 0

Of course, these are all very simple examples and many more complex possibilities exist.

Now, how do you get "digital" signals from "analog" components? Easy—by selecting components that switch on and off according to voltages applied to them. Of course, relays do this and they formed the very first "logic" circuits (in a 1950s *QST*, there was a keyer project using all relays). However, transistors are much quieter, faster and (by far) cheaper.

If you take a plain vanilla 2N2222 bipolar transistor and drive its input really "hard," the output will reach a limit. Such a condition is called "saturation." If you ground the emitter and tie the collector to a power supply through a resistor and then feed 5 V (a TTL "1") into the base (through another resistor), then the voltage at the collector will drop to a level of 0.2 V (a TTL "0"). Then, if we drop the voltage on the base to 0 V (a TTL "0"), then the collector voltage increases to the supply voltage (for a 5-V supply, a TTL "1"). Therefore, we have just "invented" a digital "inverter" using an analog component.

Logic ICs are just very large collections of transistors and other components (in miniature), configured to perform a certain logic function ("invert," "AND" and "OR" are among the most common types).

In addition to logic decisions, digital circuits also count and perform arithmetic. The simplest example is perhaps multiplying by 2.

00001×10 = 00010; 00010×10 = 00100; 00100×10 = 01000; 01000×10 = 10000

As you can see, each multiplication effectively moves the "1" to the left by one digit. An IC that does exactly that is called a "shift register." A "register" is a device containing a several "digits," usually collectively representing a number. An IC with 4 "output" pins can represent numbers from 0000 to 1111.

Although decimal addition is usually easier for most folks than decimal multiplication, the opposite is true with binary. 1 + 1 = 2 translates as 01 + 01 = 10, which is less obvious than the multiplication example above. However, the same situation occurs when you have 8 + 2 in a decimal system—the "ones place" digit becomes a zero and a value of one is "carried" over to the next higher digit. The difference is the next digit in the decimal system is a "tens place," whereas in binary it is a "twos place."

You may also see a different number system in publications that discuss digital electronics. This number system gives you numbers like "56DE" that often have an upper or lower case H after them. The H refers to Hexadecimal. Since "deci" is ten and "hex" is six, "hexadecimal" refers to a numbering system with 16 values. To express values greater than 9 in a single digit, letters are used. A is ten, B is eleven, C is twelve and so on up to F which is 15. The main reason for this is that it becomes a real chore to figure out the decimal equivalent for numbers like 1011100101001010001111000101010. Not to mention the ink consumption. Fortunately, converting between binary and hex is easy. Each hex digit is equivalent to four binary digits, so the above number can be rewritten in groups of four: 0101 1100 1010 0101 0001 1110 0010 1010 and then each group is converted to its equivalent (0101 = 5, 1100 = C, 1010 = A, etc. giving 5CA51E2A as a hex value). By convention, the digits A...F are always written in upper case.

However, it is important to remember that digital circuits still work with just 1s and 0s. There is no equivalent voltage for "B"—this is just a shorthand notation for convenience sake.

Computers and calculators rely heavily on every kind of digital circuit. However, VCRs, telephones, clock radios and the like usually just have a couple different kinds (in addition to analog circuits).

One of the other notable differences between analog and digital circuits is that many digital circuits (particularly arithmetic ones) have to be "synchronously" controlled—that is to say that the sequence of events is "stepped" from one moment to the next so that all of the parts of the circuit work together. The mechanism that does this is called the "clock" and it is a continuously running digital oscillator—it changes from a "1" state to a "0" state, then back to the "1" and back to the "0" over and over again. When you hear someone say they just bought a computer that is 800 MHz, that is the speed of the computer's main clock.

Getting back to an earlier example, in the shift register IC (2x multiplier), the clock lets the IC know when to shift the number from one output to the next (whether it shifts or not is controlled by another pin).

With basic operations (like the car and security system examples), a clock may not be needed.

Q I would like to control my transceiver with my computer, but the interfaces are rather pricey. Is there a more affordable alternative?

A Certainly—make the interface yourself. We're talking about two ICs, a voltage regulator and a handful of components. Here we describe interfaces for the ICOM, Yaesu, Ten-Tec and Kenwood transceivers.

The interfaces described here from Wally Blackburn, AA8DX, first appeared in February 1993 *QST*. They simply convert the TTL levels used by the radio to the RS-232-D levels used by the computer, and vice versa. Interfaces of this type are often referred to as level shifters. Two basic designs, one having a couple of variations, cover the popular brands of radios.

TYPE ONE: ICOM CI-V

The first interface works with newer ICOM and Ten-Tec rigs. **Fig 2-34** shows the two-wire bus system used in these radios.

The schematic for the ICOM/Ten-Tec interface is shown in **Fig 2-35**. It is also the Yaesu interface. The only difference is that the transmit data (TxD) and receive data (RxD) are jumpered together for the ICOM/Ten-Tec version.

A DB25 female (DB25F) is typically used at the computer end. The interface connects to the radio via a 1/8-inch phone plug. The sleeve is ground and the tip is the bus connection.

It is worth noting that the ICOM and Ten-Tec radios use identical basic command sets (although the Ten-Tec includes additional commands). Thus, driver software is compatible. Ten-Tec radios can be used with all popular software that supports the ICOM CI-V interface. When configuring the software, simply indicate that an ICOM

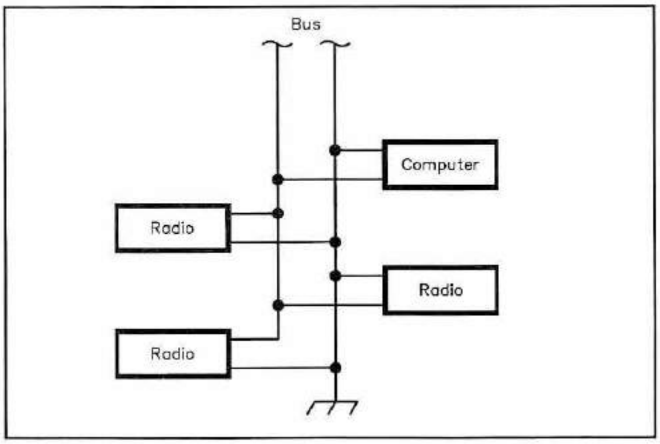


Fig 2-34—The basic two-wire bus system that ICOM and newer Ten-Tec radios share among several radios and computers. In its simplest form, the bus would include only one radio and one computer.

radio (such as the IC-735) is connected.

TYPE TWO: YAESU INTERFACE

The interface used for Yaesu rigs is identical to the one described for the ICOM/ Ten-Tec, except that RxD and TxD are not jumpered together. Refer to Fig 2-35. This arrangement uses only the RxD and TxD lines; no flow control is used.

The same computer connector is used, but the radio connector varies with model. Refer to the manual for your particular rig to determine the connector type and pin arrangement.

TYPE THREE: KENWOOD

The interface setup used with Kenwood radios is different in two ways from the previous two: Request-to-Send (RTS) and Clear-to-Send (CTS) handshaking is implemented and the polarity is reversed on the data lines.

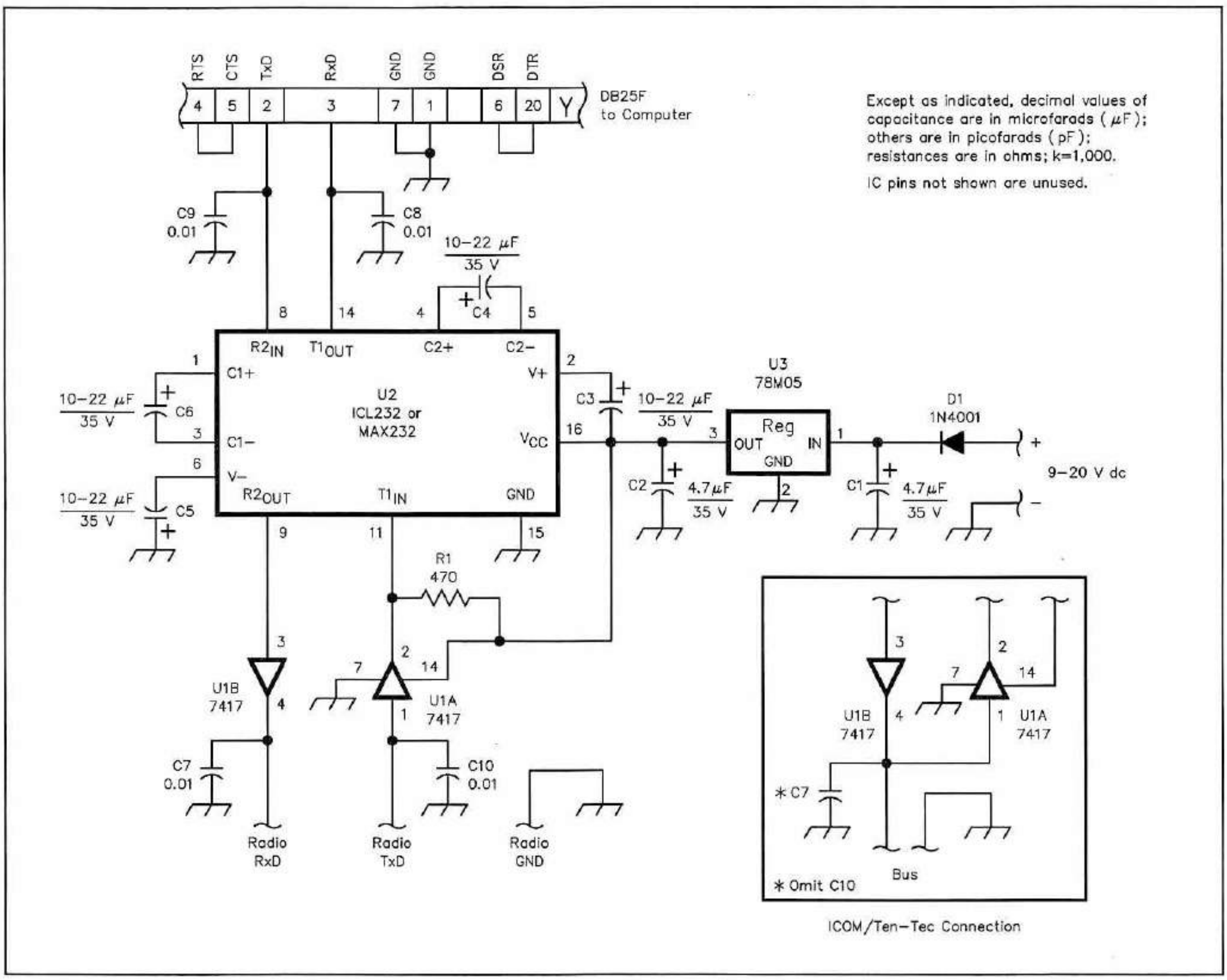


Fig 2-35—ICOM/Ten-Tec/Yaesu interface schematic. The insert shows the ICOM/Ten-Tec bus connection, which simply involves tying two pins together and eliminating a bypass capacitor.

C7-C10—0.01-µF ceramic disc.

U1—7417 hex buffer/driver.

U2—Harris ICL232 or Maxim MAX232

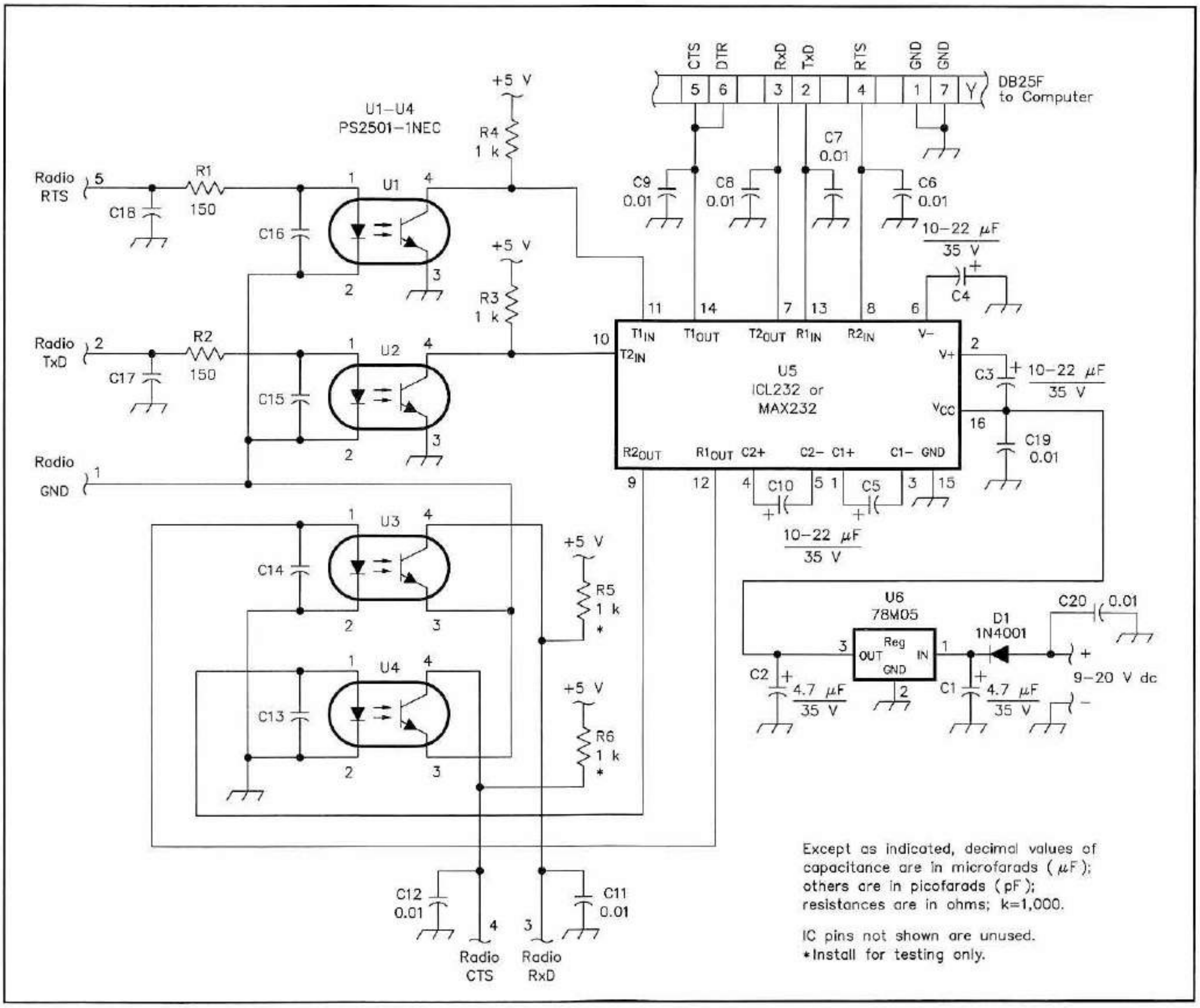


Fig 2-36—Kenwood interface schematic.
C6-C9, C11, C12, C17, C18—0.01-µF ceramic disc.
C13-C16, C19-C21—0.01 pF ceramic disc.
U1-U4—PS2501-1NEC (available from Digi-Key).
U5—Harris ICL232 or Maxim MAX232.

The schematic in **Fig 2-36** shows the Kenwood interface circuit. Note the different grounds for the computer and the radio. This, in conjunction with a separate power supply for the interface, provides excellent isolation.

The radio connector is a 6-pin DIN plug. The manual for the rig details this connector and the pin assignments.

Some of the earlier Kenwood radios require additional parts before their serial connection can be used. The TS-440S and R-5000 require installation of a chipset and some others, such as the TS-940S require an internal circuit board.

CONSTRUCTION AND TESTING

The interfaces can be built using a PC board, breadboarding, or point-to-point wiring. PC boards and MAX232 ICs are available from

FAR Circuits
18N640 Field Court
Dundee, IL 60118-9269
USA
Phone: 847-836-9148 (Voice mail)
Fax: 847-836-9148 (same as voice mail)
Email: **farcir@ais.net**
Web Site: **http://www.cl.ais.net/farcir/**

The PC board template is available from Technical Secretary, ARRL, 225 Main Street, Newington, CT 06111. Article copies must be prepaid ($3 for ARRL Members, $5 for nonmembers at this writing). You may order by telephone (860-594-0200) and pay by credit card.

It is a good idea to enclose the interface in a metal case and ground it well. Use of a separate power supply is also a good idea. Since these interfaces draw only 10 to 20 mA,

Table 2-4

Kenwood Interface Testing

Apply	*Result*
GND to Radio-5	–8 to –12 V at PC-5
+5 V to Radio-5	+8 to +12 V at PC-5
+9 V to PC-4	+5 V at Radio-4
–9 V to PC-4	0 V at Radio-4
GND to Radio-2	–8 to –12 at PC-3
+5 V to Radio-2	+8 to +12 V at PC-3
+9 V to PC-2	+5 V to Radio-3
–9 V to PC-2	0 V at Radio-3

Table 2-5

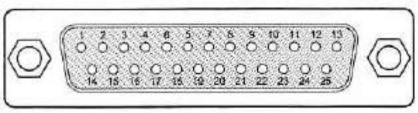
ICOM/Ten-Tec Interface Testing

Apply	*Result*
GND to Bus	+8 to +12 V at PC-3
+5 V to Bus	–8 to –12 V at PC-3
–9 V to PC-2	+5 V on Bus
+9 V to PC-2	0 V on Bus

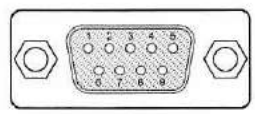
Table 2-6

Yaesu Interface Testing

Apply	*Result*
GND to Radio TxD	+8 to +12 V at PC-3
+5 V to Radio TxD	–8 to –12 V at PC-3
+9 V to PC-2	0 V at Radio RxD
–9 V to PC-2	+5 V at Radio RxD



Pin	Direction	Description
1	GND	Earth Ground
2	O	Transmit Data (TX)
3	I	Receive Data (RX)
4	O	Request To Send (RTS)
5	I	Clear To Send (CTS)
6	I	Data Set Ready (DSR)
7	GND	Signal Ground (GND)
8	I	Data Carrier Detect (DCD)
20	O	Data Terminal Ready (DTR)
22	I	Ring Indicator (RI)



Pin	Direction	Description
1	I	Data Carrier Detect (DCD)
2	I	Receive Data (RX)
3	O	Transmit Data (TX)
4	O	Data Terminal Ready (DTR)
5	GND	Signal Ground (GND)
6	I	Data Set Ready (DSR)
7	O	Request To Send (RTS)
8	I	Clear To Send (CTS)
9	I	Ring Indicator (RI)

Fig 2-37—Signal "pin outs" for 9 and 25-pin serial connectors.

a wall transformer can be used.

The serial ports of both the radio and the computer must be set to the same baud rate, parity, and number of start and stop bits. Check your radio's documentation and configure your software or use the PC DOS/MS-DOS MODE command as described in the computer manual.

Q I want to make a serial cable to connect my packet TNC to the COM port on my computer. My TNC uses a 9-pin RS-232 connector, but my computer needs a 25-pin connector. I can install the correct connectors on each end, but I need to know which pins carry which signals. Can you help?

A Take a look at **Fig 2-37**. There you'll find the most common implementations of EIA-232-D serial connections—commonly known as RS-232—for 9 and 25-pin connectors. Just be careful to match up the signals to their respective pins on both connectors!

OPERATING

Q I need to know how to convert degrees, minutes, seconds of latitude and longitude to decimal format. Can you help?

A My pleasure. Here's how to do the conversion:

1. Divide the seconds by 60.
2. Add the results to the minutes.
3. Divide the result by 60.
4. Add the result to the degrees.

For example, convert 42 deg 28' 53" to decimal format:

53/60 = 0.8833

28 + 0.8333 = 28.8833

28.8333/60 = 0.48139

42 + 0.48139 = 42.4814 degrees (when we round off)

Q When I'm participating in a conversation on the air, do I have to send the call signs of my station *and* the other station at the beginning and end of each transmission?

A The FCC requires you to identify your station every 10 minutes during a communication, and at the end of the contact. There is no requirement to ID anyone other than yourself, unless you've exchanged international third-party traffic with a foreign station. If that's the case, you must identify the other station at the end of your conversation.

Q As a new ham I'm bewildered by all the various frequency bands. Can you tell me which ones are best for reliable short, medium and long-range communication?

A Some of the greatest fun in Amateur Radio comes from using bands that are *not* "reliable," where signals are there one minute and gone the next. However, it's best to get your feet wet in a more stable environment.

For local communication, VHF/UHF FM (with or without repeaters) is a good bet but is not the only game in town. Lots of local nets flourish on 10 meters. During the day, 80 meters is very reliable (but sometimes noisy, from thunderstorms) out to 150 miles or more. Another good daytime band is 40 meters, where you can usually count on finding people 300 to 800 miles away. A simple wire antenna and 100 W can net you plenty of contacts on either band. As they say in the car commercials, your mileage may vary. At night, 80 meters lengthens out and you will find strong signals coming in from hundreds and even thousands of miles away, and 40 becomes a real long-range (DX) band with shortwave broadcast interference the major limiting factor. If at night you want to continue the kind of chats you can enjoy on 80 and 40 during the day, it's worth the trouble to get on 160 meters.

For truly reliable DX communication you have to be versatile; there's not a "one size fits all" band, although 20 meters comes the closest to that description. By the way, it's considered discourteous to use a crowded band that is open for DX to conduct a local ragchew that could just as well take place on another, less active band. The amateur bands are shown in **Fig 2-38**.

Q I am interested in learning how to do a phone patch to a particular town in Pennsylvania. Specifically, I will be doing some field work in Mississippi for the US Marine Corps. I will bring my ham stuff and thought in the evenings I would work portable in the field. One of the Marines with whom we coordinate is interested in Amateur Radio because he is always out of touch with his family and often in places without phone service. While chatting with him it occurred to me that I might be able to setup a phone patch with his family. Unfortunately I am not sure how to set up the logistics.

How do I find a ham in near this fellow's home town? Does the Marine's family need to be at the ham's shack? How does one patch the phone into the radio and control transmit and receive? Setting up phone patches is totally new to me.

A Phone patches became popular back in the fifties when "long distance" telephoning was very expensive. Just about every well equipped ham station had the capability. Back then, this was usually the only way for soldiers, sailors, marines and airmen to "phone home."

With the advancements in cheap, portable, readily available, personal communication, phone patches have somewhat fallen out of favor. Gosh, now even the Navy ships deployed at sea have Internet access so the troops can e-mail their families regularly and set up periodic video phone calls. The only popular vestige today seems to be the autopatch on the local repeater.

But there is still the need for an occasional phone patch, I suppose. Back in its heyday all you had to do was call, "CQ phone patch Tamaqua, Pennsylvania," a few times and someone in the vicinity would pop up. Now it's different.

As for setting up a phone patch schedule, there is no real way to do that—never has been. It's just a matter of luck. Getting on the air well in advance of your trip and asking around if anybody in that area does phone patching might help. Or checking into the various nets may help also. That way you can set up a schedule.

How's it done? There is a simple device (see **Fig 2-39**) called a phone patch (that is both a noun and a verb) that connects the audio input and output of the rig to the telephone line. The device contains a matching transformer and a couple of level controls (the phone companies are very touchy about how we insert signals onto their lines). The family stays at home and uses the telephone. The ham nearby places the call to them and controls the conversation with his push-to-talk switch.

It is not necessary to find a ham with a phone patch in the same town as the folks you want to call. If you are sure that they will accept a collect call from their loved one, the ham can accommodate this also.

Q I'm a relatively new ham and I've managed to enjoy several DX contacts. I keep hearing about "QSL Bureaus." What are they? How do I use them?

A QSL bureaus are useful if you're a DXer on a budget. Think of them as small post offices. As an ARRL member you have exclusive access to our Outgoing QSL Service. For just $6 per pound [at this writing], they'll ship your QSL cards to bureaus overseas. (A pound is about *150* QSL cards!) The overseas bureaus, in turn, will send your cards to the DX stations.

To use the outgoing service, presort your cards according to the call-sign prefixes of the destination DX stations. Enclose a photocopy of the address label from your current copy of *QST* (to prove membership), along with a check or money order. Wrap the package securely and send it to:

ARRL Outgoing QSL Service
225 Main St
Newington, CT 06111

The outgoing service is not available to all countries, but will reach most of the countries you're likely to encounter as a beginning DXer.

Working in reverse, the DX stations send cards to their local bureaus, who in turn ship them to *incoming* QSL bureaus here in the US. (Each call-sign district is served by an incoming QSL bureau.) If you have a large, self-addressed, stamped envelope (SASE) on file with the bureau that services your call district, they'll send the cards to you right away.

By the way, send your SASE to the incoming bureau that serves the district according to your call sign—even if you've moved to another district. Let's say you lived in

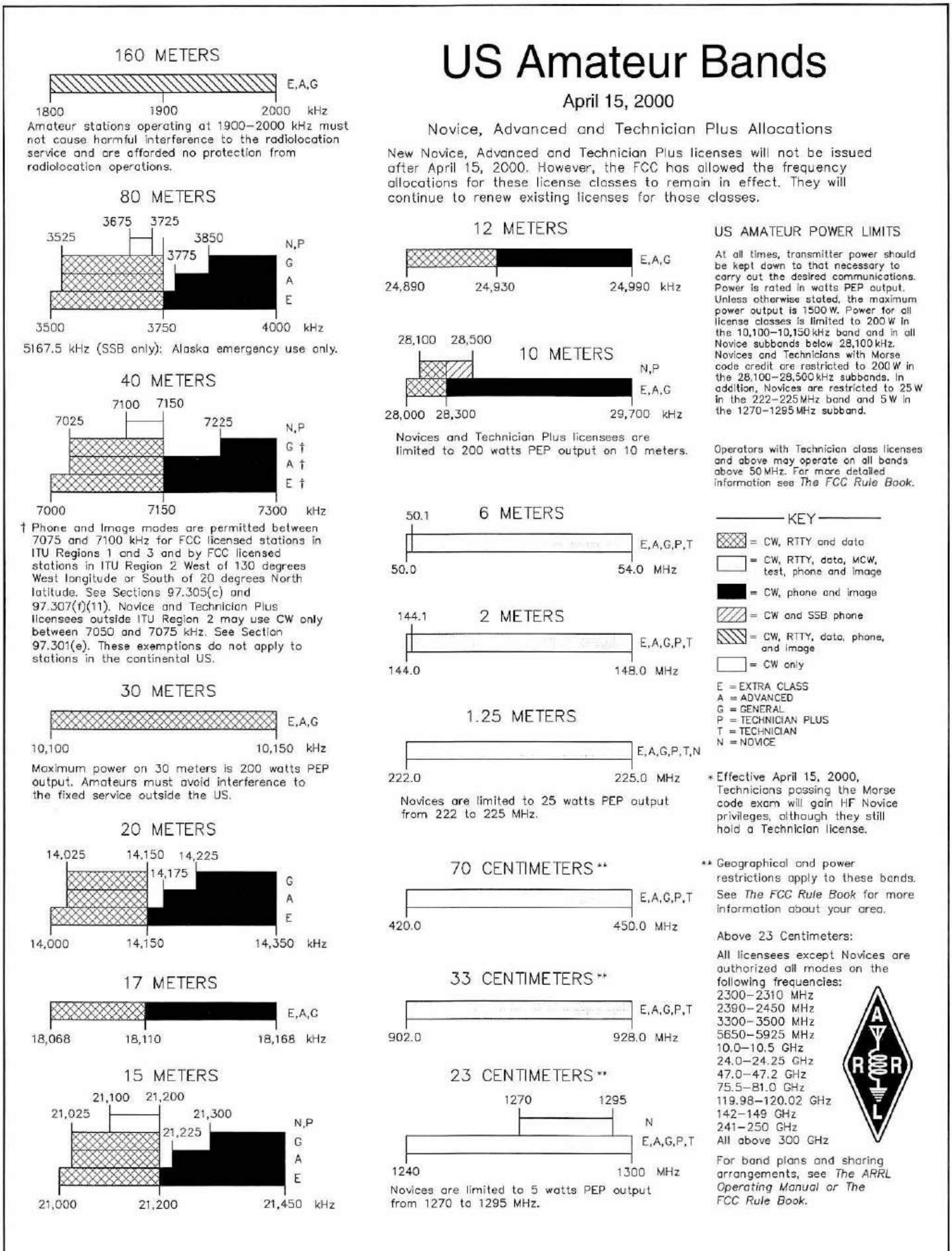


Fig 2-38—Frequency allocation chart for US amateurs.

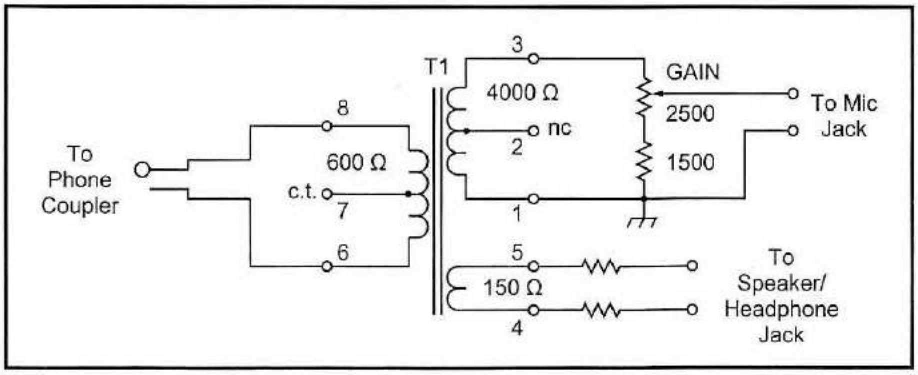


Fig 2-39—A simple phone-patch circuit. T1 is from an RM-52 remote-control unit purchased from Fair Radio Sales, Lima, OH. A push-to-talk switch, not shown, may be added to activate the transmitter.

Alabama and were issued the call sign AA4XY. A few years later, you moved to Idaho (the seventh call district), but you kept your four-land call. You would still keep your envelope on file with the district-four bureau! Of course, if you switched to, say, KC7XYZ, you'd also switch to the district-seven bureau.

The bureau system is popular because it is so inexpensive. The drawback is that the system is very slow. It's common to wait a year or longer to receive a card via the bureau. That's why some hams prefer to mail their QSLs directly to DX stations. They usually include an International Reply Coupon (IRC) for return air-mail postage and a self-addressed air-mail envelope. To learn more about the QSL bureau system, and DX QSLing in general, see the latest edition of the *ARRL Operating Manual*.

Q Whenever I get a request to QSL directly to a DX station I always include an SASE and a dollar. I thought I once read that this was proper. Is that true?

A Well .... not really. An SASE (self-addressed stamped envelope) tells me that you have put a stamp on the return envelope. A US stamp is of no use at all to the fellow in another country—he has to put *his* country's stamp on the return envelope. In addition, some countries' postal regulations require certain sized envelopes be used so he may have to use his own anyway.

As for the dollar—strictly speaking that is illegal in some countries and since the only way to redeem the dollar is on the black market, you might be exposing the recipient to some danger. Also in some countries the postal workers are expert in ferreting out mail containing currency. The proper tender for return postage is the IRC (International Reply Coupon) available at your local post office. By international agreement, these are each valued at one unit of surface postage at the destination, although some countries require more than one for surface mail. Additional IRCs are needed for Air Mail.

All that having been said, except for putting a stamp on your return envelope, what you are doing is done all the time. The proper way gets even more expensive. Your decision.

TIME

Q I'm confused regarding the proper use of Coordinated Universal Time (UTC). Should I change my UTC clock to reflect the shifts to and from Daylight Saving Time?

A Universal Coordinated Time (UTC) is the same—regardless of which time zone you live in. For hams in the US and most other areas of the world, UTC and local time don't match. UTC is always a certain number of hours ahead or behind local time. If you live in the Eastern time zone, UTC is 4 hours ahead of local time when Daylight Saving is in effect. During the winter, UTC is 5 hours ahead.

The easiest way to reduce time confusion is to keep a clock near your radio that's set to UTC. Once you've set it, don't change it—*ever* (except to correct for a fast or slow running clock, of course!). When you record a contact in your log, use this clock as your only time reference. You don't need to worry about whether or not Daylight Savings is in effect. When it's 2300 UTC at your station in New Jersey, it's 2300 UTC at the other end of the conversation in New Delhi, India—even though your local times are vastly different.

Don't forget that when it's later than 0000 UTC, it's the next *day*. For example, you might make a contact at 2200 *local* time on July 21, but that may translate to 0200 UTC *July 22*! Make sure to record the correct UTC time and date in your log.

Q A friend of mine received a QSL card with a 2075 ZULU time on it. What time would this be in regular time and how is it figured?

A Well, we have a few things going on here, so let's take them one at a time.

ZULU stems from the military system where the hours of the day are given phonetic names -0100 is ALPHA for West Africa, -0200 is BRAVO for the Azores, and on around the world, leaving out I to avoid confusions with 1 o'clock, and leaving m (Mike) for the International Date Line in the Pacific, this gets you to ZULU for midnight (0000 hours). Hence ZULU time (counting from midnight).

The times themselves are based on UTC so in essence, ZULU is the military way or saying UTC.

The apparent 75 minutes after the 20th hour is simply a matter of writing style. In much of the world under European influence, the 7 is written in script like this 7 and the 1 is 1. So the time of the contact was 2015 UTC.

While we're on the subject, contrary to popular belief, ZULU is not *Military Time*, strictly speaking. ZULU is based on UTC and Military Time is the convention of expressing time in the 24 hour system. 1900 ZULU is 7 PM in Greenwich, England and 1900 hours spoken by two soldiers in Topeka, Kansas (without saying ZULU) is 7 PM in Topeka, Kansas.

Now for part 2 of the question...**How is it figured?**

Q What is UTC and how does it compare with my local time?

A How about a little bit of history—it's a fascinating story.

When the English started navigating the seas in earnest a couple of hundred years ago, they found that their ships were not always where they thought they were. This, in fact, caused loss of ships and cargo on more than one occasion. When an ill-fated Admiral drove his whole fleet to destruction because he was 15 miles from where he thought he was, they'd had enough of this and instituted The Longitude Board and pronounced a competition to solve the problem.

A clock maker in the early 1700s by the name of John Harrison reasoned correctly, that if you knew the exact time in, let's say, England and you looked up at the sun or stars wherever you might be and determined the exact time there (astronomy had advanced to where that was easily done in those days), you could then calculate how far East or West you were from England very accurately. Of course, what was needed was a clock, accurate to within fractions of a second, on board, set to the time in England, that would survive the rigors of sea travel—which is why a lowly clockmaker is the hero in our story. After a lifetime of work, he made such a clock.

So it was that the time at the Greenwich Observatory in England, where Harrison conducted some of his experiments, became the "standard" or Mean Time (GMT) throughout the world from which you measured your position. To this day we use this measurement as the "universal" time. And along the way, it was also decided that it would be less confusing to use a 24 hour system instead of using the 12 hour method of telling time (AM and PM)—it probably made the math easier for the navigators.

In 1970 the Coordinated Universal Time system was devised by an international advisory group of technical experts within the International Telecommunication Union. The ITU felt it was best to designate a single abbreviation for use in all languages in order to minimize confusion. Since unanimous agreement could not be achieved on using either the English word order, CUT, or the French word order, TUC, the acronym UTC was chosen as a compromise. (You will note that WWV still says Coordinated Universal Time.)

So since it is now 7:02 PM in Central Kazakhstan and 9:02 AM in Connecticut, we use the universal 2:02 PM (or 1402 in the 24 hour system) to document the time of the contact.

To compute **UTC** from your home, you **add** the appropriate number of hours from your time zone (Standard, never Daylight) to that of Greenwich, England (UTC).

In other words, during Standard Time add:

5 hours Eastern
6 hours Central
7 hours Rocky Mountain
8 hours Pacific
to your local time.

Don't forget that as you approach midnight, it's after midnight (or the next day) in Greenwich—so 10 PM (2200) Wednesday on the East coast is 3 AM (0300) Thursday UTC.

During Daylight Saving add:

4 hours Eastern
5 hours Central
6 hours Rocky Mountain
7 hours Pacific

To compute what time it was at **your home** at the UTC time the QSL says it was, just reverse the process—subtract instead of add.

Here are some interesting Web sites on the subject of UTC:

AUTC/GMT conversion chart—**www.dxing.com/utcgmt.htm**

Find the local time now anywhere in the world: **www.worldtimeserver.com/**

The Greenwich Observatory Web site: **time.greenwich2000.com/**

A site about John Harrison, the fellow who made it possible: **www.discovery.com/games/someone/someone991025/answer.html**

WWV—This time is announced verbally on 1 minute intervals (with 1 second ticks) on WWV, the time signal radio station in Boulder, Colorado. The frequencies most folks receive WWV on are 5 MHz, 10 MHz, 15 MHz, 20 MHz and 25 MHz. Many US locations receive the 10 MHz signal most strongly.

3 Mobile, Portable, Repeaters

Most amateur equipment today can operate from a 12-volt supply. Many amateurs are faced with various antenna restrictions. These two factors result in one conclusion: more hams are installing radios in their cars than ever before. Here's how to do it, and what could go wrong.

Q I want to put a transceiver in my car. Where is the best place to mount a rig?

A Thousands of hams enjoy mobiling. The reasons range from the practical, with a ham who wants to operate 2-M FM on his or her way to and from work, to sheer personal enjoyment of chatting with a ham in a distant land while motoring down the highway. Some hams operate virtually 100% mobile, for a number of reasons—they may live under antenna restrictions or simply have no room for a station at home.

Your first consideration when mounting a mobile rig is *safety*. Your rig should be mounted within easy reach of the operator. In today's small cars with crowded control areas it is difficult to find a spot to mount the rig and it is tempting to place it in that wide open space under the glove compartment on the passenger side. This is fine for the passenger but could be disastrous for the driver reaching for a control while whizzing down the highway or maneuvering in traffic.

Also, the location you choose should allow you to view the dials at a glance with minimum distraction from your main objective, the road!

Finally, consider the air bags. It goes without saying that nothing should be mounted on the panel over the airbag, but also the radio should never be placed in a location where it may come in contact with a deploying air bag. It wouldn't do to have the bag snag—or even puncture—on a portion of the rig, rendering this life-saving device useless!

Most modern radios have been designed with these limitations in mind. HF rigs now come with detachable front panels that can be easily mounted on the dashboard close to the instrument cluster. VHF radios are now so small that they can be mounted just about anywhere—even in-dash mounting is a viable option or that little change cubby in the console.

Mobiling is great fun, but remember to keep it safe.

Q What will my car manufacturer have to say about installing a radio in my car? Will it void my warranty?

A Maybe; maybe not. The policies of each automobile manufacturer vary. In 1994, the ARRL Lab contacted most of the manufacturers who sell cars in the United States. The responses varied wildly, with some manufacturers providing written installation guidelines, others saying clearly that if any "aftermarket" device causes a problem in the vehicle, the manufacturer will not cover that problem under warranty and others not answering our inquiries at all. It pays to ask.

It is safe to assume that those manufacturers that have published installation guidelines do not automatically assume that installing a transmitter will void your warranty. That doesn't mean that doing so will always be trouble-free, though. The ARRL has reprinted the installation guidelines of Chrysler, General Motors and Ford in its *ARRL RFI Book*, but ARRL still receives reports from hams

Fig 3-1—Here the remote head is mounted on the dashboard within easy reach of the driver. Note the 2-meter rig mounted below the car stereo. Dressing the cables so as not to snag or get in the way is another safety consideration.

who are told by one of these company's dealers that it is not permitted to install transmitters.

The ARRL web page has summarized the manufacturers' responses at: **www.arrl.org/tis/info/rficar.html**.

Q My manufacturer doesn't have an installation guideline. Can I just use the installation guidelines of one of the other companies?

A Manufacturers' policies vary wildly. Some manufacturers are very supportive of putting transmitters in their vehicles, others say that doing so won't necessarily void the warranty, but if the transmitter causes any damage, that damage won't be covered by warranty. Hams have been successful installing transmitters in cars by following general guidelines, but this is not something that will be supported by a manufacturer unless they specifically say it is.

Q What are the general guidelines for installing a radio in an automobile?

A They vary a bit from manufacturer to manufacturer. Although not all of these are absolutely technically necessary, they appear in most of the guidelines that ARRL has seen.

- Install the transmitter and its power and antenna wiring away from sensitive vehicle electronics. Some manufacturers have even told their customer where that sensitive electronics is located in the vehicle.
- Most manufacturers recommend against using mag-mount antennas. They suggest that using a chassis-mounted antenna is best.
- They advise that the antenna should be fed with coaxial cable and that the SWR should be low.
- They advise that you should run the power leads directly to the vehicle battery. The GM guidelines include a description of a battery kit to allow you to use the GM side-post battery.

This last point has been the subject of some disagreement within the automotive EMC community. GM, for example, tells their customers that they must run both the positive and negative radio power leads to the battery. *Both* leads must be properly fused, right at the battery. The reason for the positive fuse is pretty clear: If an overload develops in the radio or if a short circuit develops in the power lead, a fuse is required to protect the vehicle. The reason it *must* be fused at the battery is that if you fuse it inside the passenger compartment, and a short circuit develops where the wire passes through the firewall or inside the engine compartment, a fuse located in the passenger compartment won't protect the vehicle.

Let's examine the issue more closely by taking a look at two possible scenarios:

1. **Negative lead fused.** If the negative-lead fuse blows but the positive-lead fuse doesn't, current to the radio will return to the battery via any available path. This could include a path through the radio's frame, its mounting bracket and the auto body. Or the current could flow through the antenna coax shield to the antenna, where the shield is probably connected to the auto body. It's quite likely that there will be significant resistance in this current path, leading to a voltage drop and subsequent poor operation of the radio, especially at high transmit power levels. On the other hand, it's unlikely that anything will burn up.

2. **Negative lead unfused.** Suppose the cable that connects the battery to the rest of the vehicle electrical system gets disconnected, but the cable to your radio stays intact. Now the entire electrical system of the car will attempt to send its many amperes of current back to the battery through your radio's ground lead. The likely result? A destroyed ground lead, maybe a destroyed radio, and possibly a fire!

Although either course presents possible problems, fusing the negative lead is least likely to cause problems if something goes haywire. Not fusing it could result in real damage. Which do *you* prefer?

Incidentally, place the fuses as close to the battery terminals as possible. Placing them further back in the engine compartment compounds the chance that frayed wires between the fuses and the battery may short with possible "spectacular" effects. Likewise if you are passing through a metal plug in the firewall, even though you should have installed a rubber grommet, if the fuses are in a few inches from the rig (where manufacturers like to place them) there is the danger that vibration may cause chaffing and an eventual short.

The negative fuse lead is required right at the battery *if the negative lead is run to the battery per the automobile manufacturer's instructions* because the connection between the battery and the engine block could fail. In that case, the negative lead for the radio could end up inadvertently serving as the ground lead for the entire car. This becomes especially important when the motor's starter is engaged. In that case, as much as 200 amperes could try to flow through that small wire. This could easily start a fire. With a negative lead fuse, if that happens, the fuse will fail.

However, other manufacturers tell you to run *only* the positive lead to the battery and instruct you to pick up the ground for the radio by some other means. In this case, it is important that you do *not* fuse the negative lead at all. The disadvantage of fusing the negative lead is that if the negative fuse opens for any reason, the transmitter's dc return path is often through other means, such as the shield of the coax feeding a grounded antenna. This can create a new set of problems.

The bottom line, however, is that if you want the manufacturer to support your installation, you need to do it the way they say it needs to be done. Either way has advantages and disadvantages. In general, it is best to run the positive lead to the battery and connect the negative lead to a good ground, either in the passenger compartment or directly to the engine block, but always follow the automobile manufacturer's own guidelines. Even then, if you do have to take your car to a dealer for service, it may be a good idea to temporarily remove your transmitting equipment. ARRL has received reports even from manufacturers that have installation guidelines that dealers have been very confused about the warranty status of vehicles with installed transmitters.

Q If I do run into problems with my installed electronics, how do I contact the manufacturer for help?

A All vehicle manufacturers have an "EMC" lab that helps with the design of their cars. However, these engineers are not in the "customer-support" business, so they generally don't ask their engineering staff to talk directly to customers. The way the process is *supposed* to work with most manufacturers is that your dealer should be your first point of contact. If the dealer is unable to resolve your problem, he can contact his regional or zone office engineering staff. If the engineer can't help, he or she will contact the factory support staff. This may take a bit of time, but it is the only way that a handful of engineers at the factory can provide help to thousands of customers.

Unfortunately, this process doesn't always work. Even in cases where the manufacturer has published installation guidelines, that manufacturer's dealers have told their customers that no such guideline exists or that if they put a transmitter in the vehicle, they will void the vehicle warranty. GM, Ford and Chrysler all have published installation guidelines. With permission, ARRL has published those guidelines in *The ARRL RFI Book*. Be armed with that information when you first talk to your dealer, and if he does not follow the procedure of contacting his zone office, ask that he do so.

Q I just bought a new car and installed my HF amateur transceiver in it. I followed the manufacturer's installation guidelines and everything is working out okay, except that when I turn on the engine, the noise level on every ham band goes up. The problem is very bad on 80 meters, about S7, but it is still S3 on 10 meters. The noise does not vary with engine speed and sounds the same across all bands. What causes this?

A There are a lot of things that can generate noise in automobiles, but the symptoms you describe sound like they are being caused by a noisy electric motor. Other possible noise sources are ignition noise and computer noise (most cars nowadays have computers controlling most engine and vehicle functions). Ignition noise is an "impulse" noise, and at low engine speeds it would exhibit a "pop pop" sound. At higher speeds, this would change into a low-pitched whine. Alternators can exhibit a similar whine, but in both cases, the noise would vary significantly with motor speed. The computers used in modern cars can also generate noise, but much like home computers, the noise tends to consist of various birdies, bleeps and buzzes that definitely vary as the receiver is being tuned. The fact that the noise is constant across each amateur band and does not vary with engine speed points toward a small electric motor as the noise source.

Most motors in vehicles operate intermittently. If the noise occurred only when you ran your windshield wipers, for example, you would suspect the wiper motor instantly. In most modern vehicles, the fuel pump is electric and it runs continuously as the motor is running. In most cases, this type of continuous noise is caused by the fuel-pump motor. It *could* be caused by other motors in the car, but the fuel pump is the most likely suspect. There is one test that you can perform that is diagnostic: Leave the car sitting overnight. With the vehicle off, turn on the HF receiver and adjust for normal reception. Then, turn the ignition switch on, without starting the car. If the noise appears for a second or two, then disappears as the fuel system pressurizes, the fuel pump is the source of the noise.

The bad news is that the fuel pump is generally located *inside* the gas tank. This usually means that this is *not* a job for a backyard mechanic. Some automobile manufacturers know about this problem. They have issued service bulletins that cover adding a filter inside the tank to cure fuel-pump RFI. Ford, for example, has published a bulletin, appended to the end of this message.

In the Ford TSB, the filter is installed inside the gas tank, with series inductors and parallel capacitors for each lead. Ford does not offer that this technique will work on any other vehicles. Information about this TSB has been added to the end of this answer.

If you have a fuel-pump noise problem, the place to start is with your dealer or automotive service person. They can determine if there are any service bulletins that apply to your car. This is especially true if your car is out of warranty. In all cases, all work on vehicles should be done by people who are qualified to do the work and who are familiar with the vehicle.

The ideal place to install the filter is right at the pump, which is inside the fuel tank. It is electrically possible to install the filter on the leads where they enter the tank, but if the tank is not well shielded, electrical noise could still be radiated by the leads between the filter and the motor. On lower HF, however, this radiation will be minimal and it may be possible for your dealer to install filters to the wires external to the gas tank.

Hams have reported various degrees of success using various filtering techniques. In some cases, ferrite inductors have been added to both wires feeding the fuel pump. It is usually more effective to use a separate choke for each wire. In general, at upper HF, one of the split bead types can be used, with a couple of turns of wire on each bead. At lower HF, it will be necessary to use a ferrite toroidal core, perhaps an FT-140-43, with at least 10 turns of wire. In addition, it may be necessary to try a 0.01 μF capacitor across the two wires, perhaps on each side of the chokes. Some have reported good results using just the capacitors. There are also *mechanical* considerations, too. Splicing wires can result in mechanical failure, or corrosion, with the result being a motor that will not run (these things seem to happen at the *worst* possible times!). In addition, heavy chokes or capacitors can vibrate as the vehicle goes over bumps, ultimately causing the wire to fail.

One last possible solution may involve replacing the fuel pump motor with an aftermarket electric fuel pump. The aftermarket pump may be less noisy and it may be easier to add the appropriate filtering to the external wires. These aftermarket pumps are usually installed external to the gas tank. It will still be necessary to remove the in-tank fuel pump, but once this is done, the external pump can be easily maintained. Your auto parts supplier should be consulted to determine which ones can be used in your car. Unfortunately, ARRL doesn't have any information about which ones are electrically quiet.

ARRL also wants to stress that any cure should be applied only by qualified repair personnel; gas tanks are not places for the backyard mechanic.

The following is the text from Ford's TSB 98-7-3. The ARRL has received a report that TSB 99-12-9 covers up to the 1999 model years.

Ref: Ford Technical Service Bulletin: 98-7-3

"Fuel system—fuel pump: whining/buzzing noise comes thru 2-way radio speakers"

Vehicles covered:

Ford

1990-93 Tempo
1990-97 Probe, Thunderbird
1990-98 Escort, Taurus
1990-99 Crown Victoria, Mustang
1997-98 Contour

Lincoln-Mercury

1990-92 Mark VII
1990-93 Topaz
1990-96 Continental
1990-97 Cougar
1990-98 Sable, Town Car
1990-99 Grand Marquis
1991-98 Tracer
1997-98 Mystique
1997-98 Mark VIII

Light Truck

1990 Bronco II
1990-96 Bronco
1990-97 Aerostar, F Super Duty, F-250 HD, F-350
1990-98 Econoline
1990-99 F-150, F-250 LD, Ranger
1991-98 Explorer
1993-98 Villager
1997-98 Expedition, Mountaineer, Windstar
1998 Navigator

The Problem:

Electrical noise on radio speakers caused by in-tank electric fuel pump.

The Fix:

Installation of an RFI filter (Part No. F1PZ-18B925-A) on the fuel pump inside the fuel tank. *Note: some light trucks may require one RFI on each fuel pump on multi-tank vehicles.

Test Procedure:

Fuel pump radio noise is relatively constant and changes only slightly with vehicle speed. If the frequency of the noise varies, or the noise comes and goes with vehicle speed, then it is NOT the fuel pump, and this fix will not be effective. Use the following procedure to determine if the fuel pump is the cause of the radio noise.

1. Turn the radio on.

2. Turn the ignition key to the RUN position, but do NOT start the engine.

3. The fuel pump should run for about 1 second with the key in the RUN position with the engine not running. Listen for noise in the radio. If the noise is present while the pump is running, and stops when the pump stops, then the noise is being generated by the pump and this procedure should help.

Additional information from the Web site at **www.4x4central.com/tips.htm#rfi** points to Service Bulletin #9117-5 and the Ford "Filter Kit," Ford Part # E7PZ9B357A. There could be other service bulletins for other Ford models.

Q I want to install a 2-meter amplifier in my car. I'd rather not mount it in the trunk, though. Can I just stuff it under the passenger seat?

A Well you could, but I wouldn't recommend it. By "stuffing" it I presume you intend to let the amplifier sit on the floor beneath the seat. Bad idea. If you're ever unfortunate enough to be in an accident, that heavy amplifier is going to go flying around the interior of your car like an angry hornet. In addition, some automobile manufacturers place the passenger-side airbag control modules beneath the seats. Do you really want an amplifier bouncing around nearby?

If you must install the amp in the passenger compartment of your car, bolt it down securely. Consider using the trunk if you possibly can. An amplifier can generate a fair amount of heat. If it doesn't have air circulation around it, it may overheat, failing, perhaps catastrophically. While the heat from the heat sinks won't start a fire, components that fail could burn, which could ignite the seat or objects in the trunk.

And don't forget to use heavy-gauge wire to supply power to your amplifier. Some amplifiers draw a respectable amount of current from your car's electrical system. You want every ampere delivered to your amplifier, not wasted as heat in your wiring!

Q I have just leased a car. I don't think the leasing company is going to appreciate me punching holes. How can I put a radio in my leased car?

A A VHF radio of about 45 watts should cause no problems with any of the electronics. If you do not want to run power directly to the battery (preferred) you can always use a cigarette lighter adapter (RadioShack 270-021)—but only if the car is new and no one smokes. The deposits left by cigarettes make the lighter useless for power.

When looking for a location for the radio the same safety considerations mentioned earlier apply.

And as for the warrantee—a little creativity might be in order. If you have the radio on a mounting bracket, just remove it at time of service and if anyone asks about the bracket, well, you have a scanner. See **Fig 3-2**. This is not entirely untrue since I'm sure your rig has scanning.

Q I'd like to install a 40-W, 2-meter mobile transceiver in my car. Why can't I tap the +12 volts from the fuse block inside the vehicle instead of going directly to the car battery?

A Any transmitter that draws more current than about 5 A or so should probably not be installed this way, unless you can get some advice from your car dealer or mechanic. Even though you could indeed power a 40-W rig from the fuse block, there are still benefits to connecting to the car battery directly. By obtaining your power at the battery you reduce the possibility of causing voltage drops at various points in the car's electrical system—drops that might cause sensitive electronics to malfunction. In addition, the low internal resistance of the car battery can act like a filter capacitor and short any stray RF to ground instead of allowing it to propagate through the rest of the wiring.

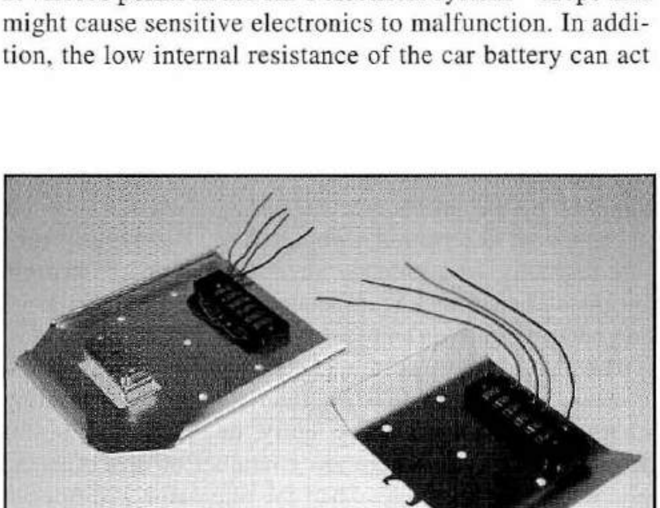


Fig 3-2—This "slide-in" adapter makes it convenient to install and remove a mobile transceiver.

But if you must use the fuse block, first, look to see if there is a spare fuse position. You may be able to tap into a spare position from the front of the block.

If your rig is low power—it uses a fuse of 5 A or less—you can try using a blade fuse tap. Radio Shack sells a package of four for a buck. You plug this little device into the input or hot side of an existing fuse on the fuse block. A wire connected to the tap provides +12, but you will have to find a good ground for the −12 volt wire.

Some people are a little nervous about using the blade fuse tap, claiming it "stretches" the fuse holder—which could be a problem later on. If you want an alternative approach, take a low amperage blade fuse and blow it—so it becomes an open circuit. Grind or file off some of the insulation on each end of the blown fuse. Next solder a blade fuse holder, such as Radio Shack 270-1213 across the blown fuse. Add a second wire on one side of the blown fuse.

Remove one of the existing fuses from the fuse block and replace it with the blown fuse, with the second wire on the *hot* side of the block. Put the fuse you just removed in the blade fuse holder, and you have now restored the original circuit. The wire hanging out now becomes your +12-V lead for the rig.

In considering this approach, however, do remember that you need to follow any installation guidelines that your vehicle manufacturer has provided. It could be *technically* acceptable to power a 5 A radio from the fuse block, but your dealer may not understand the technical subtleties and may not be willing to support an installation that is outside the published guidelines.

It's a good idea to disconnect the battery when you are working under the dash. Unfortunately, you probably will lose the memorized frequencies in your broadcast radio!

Q On second thought, maybe going directly to the battery is a better idea. Do you have any help for me on getting through the firewall?

A Good move.

Contrary to popular belief, there is *always* a way to get the power through the firewall. There will be a rubber boot over a hole ($3^1/_2$ to 4 inches in diameter) through which wires and plumbing are fed into the passenger compartment. On cars that are also sold in countries that *require* right hand drive, the export models may also include an unused, possibly metal, plug on the firewall on the passenger side for the steering column to pass through.

If you can't find a spot easily and are afraid to indiscriminately go poking around (the better part of valor), here are a couple of hints.

If you are going to be purchasing a radio or alarm for your car in the near future, while it is being installed ask the dealer if he could please snake the wires through for you.

If you don't have any such plans, you might just drop by one of the above or your local car dealer and ask them where is the best place to penetrate the firewall for *these* *here wires*. Bring the wires with you—at the first mention of ham radio their eyes glaze over.

Q I only have an HT at the moment. Can I operate mobile with any success?

A Absolutely! At the least you may have some success operating from the HT's battery and rubber duckie antenna—that is if you will be driving around within a few miles of your local repeater.

Better still, several HT manufacturers sell a cigarette adapter for their HTs giving a longer talk-time and conserving your battery for "pedestrian mobile" operation.

A 1/4 wave magnet mount antenna on the roof of the car will do wonders to increase the range of your HT. Just pass the coax through the seam of a door or crack open a window and you can have a respectable 5 watt mobile station. Keep in mind, that most mobile operators using regular 45 watt mobile rigs drop down to 5 watts for repeater work anyway!

Q I've been told that when you're using an HT in your car and powering it from the cigarette lighter socket, it's important to have your radio turned off when starting the engine. Supposedly the starter generates voltage spikes that can harm the radio. Is this true? If so, is it also true for a radio that is connected directly to the car battery?

A First, let's point out that the cigarette lighter is the last choice for obtaining power for a radio for the reasons mentioned before. However as a "quick and dirty" (pun intended) source for a temporary connection, since your HT requires so little current, it will work fine if you at least attempt to scrape off the cigarette residue from the center contact of the lighter.

Well then, yes, what you've heard is true. When you start your engine, the voltage *throughout* the electrical system jumps to about 13.8 V. Not only can you encounter some voltage "overshoot," but also substantial voltage spikes can appear. These are caused by the collapsing magnetic field in the starter motor. If your car has poor voltage regulation, these spikes and/or overshoots could damage your rig—no matter how it is connected to your car's electrical system. If you're not in the gambling mood, turn off your radio before you start your engine.

Q I recently had my 2m mobile professionally installed into my car. Even though I provided solder type PL-259 the technician soldered the center to the PL-259 but crimped the braid against the adapter and tightened the adapter to the connector. Would this type of installation cause a high or variable SWR?

A First let's clarify what gets soldered to what on a PL-259. According to Steve Katz, WB2WIK, Vice President of Engineering S&S Cable Co (Hints & Kinks, *QST*, Dec 1995). When speaking about installing a PL-259 to a cable that required an adapter/reducer, he says, "Cable and connector manufacturers surely do *not* recommend soldering the braid of the coax to the PL-295 "UHF" male connectors..."

"To *correctly* install ... do *not* tin the reducer or the braid, but fold the braid back over the reducer, screw the reducer into the PL-259 body, and *then* solder the braid to the body of the connector very rapidly through the four holes in the PL-259."

The reason for this procedure, Mr. Katz states, is because the heat of soldering the braid to the reducer can severely damage the cable and the dielectric.

The reason I bring this up is that you are not clear as to what was not soldered. Assuming that you meant that the braid was not soldered to the *body*, should you rework the connector?

Well... There are two reasons for soldering the connector: corrosion and vibration. Inside a car I don't think you have to worry about corrosion, but vibration after a very long period of time may cause a problem. It is a remote possibility so, what's done, is done. If you are presently experiencing high SWR, above 3.5:1 at the transmit frequency for which the antenna is tuned, I would repair the connector by soldering through the holes. That *may* be the problem, although it could be something else—but repair the connector first. You may be able to mechanically test the connector on receive if your receiver has an S meter. Tune a local repeater and wiggle the coax, right where it is connected to the PL-259. If the S meter reading changes, or if you hear any noise on the FM signal, you may have a loose connection. This could also show up on transmit as changes in SWR. The best advice is that if you are not experiencing any problems now, just leave it alone.

Q I have a problem with my dual-band (VHF/UHF) mobile FM transceiver. When I install it in my car I can not transmit. Apparently, from my checking, the problem looks like it points to the power from my car battery. The voltage of my car battery appears to be a bit low (most of times around 12 V as reported by the voltmeter built into the radio) and the manual of my transceiver recommends 13.8 V. I have no problem operating at home using a 13.8-V power supply. The questions are about how to solve the problem. I could be wrong about the source of the problem so correct me if you think so.

A You are correct in your suspicion that you are getting insufficient voltage to operate the radio. As you say, the recommended voltage stated in the manual must be supplied by the automobile's electrical system.

From your description, it sounds like a bad battery, voltage regulator or alternator, or a "partial short" (a term mechanics use for a low resistance that shouldn't be there) in your automotive electrical system.

Have your battery system checked out with your rig disconnected. If there is a problem—battery not holding charge or voltage regulator faulty, or insufficient power from the alternator (there are a number of diodes in the alternator and if one goes bad the alternator will not put enough power to fully charge the battery), then have that repaired/replaced first.

If everything to this point is OK, and the mechanic did not perform the time consuming (expensive) search for the "partial short," you can confirm this check for yourself. Disconnect the automobile cables from the fully charged battery and connect your rig to it and see if it operates. This will tell you if you have a low resistance path to ground somewhere in the wiring of the car.

If all the above are good, then make sure that you have a good *direct* connection from your rig to the battery (no substitutes such as fuse block or cigarette lighter).

Q Where should I mount the antenna on my sedan (or wagon, or van, or pickup)?

A The absolute best place to mount your antenna on any of the above is smack in the middle of the roof. All mobile antennas must work against a ground plane of some sort and this is supplied by the vehicle. It is advantageous, as with standard ground mounted verticals that have their radials fanned out equally in all directions, to have a symmetrical "ground plane" for your mobile antenna. VHF antennas are a considerable distance in wavelength from the ground itself and are affected greatly by location.

Also most significantly with VHF antennas, placement will greatly affect the radiation pattern. Just check with anyone who has the antenna either on his windshield or her trunk lid and commutes in a straight line to and from the repeater, and they'll tell you that the repeater works better one way than it does the other. Also HF mobilers with the antenna at the rear and to one side will tell you that as they turn 90 degrees, both the signal reports are greatly affected.

Of course, starting from the center of the roof, and living in a real world, we begin to compromise and mount it wherever the design of the car and the objections of our spouses dictate.

Q I just got a brand new car. I want to mount an HF antenna but the bumper is useless for mounting an antenna, and I don't want to drill any holes in the car. What can I do?

A One option may be to have a trailer hitch installed and mount the antenna to that. The hitch can be mounted off to the side so as not to interfere with loading trunks, tailgates and hatches at the rear of the car. Others have used large magnetic mounts with some success, although with larger HF antennas, they can come loose at highway speeds, or move around and scratch the finish a bit.

You may want to give some thought to actually drilling the hole. If you buy a new car every few years, you may not want to drill a hole because it may make the car a bit harder to sell. If you plan to keep the car until it rusts out from under you, you may as well drill the hole right now. A few years from now, you won't mind the antenna hole and you will have had the benefit of having the right antenna for all that time.

Q We know that when operating vertical, quarter wave or less, the other half of the dipole is the ground. How does a mobile antenna work since we know that the mobile is mounted on rubber tires and effectively isolated from ground?

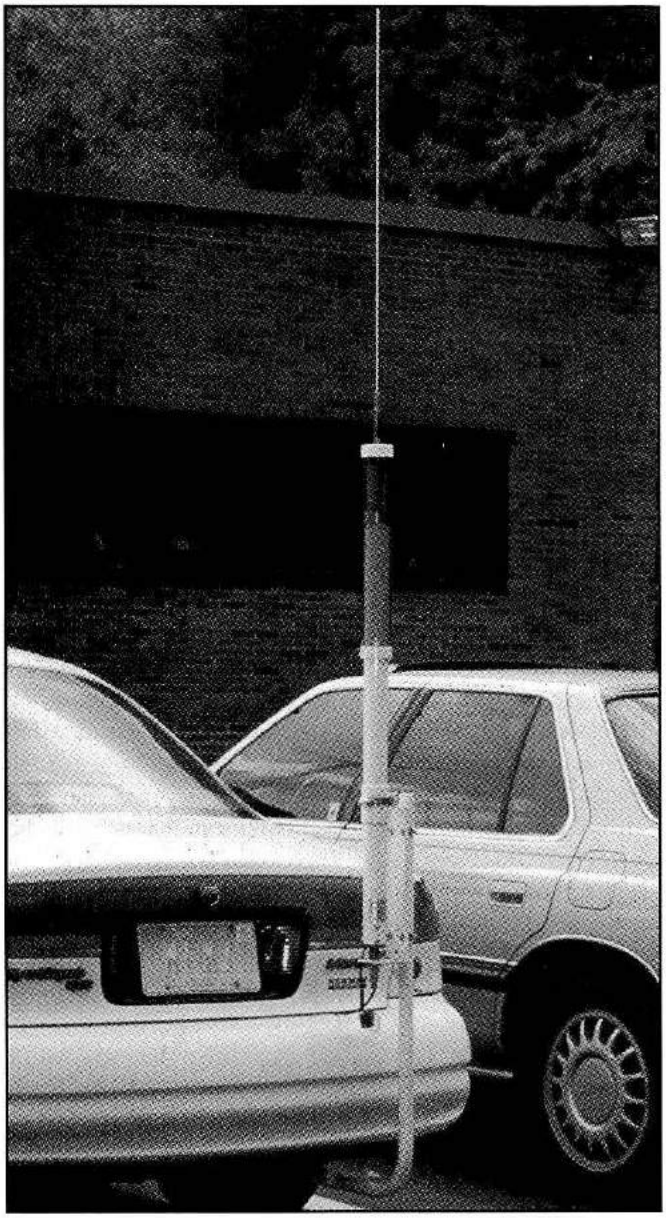


Fig 3-3—A pipe, bar or tow hitch fastened to the undercarriage can make an excellent mount for a large HF antenna.

A The quarter-wave vertical gets its "ground" in two ways. First, the vehicle itself forms a ground plane. To one degree or another, the car body is an actual radiating part of the antenna system. It is also a big capacitor to ground, with the vehicle forming one plate and the actual earth ground under the vehicle forming another. On VHF, the ground-plane effect predominates. On VHF, the car body forms a low-loss ground connection for end-fed quarter-wave antennas. On lower HF, the capacitor effect predominates, with some losses. On HF, you can assume that there is about a 10 to 20-ohm resistor in series with that "ground" connection.

Q How does a mobile magnetic-mount antenna connect to the ground plane of a car?

A Some hams believe that the ground connection takes place through the magnetic fields themselves, but this is a myth. Unless you provide a connection at the mount, ground is accomplished two ways. On some bands, the capacitance of the magnetic mount to the vehicle body connects the antenna to the body of the car. This is insufficient capacitance on the lower part of HF though. In that case, the only route to ground is the long way through the coax shield, to the radio, then to the ground terminal of the car battery and finally to the frame. If the radio itself is grounded to the frame, that will shorten the trip a bit. This can cause some "RF in the shack" problems is the shield of the coax becomes an active radiating part of the antenna system.

If you are attempting HF mobile operation, I suggest that you connect the base of your mag mount to the nearest point that has electrical continuity to the ground terminal of the battery. (Use a short length of copper braid.) As inconvenient as it seems, such a ground connection may improve the performance of your mobile station significantly. Without a ground at the base, you could incur substantial RF losses due to circulating currents. You may also notice that your antenna is difficult, if not impossible, to tune for the lowest SWR. In extreme cases, stray RF can even cause RF burns to the operator, an unsafe condition that needs to be corrected.

The good news is that mag mounts for VHF and UHF aren't nearly as touchy. The small amount of capacitance that exists between the magnet and the metal underneath is adequate to provide the necessary path to "ground" at these frequencies.

Q Two weeks ago I installed my Kenwood TS-50S in my 96 Buick Century. The chassis is grounded to the firewall and the dc power cord is run directly to the battery using number 8 cable with the appropriate fuses at both ends.

For an antenna I chose the 40 and 17 meter Hamsticks using the Lakeview license plate mount. The antenna is grounded with more number 8 cable to the bumper, spare tire wheel well and frame using ring terminals (crimped and soldered), star washers and $^1/_4$ inch bolts. All paint was scraped away to ensure good connections, and sealed with Ox-Guard. In the driveway my SWR is flat on 17 meters and on 40 using the Inducti-match it is 1.6 to 1 from 7180 to 7220. Everything works great with wonderful signal reports in Europe, South America and across the states.

All is super until operation is attempted at speeds over 40 mph up to 70 mph. The SWR jumps up to 2.2 to 1 and the power folds back to half on the TS-50S. When I slow down everything returns to normal. I borrowed a friend's big mag mount yesterday, stuck it on the trunk, and the same problem occurs on 40 but not on 17 meters. Operation on 17 appears normal with the mag mount.

Why does the SWR keep shifting on me on 40 meters and on 17 with the license plate mount? I called the Lakeview factory and they have no other reports of this happening. Two other friends here in Rochester are experiencing the same problem with the Hamsticks. Lots of discussions on the air and "expert" opinions but no concrete fix. I tied the Hamsticks back with fishing line to keep them vertical but the problem doesn't go away on the highway. I tried to simulate the problem in the driveway by pulling on the Hamstick in all directions but can't duplicate the problem.

A Well, since the problem follows the antenna to the mag mount this leads me to believe the problem is with the antenna not the license plate mount. There may be a bad connection inside the antenna which gets flaky when the wind bends the antenna.

Try mounting the 40 meter antenna back on the license plate, tie a string to the top of the antenna and have a friend tug on the string while you transmit and see if the SWR changes.

Q I have an ICOM IC-706Mk2 HF/VHF radio and I have installed it in my 1999 Chevrolet Suburban with a SGC SG-230 between the transceiver and an 8' whip antenna. The only thing that the manual doesn't address is what kind of line do I run from the tuner to the antenna? Should I use coaxial cable or just a piece of wire to the center screw at the bottom of the mount? I've read all of the review articles and the FAQs and none seem to make reference to this issue.

A This type of antenna tuner is designed to accommodate a long wire antenna so no shield connection is provided. In a mobile installation, you do not want to radiate RF inside the passenger compartment. Doing so would be inefficient because most of the energy radiated inside the car would not be heard by the distant station. It is also probably unsafe. To use that tuner mobile, you should use coax, attaching center conductor to the tuner random-wire output and the shield of the coax to the tuner chassis. Outside the vehicle, ground the shield of the coax to the chassis of the car, at the antenna mount.

Q I drive a 95 Chevy Lumina APV. It has basically the plastic body on it. It also has darkened windows. I have no luggage rack on it. Is there ANY way short of drilling a hole in the top (the wife would kill THAT idea!) to mount a mobile antenna on it? Does anyone make a work around? I am only looking at running 2 meter FM.

A Vehicles with exteriors made of plastic or other composites offer poor ground planes for mobile antennas. Without a decent ground plane, your antenna system may exhibit a high SWR and a grossly distorted radiation pattern.

Here are a few suggestions:

You could install an antenna on the roof and create your own ground plane by gluing a 19-inch square piece of aluminum sheet metal to the underside of the roof. (You will need to remove ceiling upholstery to do this, however.) Attach the ground portion of the antenna to the foil. This makes a fine ground plane for a vertical $^1/_4$-wavelength antenna. You can accomplish the same thing by running three or four quarter-wave radials in place of the aluminum.

You could also install the antenna near a corner of the roof and thread a 19-inch piece of wire down the inside of one of the roof supports.

If you can locate one of the metal ribs inside the roof, you might be able to use it as the ground connection for a roof-mounted antenna. Once again, you might want to attach pieces of foil or sheet metal to the rib to enhance the ground plane.

Check out 1/2-wavelength antenna designs. Many of these do not require ground planes for good performance.

An "on-glass" antenna is a worthwhile alternative to body-mounted antennas. If the design requires a ground connection, you can usually find it nearby on the window frame (see details elsewhere in this chapter).

Roof racks may be available for your car. Rather large antennas have been attached to roof racks.

There are mounts designed to mount on the trunk or hatch lid (sources listed below). See **Fig 3-4**. You can then run a ground wire to any nearby screw or bolt that contacts the metal frame. You might also check the important information we have in the antenna chapter of this book on on-glass antennas and tinted windows.

Comet Antenna
1275 North Grove Street
Anaheim, CA 92806
USA
Phone: 714-630-4541
800-962-2611
Fax: 714-630-7024
Web Site: **www.cometantenna.com/**

Diamond Antenna
c/o RF Parts Co
435 South Pacific St
San Marcos, CA 92069
USA
Phone: 760-744-0700
800-737-2787 (orders only)
Fax: 760-744-1943
Email: rfp@rfparts.com
Web Site: **www.rfparts.com/**

Q I'm trying to decide between a 1/4-wave and a 5/8-wave antenna for my 2-meter mobile radio. What's the difference?

A If your operating habits confine you to an area of strong repeater coverage, you probably won't notice any difference in the performance of these antennas. The shorter and typically less expensive 1/4-wavelength is as good a choice as any. If, however, you operate in a fringe coverage area, a 5/8-wavelength model may provide some badly needed gain. The 3/4-wavelength antenna is also a good choice, although it tends to waste signal energy at high angles.

The main difference is the length of the antennas and the effect this has on their performance. A 1/4-wave antenna is about 19 inches long at 146 MHz, while a 5/8 wave is approximately 4 feet long at the same frequency.

All antennas radiate energy in specific *patterns*—just like patterns of light cast by lamps. The type of pattern created by a mobile antenna depends on a host of variables such as the size of your car, the location of the antenna, how well the antenna system is grounded to the chassis and so on. Under ideal circumstances, a 1/4-wave antenna will radiate energy in a pattern similar to the one shown in **Fig 3-5A**.

The radiation pattern of a 5/8-wave antenna is quite different. As you can see in Fig 3-5B, its idealized radiation pattern has bulges where the energy is concentrated in particular directions. Whenever you concentrate energy, you get increased *gain*—just as the reflector in a flashlight concentrates light, making it very bright in one direction. So, generally speaking, a 5/8-wave antenna has somewhat greater gain than a 1/4-wave antenna.

My recommendation is that you take an informal survey among the hams in your area. Ask what type of mobile antennas they use (1/4 or 5/8 wave), and what they think of their performance. See **Fig 3-6**.

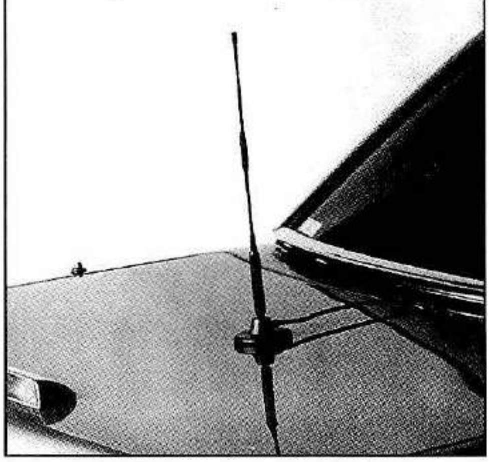


Fig 3-4—A trunk-mount antenna can be both convenient and effective.

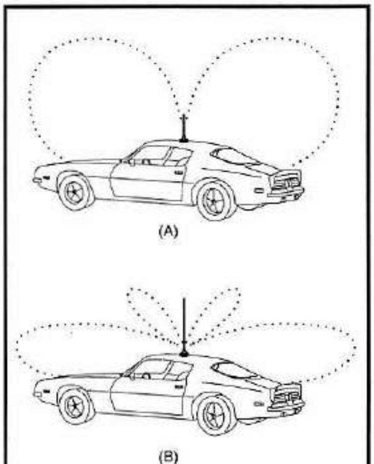


Fig 3-5—A comparison of the patterns of different types of mobile antennas. The 1/4-wavelength antenna and its 3/4-wavelength big brother provide a close match for coax. A 5/8-wavelength antenna, however, requires a matching network that's typically located in its base.

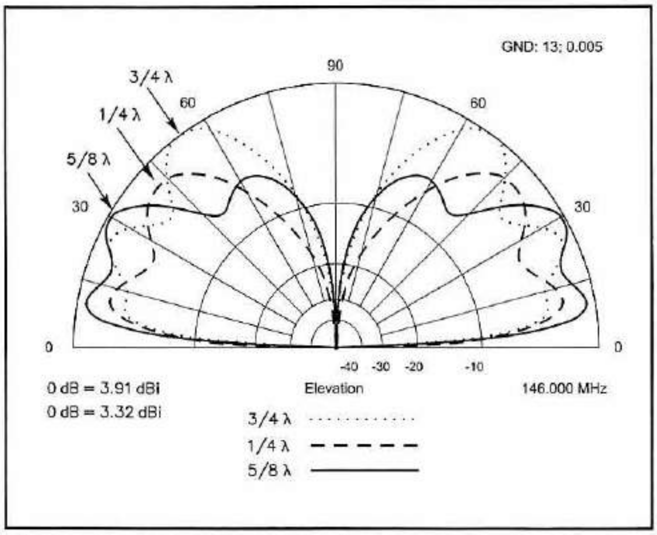


Fig 3-6—Typical antenna radiation patterns for 3/4, 5/8, and 1/4-wavelength mobile antennas. Notice that the patterns for the 3/4 and 5/8-wavelength models bulge outward, indicating somewhat improved gain toward the horizon.

Q My new car has a plastic roof, so a roof-mounted wavelength vertical for 2 meters is out of the question. I'm considering an on-glass mobile antenna. How well do they work?

A Some hams report excellent results. Others are less than enthusiastic. For most applications an on-glass antenna will perform adequately. This is particularly true if you do most of your VHF/UHF mobile operating well within the coverage of a sensitive repeater system. If you think you'll be operating in fringe areas, however, the "compromise" aspects of an on-glass antenna versus a more traditional mobile antenna may be something to consider.

An on-glass antenna system functions by passing RF to and from the interior of the vehicle through the window glass. The "secret" of the system is found in the two adhesive plates that you attach to the window, one inside and one outside. With the glass between them they create a capacitor that passes RF.

Just remember to read the manufacturer's instructions and follow them to the letter. For example, most on-glass antennas require a ground connection inside the car. Any nearby screw may do the job, but make sure it's *really* connected to the body of the car. Take a volt-ohm meter (VOM) and measure the resistance between the negative terminal of your car battery and the screw (you'll need a couple of insulated extension wires for your VOM). The reading should be very low, less than 20 ohms. If it's higher, the screw isn't grounded!

The most important thing to know about glass-mount antennas is that you must follow the installation procedures to the letter. Read and re-read. Check and double check. You get only one chance to attach the adhesive mounting hardware on each side of the glass. Once they touch the surface, you are committed to their placement. I cannot stress this point enough. The two halves must match per the instructions and once attached, they can't be moved without destroying them. Replacement kits are available if, later on, you decide to move the antenna to another vehicle.

Mount the antenna as high as possible on the glass, so that the radiating element is as far above the heads of your passengers as possible. This may not be all that important if you are running just a few watts, but at high power it becomes a safety issue. A couple of hints: If you plan to mount the antenna at the extreme edge of the windshield, beware that the edge on the inside may not line up with the edge outside. There can be up to 1" difference. The two halves of the antenna mount must align precisely.

Every installation is different, but I'd suggest that you avoid installing the antenna over embedded heating elements. If you are installing the antenna at the top center of the front windshield, make absolutely sure, before installing the antenna base, that it will be clear of your windshield wipers—you may have to go to a smaller size wiper. In addition, there is the issue of passivated glass. Passivation is a process by which tin, copper, magnesium, iron, titanium or gold is applied to the finished glass, or during the manufacture of the glass. Some amateurs report difficulty installing and tuning on-glass antennas that are attached to passivated glass, but others say it isn't a problem.

Also, beware of special tints used in some rear-window defrosting systems. An on-glass antenna works by transferring radio frequency (RF) energy through the glass. Some of these tints are metallic and will block RF. If your rear-window defroster uses wires embedded in glass, *don't* mount your antenna over these wires.

Here is what two major manufacturers of on-glass antennas had to say:

Antenna Specialists

"OEM window tints vary widely, and most have been found to be acceptable based upon final installations. Ford Instaclear(r) is a product that is known to degrade performance. Any after-market tint should absolutely be trimmed away before the "On-Glass" installation. We do not have a listing by vehicle model as to which antennas are compatible.

"The black mask paint used around the perimeter of the rear window glass on domestic vehicles has not been shown to be detrimental to the glass mount installation. The only difficulty in this preferred installation is the inside to outside alignment of the coupling box to base foot. Just be sure to clear the defogger wires as mentioned.

Larsen

"The performance of glass mount antennas can be affected by metal in the glass. The metal will come from two sources. Sometimes the materials used to tint glass contain metal; this seems to be especially true of after market tinting products. Passivated glass also contains metal particles. The metallic content of either tinting or passivation will interfere with the transfer of RF energy through the glass. Limited testing of the cars in our parking lot shows that most factory tinted windows do not seem to have metallic content in what ever is used to tint the windows.

"Small metal particles are placed in passivated glass to reduce UV radiation.

"Passivated glass could be clear in the visual range but is usually tinted. Passivated glass can be detected easily by two methods. A capacitance measurement can be made or the label on the glass may tell you if the glass is passivated. The list of the labels to look for is below:

Solar-Coat	***Solar-Cool***
Cool-Off	Solar-Ray
EZE-Cool	Soft-Ray
EZI-Eyes	Solar-Soft

"These are the labels that Radiall/Larsen Antenna Technologies knows about at this time. There may be other labels which indicate passivation that we are not aware of.

"As indicated above I have done some testing of vehicles in our parking lot. For the vehicles I have tested the black or darkly tinted area at the top of the window would work just fine for an on-glass antenna. I have not made a visit to a car dealer with my test equipment to determine if the same is true on the brand new cars.

"Please note that Radiall/Larsen uses a patented coupling technique on our on-glass antennas. The coupling technique is very efficient but unfortunately is sensitive to glass thickness in the VHF and low UHF frequency range. Our antennas are designed to be used on the back and side windows of a vehicle, not on the front window.

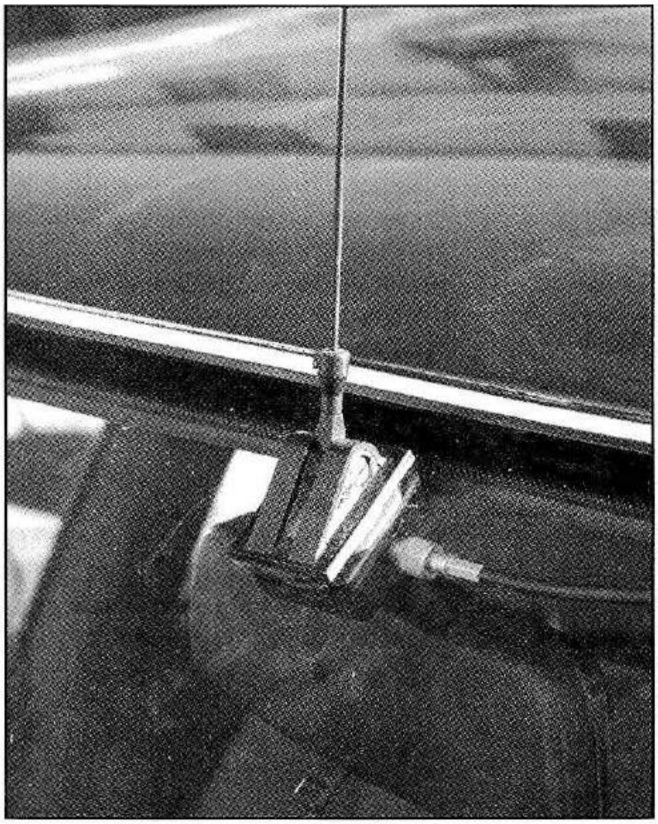


Fig 3-7—An Antenna Specialists on-glass antenna mounted at the top center of the front windshield.

Q I don't want to risk scratching the finish of my car with a magnetic mount, so an on-glass antenna seems like a decent compromise. What's your opinion?

A For most applications an on-glass antenna will perform adequately. But don't give up on the mag-mount just yet. If you use ample car wax, or better still encase the magnetic base in a plastic bag or place it on a small square of plastic such as a piece of heavy duty sandwich bag, magnetic-mount antenna doesn't have to present a danger to your car's finish.

Q I'm trying to use a 102-inch stainless-steel whip as my 2-meter mobile antenna. I can't seem to get the SWR down, though. What's wrong?

A The problem is the length. A 102-inch whip isn't resonant within the 2-meter band. That would account for the high SWR you're seeing.

When you're trying to calculate the length of your mobile whip, use the formula 234/frequency (in MHz). The result will be a quarter wavelength for the frequency in question. Using this formula, a quarter-wave whip at 146 MHz would be about 19 inches.

(234/146 = 1.6 feet, or about 19 inches.)

Q I own a vertical HF mobile antenna that I use on a 33-foot trailer. The body of the trailer is mostly fiberglass, so I've installed four 30-foot copper-braid radials on the roof. The radials are also connected to the aluminum ladder that is attached to the trailer frame.

When I mount the antenna high on the ladder, the lowest obtainable SWR readings are 1.5:1, 1.9:1 and 3:1 on 80, 40 and 20 meters respectively. If I attach the antenna to the bumper (much lower, of course), the SWR on 20 meters drops dramatically to 1.6:1. The SWRs for the other bands remain essentially unchanged.

Why is the 20-meter SWR so much better when the antenna is mounted on the bumper? How can I achieve the same SWR with the antenna installed high on the ladder? (This is what I would prefer.)

A You have come across an interesting phenomenon that is not very well appreciated by the amateur fraternity. Your four radials start at the ladder on one end and go the length of your fiberglass trailer's roof to form an *elevated counterpoise* for your multiband mobile whip. Because of the length of your trailer, each radial just happens to be close to quarter-wavelength resonance on 40 meters. That's good and bad.

Think of each radial as being a sort of a two-wire, quarter-wavelength transmission line, with the earth forming the second "wire" of the line. On 40 meters, each transmission line transforms the open circuit at its outer end into a low impedance at the base of the vertical radiator mounted on the ladder. The transformed impedances from each of the four radials combine in parallel to create an even lower impedance. This acts as an effective ground counterpoise for your mobile whip. No doubt you have a good signal on 40 meters, although the asymmetry of the radial layout will probably favor certain azimuth directions. No big deal; you still get out well on 40.

Now, let's look at the situation on 20 meters. On this band the four radials are close to half-wave resonance. Each ersatz transmission line transforms the high impedance at its outer end to a high impedance at the base of the vertical radiator. The counterpoise is not acting like a counterpoise anymore!

When you move the vertical whip down to the bumper, several things come into play. It is now closer to the earth, effectively raising ground losses. More importantly, the bumper and lower body frame of the trailer no longer form a half-wave counterpoise on 20 meters. This is true on 80 meters too—whether located on the roof or the bumper, the counterpoise is not half-wave resonant. The system probably is reasonably effective down on the bumper, but I agree with you that it is better to get the vertical whip up in the air on the roof of the trailer. That way you keep RF away from humans, and you also launch your signals better, without the influence of the trailer body getting into the act.

This story reminds me of a discussion I had with N6BV, another staffer here at HQ. He had put up a full-sized 80-meter ground plane, with four quarter-wave radials elevated 10 feet off the ground. After he put up another 80-meter antenna, he no longer needed the ground plane, so he shortened the vertical portion of the radiator for 40-meter operation. However, he left the counterpoise radials alone, following the amateur dictum: "If a little is good, more must be even better..."

Although he shouldn't have been, he was very surprised to find that the SWR was sky-high on 40 meters—the 65-foot long radials were now half-wave resonant on 40. When he shortened each of the four elevated radials to 33 feet long, the 40-meter ground plane performed exactly like it was supposed to do.

So put the vertical whip back up on the ladder, and lay out several 16-foot radials on the roof of the trailer, connecting them in parallel with the existing radials at the ladder. The new radials needn't be made of bare copper braid; insulated #14 house wire or even #18 will do fine. You should find that the SWR on 20 meters will now be normal.

Q A while back I installed a spring mount on the back cowling of my car. After using it for several years on 40-meter SSB, I now want to get on 2-meter FM. Can I use the same mount for a 2-meter antenna?

A Sure! For a quick and easy antenna, you might be able to use a piece of steel or brass rod, threaded to match the mount's thread. Cut the rod to about 19 inches—you may want to check the SWR later and cut it back a bit more. This isn't an ideal mobile antenna for 2 meters, but it should be adequate for most applications. And it's certainly less expensive than buying a new antenna and mount.

Q It seems as though HF mobile antennas come in one of two varieties: slender, low wind-profile models or huge contraptions with big coils and cylinders. Which type is best?

A Every HF mobile antenna represents a compromise of one kind or another. The large antennas are more efficient radiators, but they detract from the aesthetics of the vehicle (depending on your point of view!). They also require heavy-duty mounting hardware. The slender, stick-like antennas are less visually imposing and can be attached with simpler mounts. Even so, they are less efficient radiators than their big brothers, particularly on the lower bands.

If you like your HF mobile operating on 80 or 40 meters, and you demand the best performance possible, you may want to consider the "ugly" antennas. But if appearances are important, and if you operate primarily on 20 meters and up, the low-profile models may be a better choice.

Q What are those little balls on the ends of mobile antennas for? Mine was knocked off recently. Will its loss affect the antenna's signal pattern?

A I doubt it. Many believe the ball is just there as a safety device, kind of like the little ball on the end of a sword used for fencing (the sport). In addition, the ball helps reduce corona discharge at higher power levels. For typical VHF mobile operation, I don't think you'll notice any difference in performance. As a safety precaution, you may want to wrap a bit of tape around the end and cover it with a short length of heat shrink tubing. Like my mother says, "You'll put somebody's eye out!"

Q What is picket-fencing? What causes it?

A Picket-fencing is the term used to describe the audio output of a mobile FM radio as the signal periodically drops in and out of the receiving threshold of receiver (like watching a picket fence go by in a highway). It is typically caused by *multipath* causing signal cancellation.

Multipath is an effect caused by the fact that radio waves can be reflected by conductors that are large in terms of wavelength. At HF, this is usually not noticed because other than large trucks, most of the conductors near a car are not big enough to reflect signals. On VHF, however, nearly everything around you is a potential reflector of radio signals. If you are listening to a nearby repeater, you are receiving both the signal from the repeater and the signal that is bouncing off of the cars around you, the metal guard rails around you, nearby buildings, etc. These multiple signals can be in phase at one point, and out of phase at another point about a half-wavelength away. They will add up where they are in phase, and cancel where they are out of phase. So when you are driving down the road, you are driving through in-phase and out-of-phase locations rapidly. The additions and cancellations can be very regular in nature, so the result can be flutter. Someone once named this "picket fencing" and the name just stuck. Because FM receivers use limiting to remove amplitude variations, this effect is usually only noticed on weak signals.

Q I'm considering 6-meter SSB mobile operating. Would it be a waste of my time and money? Do I have to put one of those ugly horizontally polarized antennas on my car?

A No and no. *QST* VHF columnist Emil Pocock, W3EP, explains: Six-meter mobile operating can be quite a lot of fun. For example, you may encounter sporadic-E band openings in the spring and summer months, or at other times unexpectedly. You can make local contacts as well.

For E-skip (or any ionospheric mode) polarization does not matter. What goes up vertical comes down hyperbolic (every which way); the same is true for horizontal. So, a quarter-wavelength whip antenna will work well and isn't too unsightly.

If you can get your hands on a multimode transceiver, check out 6-meter FM and AM as well. A few hams are even trying 6-meter packet. Have fun!

Q I just installed an HF transceiver in my car and it seems to be working well. Whenever I key the radio, however, I can hear the sound of the engine changing just a little. In addition, the tachometer indicates a slightly reduced RPM. Is this normal?

A You don't mention how much power you're running, but if you are using a typical 100-W transceiver, you're probably drawing a substantial amount of current in the transmit mode. If you're operating SSB, for example, the radio could be pulling as much as 25 A on voice peaks. This is a big load on your car's battery, and the alternator responds by attempting to compensate and maintain the battery's charge. The harder the alternator works, the greater mechanical load it places on your engine. Your engine works a little harder and, unless you give it more gas by pressing on the accelerator, it will respond by running a bit slower. You hear the effect and see it on your tachometer. Don't worry. If your alternator and battery are in good shape, no harm is done.

If the engine speed varies a lot, or the "check engine" light comes on, your radio may be getting into the vehicle electronics, perhaps confusing the engine-control module (ECM) into thinking your RF signal is a signal from one of the vehicle's sensors. In this case, carefully check your installation for problems or deviations from the published guidelines or recommended practices and contact your dealer for help.

Q For camping and backpacking, should I bring an VHF/UHF HT or an HF QRP rig for emergencies?

A The answer to this question is largely influenced by the location and surrounding terrain of your site. Keep in mind that VHF/UHF communication is, for the most part, a line-of-sight means of communication. That is to say, the HT must be able to "see", the receiving antenna (trees and underbrush excepted of course).

One of the factors that govern an HT's effective communication range are the type of antenna you are using. Quarter-wavelength telescoping antennas, for example, are more efficient and vastly superior to the "rubber duck" antennas supplied with most HTs. Height is another important factor. Some hams have taken HTs to mountaintops and have communicated over 200 or 300 miles. The same HTs in the valleys below, however, could hardly get into the local repeaters.

For communication between members of the party on a mountainside or in a forest, an HT will work well as long as the members are not separated by an intervening hill or they do not meander to the other side of a mountain. Contact with "civilization" in an emergency could be impossible if there is not a repeater available on a nearby highpoint that is within line-of-sight of your HT.

A QRP rig, especially on 80 or 40-meters, is a good emergency rig to have along. These bands will afford you local to mid-distance communication virtually 24-hours a day. The ground wave will somewhat follow the contour of the land and the skywave will get you out of a deep valley.

So for a jaunt through a local state park, the HT; for a trip to virgin forests or the mountains, the 80-and/or 40-meter QRP rig.

Update: Yaesu has announced the FT-817. This is a small, self-contained, internal battery-powered, Multimode Portable Transceiver covering the HF, VHF and UHF bands. This may be something to consider for the avid camper, backpacker or mountain climber.

Q I often take my 2-meter/70-cm HT with me on hiking trips, but I find that it's difficult to access repeaters when I am in fringe coverage areas. I've considered purchasing a 6-meter HT in the hope that I might enjoy greater range, but I've been told that the effective range would be limited because such an HT uses FM instead of SSB. Is this true?

A Many of the conditions discussed in the previous question apply here. Additionally, when it comes to local/regional FM coverage, 6 and 2 meters are very similar. The reason that SSB outperforms FM on either band is because an FM receiver requires a much stronger signal to produce copyable audio. An SSB receiver, however, can produce copyable audio with much less signal energy. Therefore, you can achieve a greater effective range with SSB compared to FM.

Q I just dropped my HT into a pond! I managed to fish it out, but it's soaked. Is it ruined?

A Not necessarily. Disconnect the battery pack and then start disassembling the radio. As soon as you've exposed the circuit boards, rinse them with fresh water. Use a hair dryer on a low-heat setting to dry the boards thoroughly. Do the same to the battery pack. The key is to dry everything as quickly as possible before corrosion can gain a foothold. Be careful not to overdo the heat, though.

Don't attempt to reassemble and test the radio until you're certain that every nook and cranny is dry. Use alcohol to gently clean away mud or debris. When you're ready for the test, connect your radio to a variable dc power supply that has a current meter. Set the power supply voltage to zero and turn on the radio. Now *slowly* raise the voltage as you watch the current meter. In the receive mode, most HTs draw between 100 and 300 milliamps. If the current flow surges above this level before you reach the proper operating voltage, something is wrong. Turn off the power supply and consider sending your radio to a service center.

Q How does a repeater work?

A A repeater is a device which retransmits received signals in order to provide improved communications range and coverage. This communications enhancement is possible because the repeater can be located at an elevated site which has coverage that is superior to that obtained by most stations. A major improvement is usually found when a repeater is used between VHF mobile stations, which normally are severely limited by their low antenna heights and resulting short communications range. This is especially true where rough terrain exists.

The simplest repeater consists of a receiver with its audio output directly connected to the audio input of an associated transmitter tuned to a second frequency. In this way, everything received on the first frequency (input) is retransmitted on the second frequency (output). But, certain additional features are required to produce a workable repeater. These are shown in **Fig 3-8**.

The duplexer, a collection of very narrow filters, allows a single antenna to be used for simultaneous reception and transmission on the two different frequencies. **Fig 3-9** shows the communications path between two stations using a repeater.

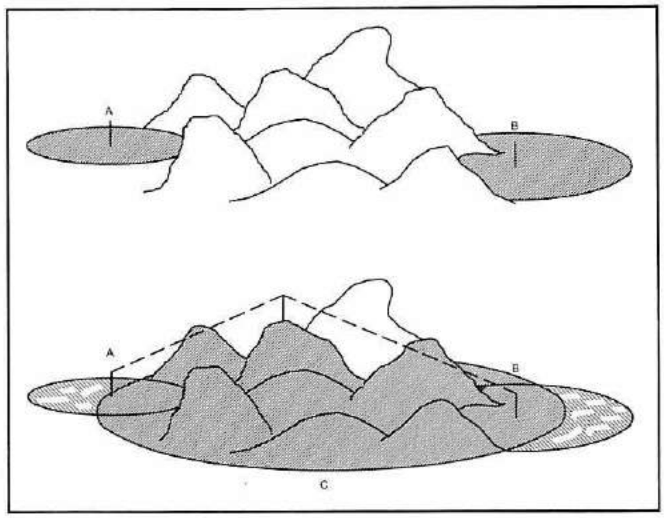


Fig 3-9—In the upper diagram, stations A and B cannot communicate because their mutual coverage is limited by the mountains between them. In the lower diagram, stations A and B can communicate because the coverage of each station falls within coverage of repeater C, which is on a mountaintop.

Q Why do most 2-meter FM repeaters use a 600-kHz split between their input and output frequencies?

A Early amateur FM activity used converted land-mobile gear. On 2 meters, high-band (152 to 174-MHz) gear was converted down in frequency. Early activity centered on 146.94-MHz simplex, this being about the highest frequency that Technicians could use with 15-kHz FM deviation and still be sure they stayed within their band (which ended at 147 MHz at the time). When repeaters came along, people wanted to be able to transmit on both 146.94 MHz (in areas where there were no repeaters on that frequency) and on the repeater input frequency without having to retune their transmitters. On the other hand, the repeater input and output frequencies had to be as far apart as possible, for obvious reasons. By trial and error it was determined that 600 kHz was about as far as the equipment of the time could be stretched without retuning. So, 146.34 MHz became the standard repeater input frequency (for 146.94-MHz output). That set the 600-kHz standard for the repeaters that followed.

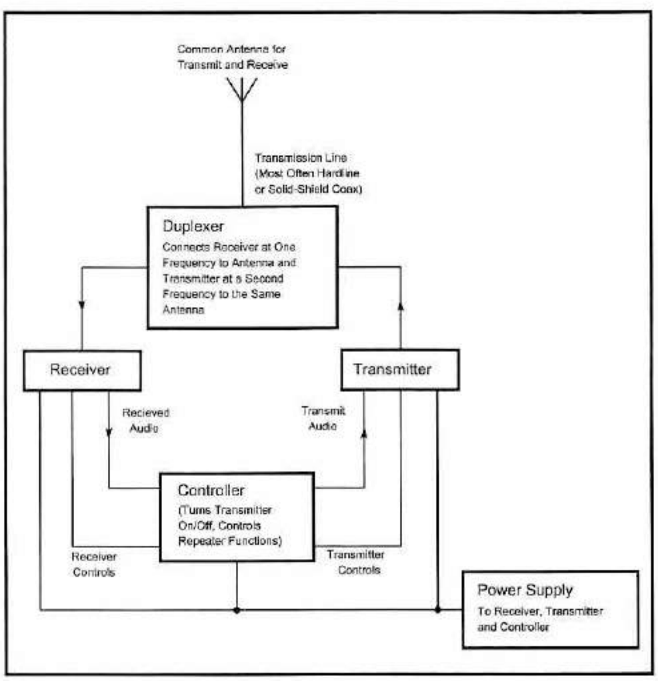


Fig 3-8—A repeater system is a fairly complex collection of equipment.

Q Why do repeaters operate with offset frequencies instead of just using simplex?

A To answer your question, we need to talk briefly about how repeaters work. The instant you key your microphone, the repeater relays the content of your signal on its output frequency *while still listening to your transmitted signal*. With its tall antennas and considerable output power, the repeater spreads your signal over a large area—much larger than your transceiver could cover by itself. When you release the mike button, you immediately hear the replies coming back to you through the same repeater. (It's listening to the other stations while it is transmitting to you.) The act of transmitting and receiving at the same time is known as *duplex* communication.

Engineering necessity requires that efficient duplex radio communication take place on separate frequencies. Otherwise, the transmit energy would overwhelm the receiver, making it deaf to all incoming signals (then there's the problem of horrendous feedback, damage to sensitive components and so on). But if you use separate frequencies for transmission and reception, it's a different story.

Two-meter repeaters usually separate transmit and receive frequencies by 600 kHz. At this offset you can keep most of the transmit RF out of the receiver by using proper filtering. Many repeaters use ultra-sharp filters called *duplexers* to allow the repeater to transmit and receive simultaneously *from the same antenna*. The isolating action of the duplexer, in combination with the buffer provided by the frequency separation, makes this feat possible.

This is not to say that you cannot have simplex repeaters. For example, you could use a digital device to record the receive audio, retransmitting the content when the user has finished talking. There is a significant time delay, however, which makes this method unattractive. You might talk for two minutes, then wait for another two minutes while the repeater retransmitted what you said. By the time someone could reply, four minutes would have passed since you first keyed the microphone. Simplex repeaters are possible through this approach and several others, but they cannot rival the efficiency of duplex systems.

Q I'm a relatively new ham and I want to know more about autopatches. I know they have something to do with telephones, but that's about all. Can you help?

A An autopatch is a device that allows hams to place telephone calls from their automobiles or even from hand-held transceivers. You'll commonly find autopatches as part of repeater systems, although simplex autopatches exist as well.

While they may seem similar, an autopatch is not the same as a cellular telephone. They both use RF, but the similarity ends there. Autopatches are comparable to old-fashioned "party lines." When you make an autopatch call, *everyone* hears your conversation. Cell phones are relatively private by comparison. And conventional repeater autopatches are only *half-duplex* devices. This means that you and the person you've called must take turns talking. Cell phones, on the other hand, are *full duplex;* you can interrupt each other at will.

Just because you're able to use a repeater, don't expect free access to its autopatch. Most repeater groups require autopatch users to be paid members. As a member in good standing, you'll receive the "secret" codes that operate the autopatch. If you desperately need to use an autopatch and you're not a member, there is usually a member on frequency who can operate it for you.

The *control operator* has the last word about what takes place on his or her repeater—including the autopatch. For example, some control operators don't mind if you use the autopatch to order a pizza. Others mind very much! Listen for a while and learn the pattern. If in doubt, don't do it until you can speak to the control operator.

Q My local 2-meter repeater has a crossband link to the 10-meter band. Last week I heard someone using the link to talk to a ham in Argentina! I'd like to do this too, but I'm a Technician. Since my license doesn't give me privileges on 10 meters, I'm out of luck, right?

A Not at all! Crossband links are for you, too! Legally speaking, it works like this: The control operator of your 2-meter repeater must have privileges on the HF bands or the link would be illegal. When you use the crossband link, you're really using someone else's station—just as though you were present at the site with the control operator standing beside you.

So enjoy the 10-meter crossband repeater. And if anyone tries to tell you you're operating illegally, advise them—politely—to review the FCC rules!

Q My local repeater switched CTCSS access tones from 107.2 Hz to 151.4 Hz. Before the switch, I never heard the tones in my Yaesu FT-2500M transceiver. Now that the system has moved to 151.4 Hz, I hear them all the time. Three other hams in our club own FT-2500Ms and they all have the same problem. I know you're not supposed to be able to hear CTCSS tones, but we can—and it sounds awful! What is the cure?

A CTCSS tones are called "subaudible," but this isn't always the case. Some repeaters are designed to strip off any subaudible tones before they reach the output. They use the tones at the receiver to control access, but that's all. Other repeater systems deliberately pass the CTCSS tones untouched for various reasons.

It sounds like your repeater does not eliminate the CTCSS tone from the output. You might want to ask the repeater trustees to configure the machine to do so. This might involve placing either a 151-Hz notch filter or a 200-Hz high-pass filter in the audio line between the repeater receiver and transmitter. (*The ARRL Handbook* has a section on filter design.)

The FT2500M probably has a good low-frequency audio response, so it hears the 151.4-Hz tone just fine. Unfortunately, it is no easy task to modify modern radio equipment. The use of surface-mount components results in a lot of features in a small space, but the technology makes it almost impossible to do major modifications. If you could find a way to decrease the value of several of the coupling capacitors in the receiver audio section, that might do the trick. Alternatively, an external audio filter may help screen out the annoying tones.

Q I was told that my audio was low on the local repeater. I went into the rig and turned up the audio gain control. Now they tell me that I occasionally drop out of the repeater in the middle of a sentence. Any ideas?

A Yes, you tweaked that pot a bit too far. When you turned up the transmit audio, you increased the transmitter *deviation*—how far the signal swings in frequency as you talk. The higher the deviation, the louder you sound, until you deviate so far that you go out of the passband of the repeater receiver. If the receiver is set for 5-kHz deviation, and you speak loudly enough to deviate 6 kHz, the repeater will not transmit your audio for that part of your transmission. The result is missing words or sentences. Play it cool—turn the transmit audio gain down or move the microphone farther from your mouth.

4 Batteries

The subject of batteries is a bit more complex than their simple schematic symbol might imply. This chapter covers how to select them, use them and recharge different types of batteries.

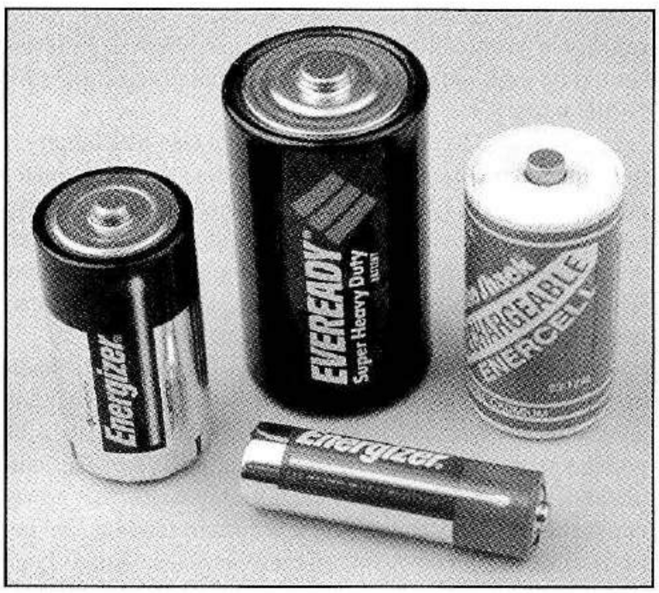
Q I am a brand new ham, and have noticed that there are lots more types of batteries than I knew about in my pre-ham days. It seems that different battery types are better for different uses. Can you give me a quick rundown?

A Sure. Here are some of the more popular battery types.

Zinc-carbon—The common "flashlight" battery, probably the most widely used battery worldwide, has been around for over 100 years. These are low in cost, high in reliability, readily available, come in a variety of sizes and configurations and have a reasonable shelf life. Recent improvements have given this battery a higher power density (power available per unit volume), better leak resistance and mechanical shock resistance. With its long shelf life and slow, steady discharge rate it makes an excellent flashlight battery. Under refrigerated conditions these batteries can be stored for up to 10 years. Zinc-carbon batteries can't be recharged. They are actually getting hard to find, though. Most of the consumer batteries sold in retail stores are alkaline.

Alkaline—This is *the* common battery today. Although more expensive than the zinc-carbon, alkalines have a higher energy capacity and far outlast regular zinc-carbon batteries in use. How much longer depends on the type of equipment and how it is used. One of the characteristics of the alkaline is that they maintain a steady voltage for a long portion of their cycle and then the voltage drops off sharply. Alkaline batteries are ideal for calculators, toys, cassette recorders and other heavy-drain equipment. They are also ideal as emergency backup batteries for HTs in time of power failure when your expensive rechargeable batteries are of limited use. They can be stored for up to 5 years.

Rechargeable alkaline—Most alkaline batteries can't be recharged, but some battery manufacturers make an alkaline battery that can be recharged with a specially designed charger. Cousin to disposable alkaline cells, reusable alkaline cells are good for low-cost and low-power applications. They're known for having a very low self-discharge rate. Also, these batteries do not self-discharge as fast as NiCds—therefore, you can buy them already charged.



When tested by the ARRL Lab several years ago, the batteries were good for about 25 charge cycles. Their capacity dropped off with each recharge cycle. (It is likely that the manufacturers have made some improvements in the batteries since the article was written. Ed Hare, W1RFI and Mike Gruber, now W1MG, wrote an article, "Testing Rechargeable Alkaline Batteries—and More," *QEX*, April 1996. It is available for download from *ARRLWeb*. See the section on "More Information" at the end of this chapter for the Web address.)

Nickel-cadmium (NiCd)—These are the most common type of rechargeable battery. This technology has been around for a while, used where long use life, high discharge rate and reasonable prices are important. Like alkaline batteries, they maintain a steady voltage until they are very near their discharge cycle. They do have a slightly lower cell voltage that may render them incompatible with some equipment that requires a higher voltage. NiCd batteries are commonly used in HTs. They don't have a long shelf life because they tend to self-discharge, losing about 10% of their charge per month of storage. Like any rechargeable battery, they need to be charged correctly—overcharging can damage them. It is not a good idea to completely discharge NiCd cells connected in series. If one cell completely discharges before the other cells do, it can be "reverse charged" by the other batteries, possibly causing damage.

Nickel-metal hydride (NiMH)—This is another useful popular rechargeable battery. Its technology has been around for about 10 years, but has just recently exploded into the consumer market. This battery, for its physical size, has a higher power density than NiCd, but also has a reduced total number of charge/discharge cycles and a lower peak output current (because of higher internal resistance). These, although more expensive than NiCds, are sometimes preferred for power hungry devices such as full 5-watt HTs and digital cameras. In addition, the shelf life appears to be greater than that of NiCds—your HT won't run down as quickly when not in use. NiMH batteries should be used only with chargers especially designed for NiMH batteries.

Lead-acid—The most common form of lead-acid battery is the common automobile battery. They consist of lead plates and an acid electrolyte. They may be sealed, or may have vent holes and removable covers that permit you to add water. Automobile batteries are not good for applications where they will be repeatedly deeply discharged. Marine or golf-cart batteries are more suited to such applications.

Sealed lead acid (SLA) or *gel cells*—These use a technology similar to that used in automobile battery: lead plates and an acid electrolyte. The acid is in the form of a gel (thus the popular name "gel cells"). Unlike car batteries, they are completely sealed. They are best suited for higher-current power applications, or those requiring low current for extended periods of time. The downside of these batteries is their large physical size and weight, although the smaller ones (3×2×3 inches) are suitable for QRP portable operation.

Lithium-ion (Li-Ion)—Li-Ion cells provide a much higher power density than NiCd. The downside is that they require very tight control of charge current, charge voltage and discharge to defend against plating metallic lithium inside the battery. These have begun to show up in some HTs and have recently become the battery of choice for laptop computers.

Q I have seen NiCd batteries available everywhere. How are they supposed to be used?

A For longest life, a NiCd battery should be charged over a time period of no more than 15 or 20 hours and the charge current should be less than the ampere/hour rating of the battery. The batteries will last longer if they are charged as slowly as practical. Although an oversimplified view would be to assume that an 800 mA/H pack will supply 800 mA for 1 hour or 100 mA for 8 hours, this is not the actual case. The manufacturer's rating is typically based on a given discharge current (perhaps 1/10th of the pack capacity, often called the "0.1C" rate), with different actual discharge times for different rates.

Most NiCd battery manufacturers don't actually recommend a particular charge or discharge rate, but will include charts in their battery data sheets showing the various tradeoffs for different current levels used, as well as for different charge methods. Generally speaking, the lower the charge (and discharge) current, the longer the battery life. Although the discharge current is determined by the load (such as your HT), charge current is determined by the type of charger you use. Fast chargers are convenient, but "trickle" chargers will lengthen the total battery life compared to fast-charge use.

Some battery manufacturers indicate that a battery can be kept on "trickle" charge indefinitely (a low rate that theoretically will not damage a battery), but unlike lead acid batteries, unwanted chemical reactions can occur if one attempts to keep NiCd batteries constantly "topped off."

NiCds in a battery pack should always be recharged before the voltage of any cell goes to zero volts, but this can be difficult to detect in a pack with large numbers of cells. One solution is to monitor each cell individually which is not always possible with small battery packs. A more practical solution is to avoid deep discharges whenever possible.

Table 4-1
Small Rechargeable Battery Type Comparisons

	NiCd	*NiMH*	*SLA*	*Li-Ion*	*Li-Polymer*	*Rechargeable Alkaline*
Energy density	40-60	60-80	30	100	150-200	80
Cycle life *	500-1500	500	200-500	500-1000	100-150	10
Fast charge time	1 h	2-4 h	8-16 h	3-4 h	8-15 h	2-3 h
Overcharge tolerance	Moderate	Low	High	Very low	N/A	Moderate
Self-discharge (per month)	25%	30%	5%	10%**	N/A**	0.3%
Individual cell voltage	1.25 V	1.25 V	2 V	3.6 V	2.7 V	1.5 V
Maximum load current***	>2C	0.5-1C	0.2C	1C	0.2C	0.2C
Typical averaged cost (with NiCd being unity)	1.0	1.4	0.5	2.0	0.9 (est)	0.1

*Cycle life is when full capacity decreases from 100% to 80%. For rechargeable alkaline, it drops to 65%.
**Control and protection circuitry contained within the battery pack typically consume 3% per month.
***The C specified here refers to the cell's ampere-hour capacity. For example, if a cell is rated at 1.5 Ah and you discharge it at a 1C rate, you will be drawing 1.5 A for 1 hour. If you draw only 0.75 A from it (0.5C), the cell should last for 2 hours.

Q Should I buy a charger for my NiCd batteries, or can I build one?

A From a cost viewpoint, you will be ahead to buy one. "Department-store" chargers are inexpensive and can be used to recharge individual cells. A bit more expensive, the charger that comes as an option with most HTs is customized for that particular product. But battery charger circuits are relatively simple, so they can make a good beginner's construction project.

In some cases, the constructed project may work better than the commercial products. The "Smart Charger" that appeared in September 1994 *QST* and subsequent editions of the *ARRL Handbook* has circuitry that senses when the battery is fully charged, then switches to a trickle charge mode. It also is programmable for different battery types by changing a resistor value. The complete article is available on *ARRLWeb*. See the "More Resources" section at the end of this chapter for the Web address. Fig 4-2 is the schematic and parts list:

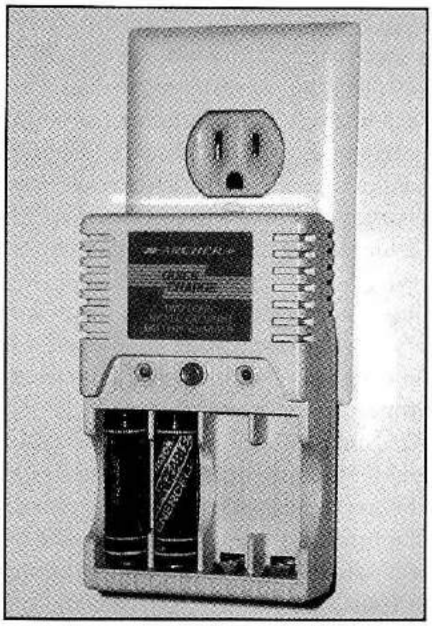


Fig 4-1—This type of inexpensive NiCd battery charger is available at most department and electronics stores.

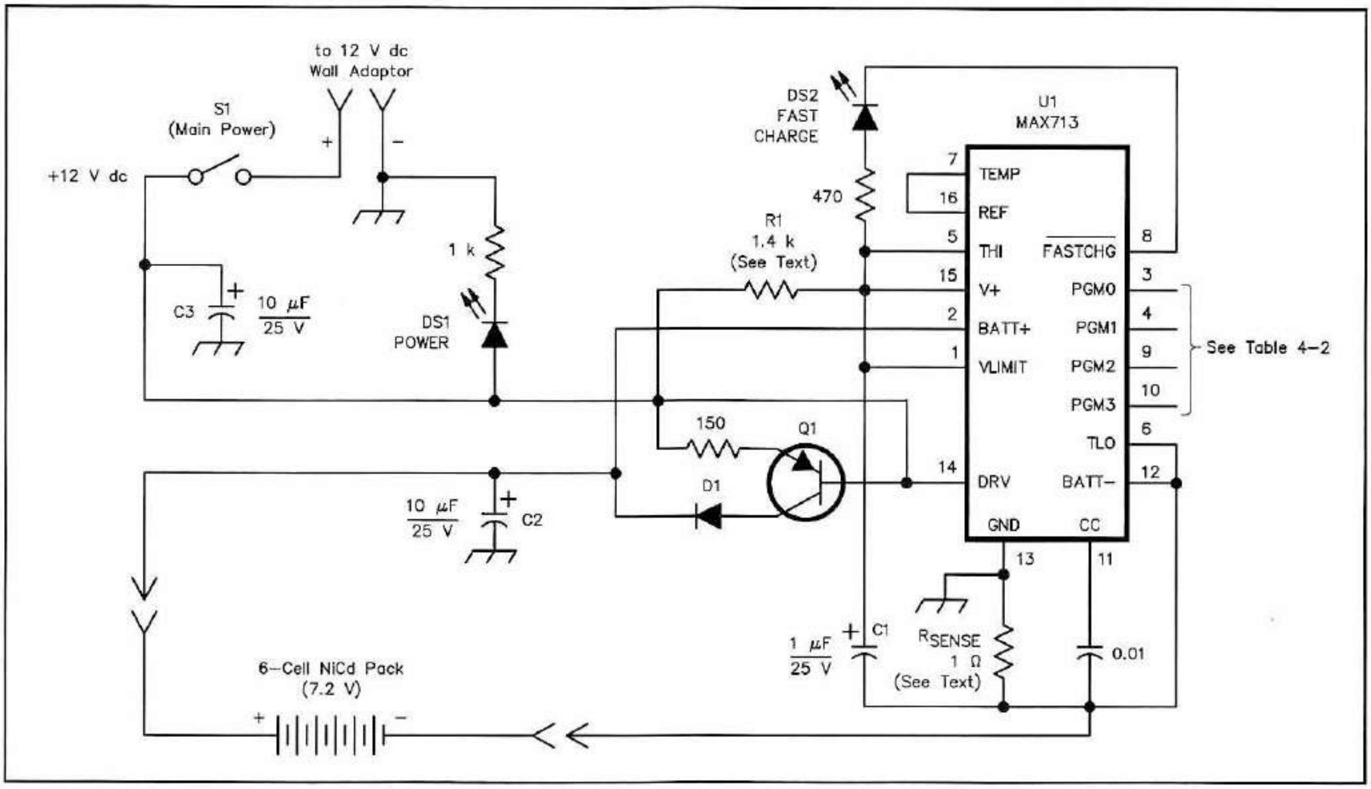


Fig 4-2—Schematic diagram of the smart charger, as set up to charge a 7.2-V pack. This is from "A Smart Charger For Nickel-Cadmium Batteries," by Steven Avrtich, WB1EOB, which appeared in Sep 1994 *QST*.

Parts list: All parts except the MAX713CPE are available at RadioShack. The MAXI713CPE or a complete kit of parts is available from the Digikey Corporation, 701 Brooks Ave S, PO Box 677, Thief River Falls, MN 56701-0677, Tel: 800-344-4539 (800-DIGI-KEY), Fax: 218-681-3380, www.digikey.com/

D1—1N4001 or equivalent.
DS1—Green LED (RadioShack 276-022).
DS2—Yellow LED (RadioShack 276-021).
Q1—MJS2955 PNP power transistor (RadioShack 276-2043).
R1—1.4 kΩ (see text).
R_{sense}—1 Ω (see text).
S1—SPST switch (RadioShack 275-612).
U1—Maxim MAX713CPE single-chip battery charger (Digikey MAX713CPE-ND).
Misc—The wall-cube power supply used in this project is a RadioShack 273-1652. Any 12-V supply can be used. The enclosure is a RadioShack plastic project box (RadioShack 270-627).
This charger can fast or trickle charge any NiCd battery pack with voltages ranging from 1.2 to 12 V. The charger can beprogrammed at charge rates from trickle charge to a fast charge of 20 minutes.

Construction

The construction is pretty straightforward. A PC board is not available for this project, but any of a number of construction techniques can be used, most variations of point-to-point wiring. A description of the various techniques that can be used to construct circuits is beyond the scope of this book, but the Construction chapter in any recent *ARRL Handbook* describes a number of different techniques that can be used.

The value of R1 must be calculated based on the power supply voltage. For a 12-volt supply, it should be 1.4 kohms. This value can be obtained by using a 1kohm resistor in series with a 390-ohm value. Another resistor, R_{sense}, determines the charge current. Normally, a NiCd should be charged at a rate from 10% to 50% of its rated capacity in ampere/hours. This charger is generally designed to charge at the 50% rate, with a timeout of 2.5 hours. First, determine the desired charge rate by dividing the battery rating ampere/hours by two. Then, R_{sense} = (.25 / charge rate). The value for properly charging a 500 mA/hr NiCd pack would be 1 ohm.

Next, program the voltage. **Table 4-2** shows the connections that must be made to the PGM1 (pin 4) and PGM0 (pin 3) connections on the MAX713. These pins will either be connected to V+ (pin 15), REF (pin 16), BATT– (pin 12) or left open (no connection). The article has a more complete table, but this table should suffice for most batteries.

The last step needed is to determine the timeout period. For the 50% charge rate described earlier, the timeout rate should be programmed to 264 minutes by connecting PGM3 (pin 10) to BATT– (pin 12) and connecting PGM2 (pin 9) to BATT– (pin 12). Other timeout periods are shown in a table in the article.

In use, the charge current for this example should be 250 mA. The voltage should slowly rise and after the battery is charged, or after 2.5 hours the fast-charge LED (DS2) should go out.

Table 4-2
MAXIM MAX713 Programming for 1- to 16-Cell Packs

Number of Cells	*PGM1*	*PGM0*
1	V+	V+
2	OPEN	V+
3	REF	V+
4	BATT–	V+
5	V+	OPEN
6	OPEN	OPEN
7	REF	OPEN
8	BATT–	OPEN
9	V+	REF
10	OPEN	REF
11	REF	REF
12	BATT–	REF
13	V+	BATT–
14	OPEN	BATT–
15	REF	BATT–
16	BATT–	BATT–

OPEN Not connected
BATT– Connect to pin 12
REF Connect to pin 16
V+ Connect to pin 15

Q I want to store some of my NiCd batteries for a long time. Should they be fully charged or fully discharged?

A You won't harm a NiCd by storing it uncharged. In fact, some manufacturers recommend it. If you think about it, a NiCd will lose about 10% of its charge per month, so after a "long period," it would be pretty much discharged anyway. When it's time to use the battery, however, be sure to charge it first. Some of the cells in the pack may be at a lower charge than others. If you try to use the pack without recharging, the cells that are not discharged could apply a reverse-polarity voltage to the discharged cells. This will probably effectively ruin the pack.

Q I have heard that NiCd batteries will develop a "memory." All sorts of conflicting advice is given to prevent this. Will memory effect harm my NiCd batteries?

A True memory effect does exist; but in fact, it is virtually nonexistent. It is a rare phenomenon that is difficult to reproduce, even under laboratory conditions. It can be caused when a NiCd battery is repeatedly charged and discharged to exactly the same level. When it occurs, the cell "remembers" the level of the charged state and is difficult to charge past this state to full charge. It was first observed in NiCd cells used in satellites that have a constant current rate and are charged by solar panels that spend the same amount of time in sunlight every day. Under normal use, where the battery is discharged to an undetermined state, then charged again at random intervals, it is not at all likely to be encountered.

Hams often confuse a phenomenon known as "voltage depression" with memory effect. Voltage depression occurs when a NiCd is continuously overcharged, perhaps left permanently in a charger between uses. The output voltage and the energy capacity of the battery can be decreased by such overcharging.

Mike Gruber, then WA1SVF, wrote an article called "A NiCd Never Forgets ... or Does It" that appeared in the November 1994 issue of *QST*. A reprint of this article is available on *ARRLWeb*. See the section on More Information at the end of this chapter for the Web address.

Q I used to fly radio-controlled model airplanes. The NiCd batteries we used were kept in shape by a "cycler." It automatically discharged the batteries to the right level, recharged them, and then maintained them on trickle charge for an indefinite period with no damage. Is there such a cycler available for the NiCds used in amateur hand-held transceivers?

A It is not generally necessary or advisable to discharge NiCds on a routine basis in a fixture. This practice may do more harm than good, and only helps in the case of voltage depression. In almost all cases, the "random" way hams use their NiCds ensure that they are charged and discharged properly to prevent unwanted degradation.

Q **Are nickel metal hydride batteries worth the money?**

A If you are looking for a significant improvement in the length of time a charge lasts for only a small price increase over NiCds, then the answer is a qualified "yes." You may also need a special charger to prevent overcharging the batteries, since NiMH cells are not as overcharge-tolerant as NiCds, and the charger will add to your total cost.

There is also another tradeoff with NiMH batteries—you will get fewer charge/discharge cycles from them. Ideally, you can recharge a NiCd about 1000 times before it needs replacing (although there are a number of things that can shorten battery life). NiMH batteries can typically be recharged only about 500 times before replacement is required. For an HT that gets charged once a week, however, the battery would last about 10 years under ideal conditions.

Q **I recently noticed some new "high capacity" nickel-cadmium (NiCd) batteries in the RadioShack catalog and am trying to find more information about them. I downloaded the spec sheet for the AA size batteries (the only specs I could find) from the RadioShack Web site and it seems to confirm the capacity claim, but I wonder if there is some kind of hidden drawback. If these things really have twice the capacity of standard NiCds, I would think they would be showing up in more NiCd applications. Can you shed some light on these?**

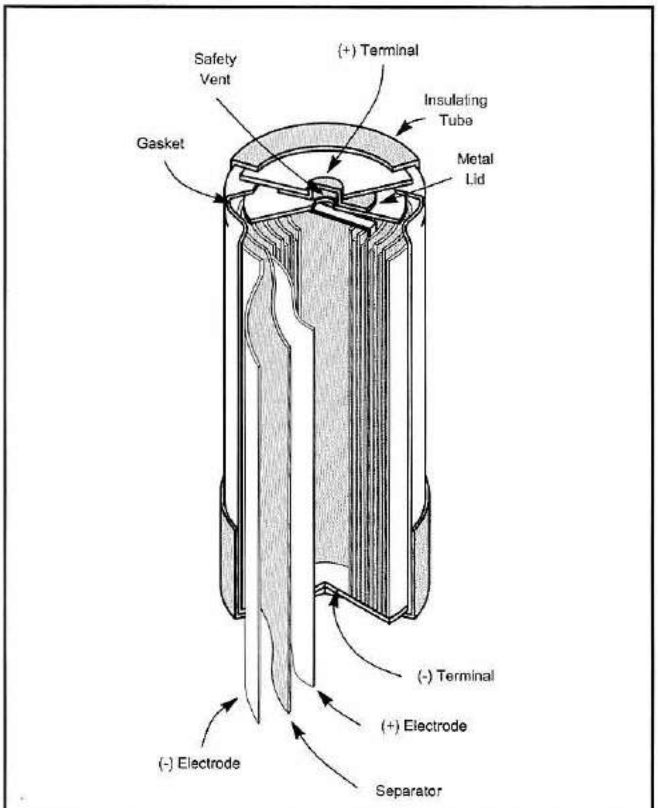


Fig 4-3—Cutaway drawing of a nickel-metal hydride (NiMH) cell. Except the for cathode, which is made of hydrogen-storage metal instead of cadmium, the construction is similar to that of the nickel-cadmium (NiCd) cell. Hydrogen-storage metal is preferred because it is less toxic than cadmium and gives the NiMH cell a greater energy storage capacity.

A For this answer we defer to internationally known battery expert and ARRL Technical Advisor Ken Stuart, W3VVN.

> Yep, there are some "super cells" out there, and they are about as good as the claims. So what gives? Just the usual situations.
>
> First off, anyone can make a cell that has higher than usual capacity. How? Simple. Use a better separator between the plates, one which is more uniform in thickness, maybe a little tougher, has undergone more quality control, and just happens to cost a little more as a result.
>
> Now, let's do the same thing to the plates by making the thickness more uniform, so that everything packs better. Of course, this also adds to the cost of the cell. We also use a finer powder for the sintering process in making those plates, which increases the available reactive surface area. Finally, we can also use a more critical process for winding the plate-separator "sandwich" into a spiral slug and inserting this into the can. By doing all this, we now have a cell that has lots more ampere-hour capacity.
>
> Why don't we see these cells in more applications? Pretend for a moment that you are a manufacturer of video cameras and you want to choose cells to use in your new product line. Do you want to spend the extra bucks for the high-capacity cells, thereby increasing the sale price of the unit? Or do you want to go with the cheapest cells you can find to keep the end cost of your SuperCam down to competitive levels? Remember, you're in the business to manufacture and sell cameras, not batteries. And likewise, manufacturers of replacement battery packs know that the average Joe Customer usually wants the cheapest replacement he can get. In other words, it boils down to supply and demand. In this case the demand for super cells is light and so, consequently, is the supply.

Q **I'm exploring options for powering my hand-held radio from other types of compact batteries during public service activities. I don't want to rely strictly on the NiCd power pack that came with the H-T. What do you think about using alkaline D cells, or perhaps carbon-zinc cells for backup power?**

A D cells offer a reasonable alternative, but even if alkaline, they may not provide enough power to allow you to use the full output of your H-T over an extended period of time. Standard alkaline batteries are pretty marginal for powering modern hand-held transceivers that produce 5 W or more. Rechargeable alkaline batteries are another option, but they're not as good as standard alkaline batteries for delivering high current. Frankly, I wouldn't even bother with normal carbon-zinc cells.

For inexpensive large-capacity rechargeable power, you may also want to consider sealed lead-acid or gelled-electrolyte batteries (gel-cells). The differences between them are pretty much academic to the end user, but you can say they are a safer version of standard lead-acid batteries. These types come in a wide variety of sizes that are inexpensive because of their wide commercial applications (such as emergency lighting and power backup systems). Check with your local fire/burglar alarm installers. They usually try to sell their customers up to a larger capacity battery and may have quantities of the smaller standard ones, just right for HTs or QRP rigs, at a very reasonable price. These can sometimes be found at flea markets and

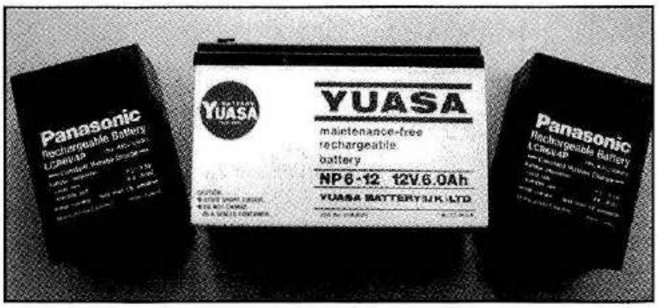


Fig 4-4—Typical gel-cell lead acid batteries.

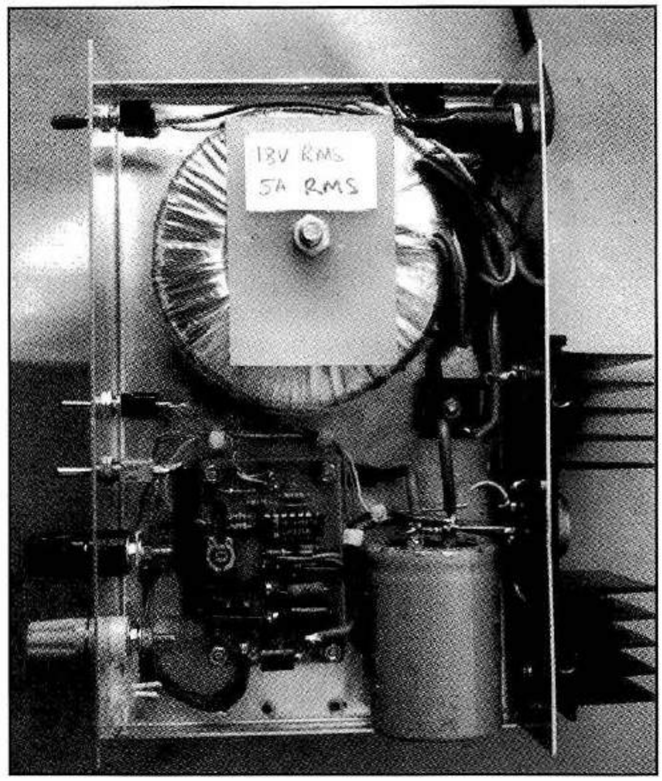
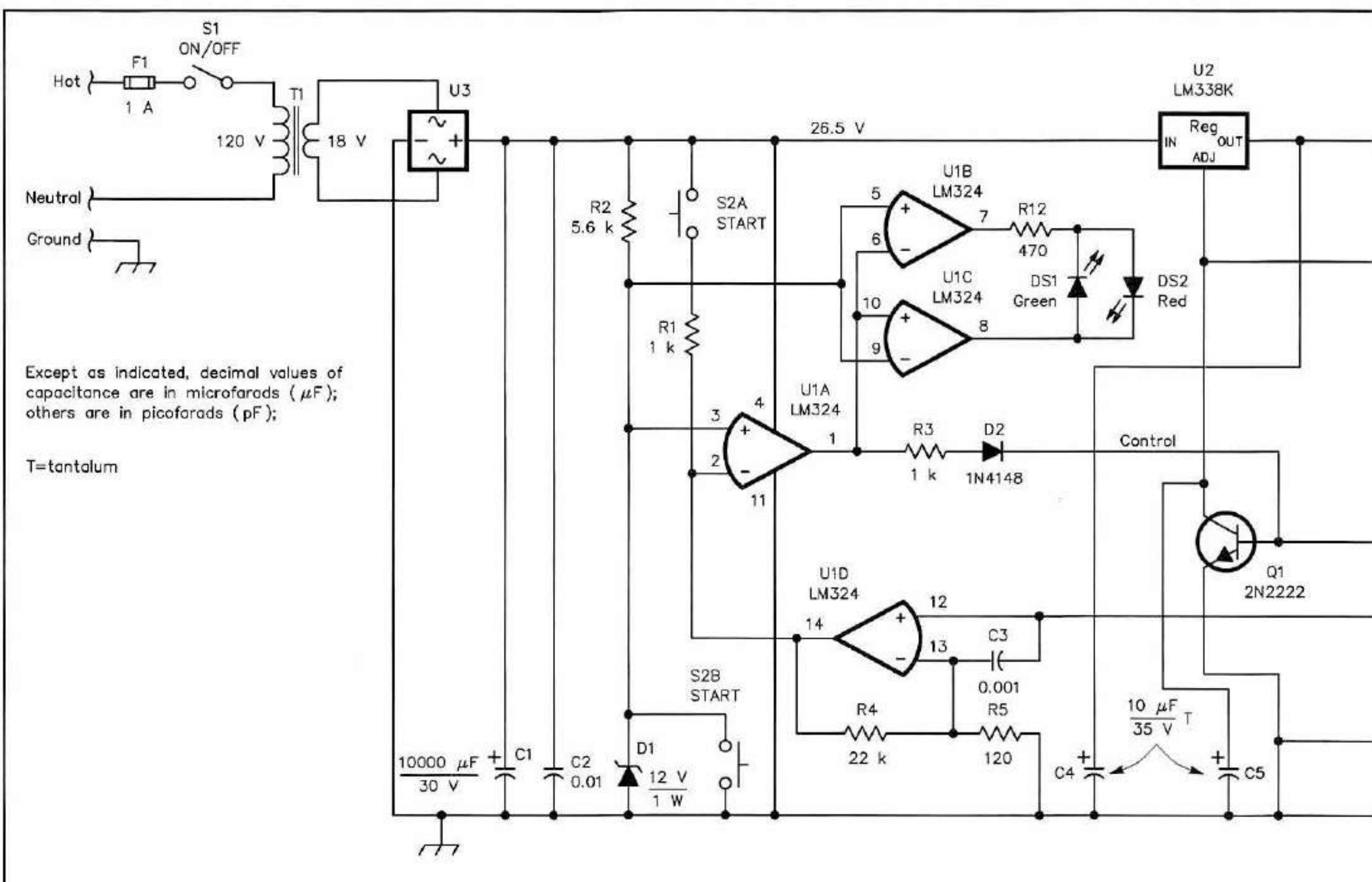


Fig 4-5—This charger can be used to charge gelled-cell, lead-acid batteries.



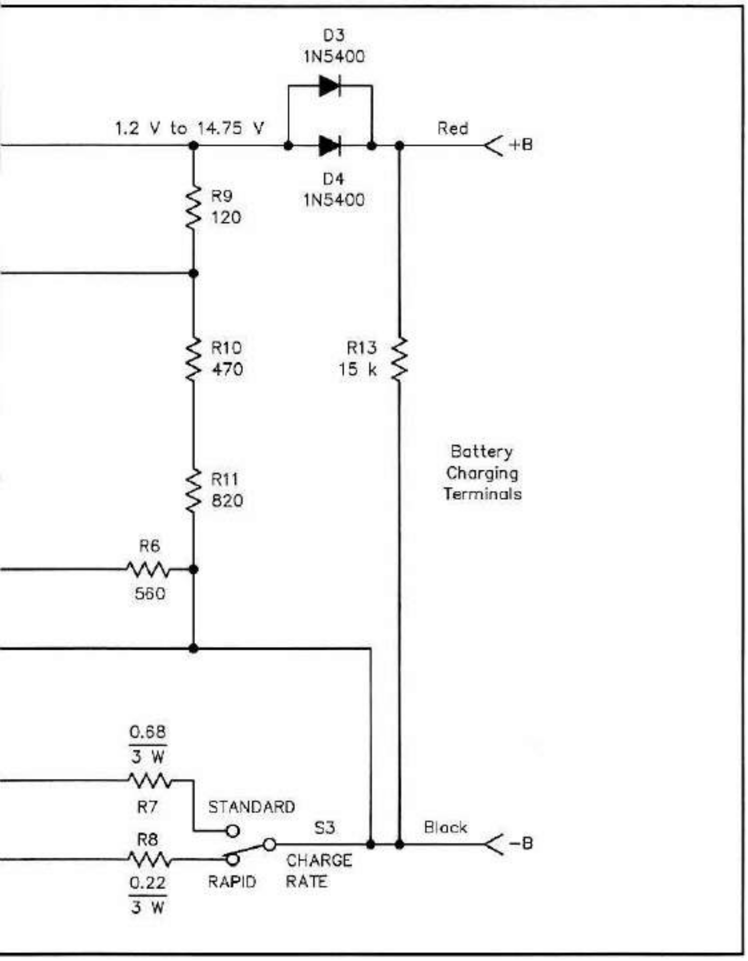
hamfests for as little as $6 to $8. Though a bit pricey compared to flea-market bargains, they are also often available a local electronics parts outlets.

Construction

Complete details are found in the original article. If you are using the PC board, it is easier to solder two wires to the holes for D2, then solder D2 to the wires after testing is done. U2 *must* be isolated from the heat sink by an insulator and conductive grease.

Testing the Charger

Apply line voltage and set S1 to the ON position. The green LED should light and about 14.7 volts should appear on the charging terminals. If this is correct, remove power from the unit and install D2. Again, apply line voltage. The voltage across the charging terminals should be approximately 0.6 volts. Hole the start switch and check that there is again 14.7 volts at the charging terminals. Set the CHARGE RATE switch (S3) to STANDARD. Connect an ammeter across the charging terminals. Verify that the charger goes immediately into the charge mode, the red LED lights and about 1 A is flowing. Turn off the power. Set S3 to RAPID CHARGING. When the charger is turned back on, the red LED should light and about 3 A should flow. The unit is now ready for charging. When the charge is complete, the green LED should light.



Q I'm rebuilding my station to make it more functional during emergencies. What type of back-up battery should I use? A lead-acid battery or a gel cell?

A A gel-cell is actually a type of lead-acid cell that has a gelatin electrolyte instead of the usual liquid. The advantages include no-spill, all-position operation. (A typical lead acid battery can spill or leak if turned upside-down.)

Smaller gel-cells are best for backpacking or camping operation. Larger lead acids can be used in high-current applications as well as stationary installations. If you don't mind the hassles of the lead-acid design, these batteries are often less expensive than gel-cells. There are actually several types of lead-acid batteries. The types used to start automobiles aren't designed to be deeply discharged, and are usually poor choices for amateur stations. If repeatedly heavily discharged, a typical auto battery will fail prematurely. Marine or golf cart batteries are much better because they are designed to be more deeply discharged.

Q How do I charge gel-cell batteries with my solar panel?

A Your best bet would be to use a charge controller made for this purpose (**Fig 4-7**). **Fig 4-8** shows a circuit for such a charger. A kit consisting of the Micro M PC board, schematic, parts overlay, power MOSFET, resistor SIPs, and blocking diode is available for $15 from SunLight Energy Systems, 955 Manchester Ave SW, North Lawrence, OH 44666, tel 330-832-3114, fax 330-832-4161, Email: **prosolar@sssnet.com**, Web: **www.seslogic.com/**

Assembly

Construction is pretty straightforward. Watch polarity on the ICs and polarized capacitors.

Fig 4-6—Schematic of the battery charger. The parts are available from most electronics distributors. See www.arrl.org/tis/tisfind.html for sources. Equivalent parts can be substituted. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units. This circuit was featured in "A Lead-Acid Battery Charger," by Ben Spencer, G4YNM, which appeared in Mar 1994 *QST*.

D1—12-V, 1-W Zener diode
DS1—Green LED
DS2—Red LED
F1—1-A, slow-blow
Q1—2N2222 or equivalent
S1—SPST toggle switch
S2—DPST momentary push-button or toggle switch
S3—SPDT toggle switch
T1—120-V primary, 18-V, 5-A secondary
U1—LM324 quad op amp
U2—LM338 K 5-A voltage regulator
U3—50-V, 6-A bridge rectifier
Misc: Heat-shrink tubing, 2-degrees/W heat sink; TO-3 transistor mounting kit; heat-conductive grease; panel-mount fuse holder; ac-line cord; chassis grommet; binding posts (red and black); mounting hardware; 2.5-mm cable; hookup wire.
Note: PC boards for this project are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118-9269, tel: 847-836-9148 (Voice mail), fax: 847-836-9148 (same as voice mail), Email: farcir@ais.net, Web Site: www.cl.ais.net/farcir/

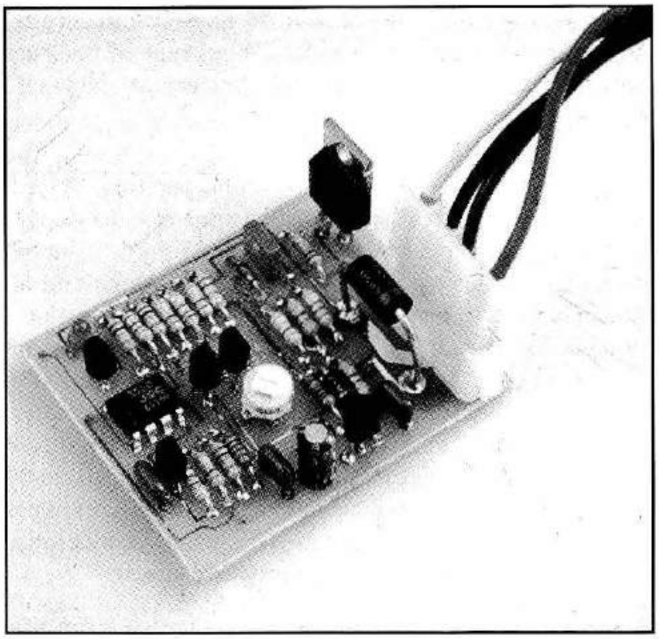
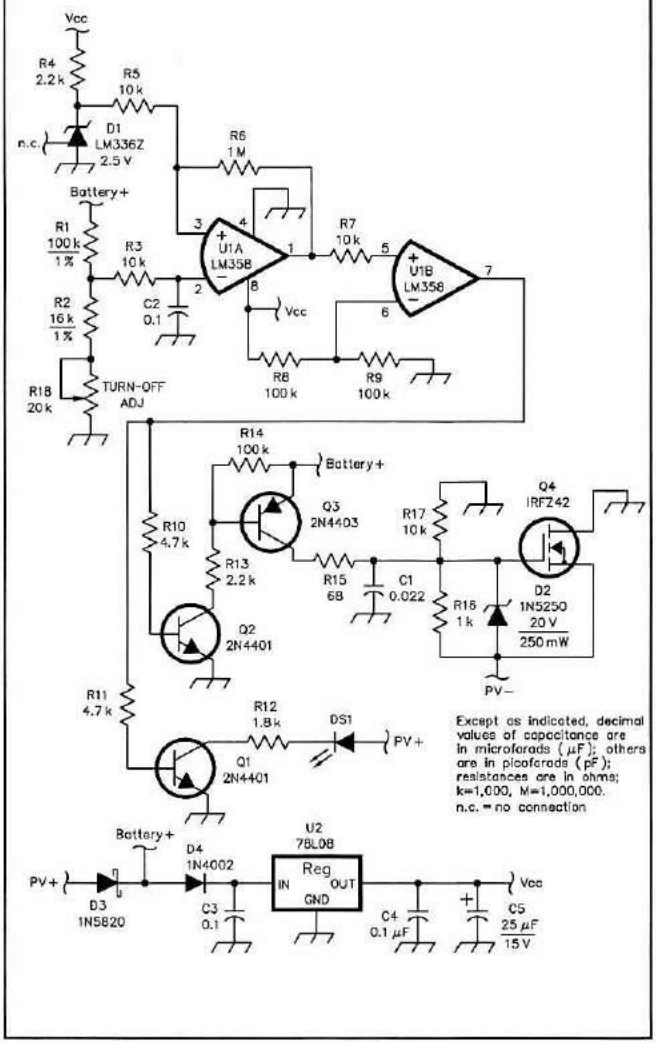


Fig 4-7—This photo shows the small solar charger, ready for action.



Testing

To test the charger, connect the PV+ input to a fully illuminated solar panel or an 18 to 20 volt power supply. Connect a separate power supply to 14.2 volts and connect it to the charging terminals. Adjust R18 fully CCW. Measure the voltage at the gate of Q4 (about 12 volts). Slowly turn R18 clockwise until the gate voltage just drops to zero. The charger is now ready for use.

Q I want to run my 100-watt HF transceiver off my car battery while I am camping. Can I do this?

A Automobile batteries are designed to deliver very high currents for short periods of time doing an important job—starting your car! The starter may draw 100 amps or more for few seconds, slightly discharging the battery. The battery is then recharged fairly quickly by the automobile's alternator. Car batteries are *not* intended for slow, deep discharges. As W1RFI has learned the hard way in the ARRL HQ parking lot, leaving the car lights on one time too many and deeply discharging the battery will cause an older car battery to fail. Of course, this is probably not quite as serious as the real risk—running the transceiver a bit too long and discharging the battery to the point where it won't start the car. (W1RFI has also done a lot of HF CW mobile work, and he knew all about this problem, too!) It is okay to run a transceiver off of the car battery for short periods, but if you intend to do a lot of mobile operation when the car is not running, consider running the transceiver from a deep-discharge battery, such as a golf-cart or marine-use battery.

A deep-discharge battery is made with thicker plates than a conventional battery, so it gets the best of both worlds. It can deliver high currents to start vehicles, although it is not

Fig 4-8—The Micro M circuit. DK part numbers in parentheses are Digi-Key (Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677; tel 800-344-4539, 218-681-6674; fax 218-681-3380; on the Web at www.digikey.com). Parts are also available from Hosfelt Electronics, 2700 Sunset Blvd, Steubenville, OH 43952; tel 800-524-6464; 614-264-6464; fax 614-264-5414. Equivalent parts may be substituted. This circuit appeared in an article, "The Micro-M—A Miniature Charge Controller," by Michael Bryce, WB8VGE, Sep 1996 *QST*.

D1—LM336Z 2.5-V reference diode (DK LM336Z2.5).
D2—1N5250 Zener diode (DK 1N5250BCT).
D3—1N5820, 3-A Schottky diode (DK 1N5820CT).
D4—1N4002 (DK 1N4002CT).
DS1—Red LED (DK P300).
Q1, Q2—2N4401 NPN transistor (DK 2N4401); 2N2907 (see text).
Q3—2N4403 or 2N3906 PNP transistor (DK 2N3906A); 2N2222 (see text).
Q4—N-channel power HEXFET (DK IRFZ42).
R18—20-kW PC-mount trimmer potentiometer (DK 36C24).
U1—LM358 op amp (DK LM358AN).
U2—78L08 regulator (DK AN78L08).
Misc: PC-board pin-header (DK A1470); in-line plug (DK A14282); male pins (DK A1441); female sockets (DK A1440).
Note: A complete kit of parts is including the PC board is available from SunLight Energy Systems, 955 Manchester Ave SW, North Lawrence, OH 44666, Tel: 330-832-3114, Fax: 330-832-4161, Email: prosolar@ssenet.com, Web: www.seslogic.com/.

quite as good at this as a conventional auto battery. But it is also designed to deliver moderate currents for long periods of time, maintaining a relatively flat output voltage until it is deeply discharged. W1RFI reports that he has used them as his primary automobile battery with reasonable success, but finds he needs to replace them every couple of years. This may be a small price to pay to prevent the much higher cost of calling for road service to jump start a discharged battery. He has also occasionally used a marine battery that is installed in the trunk or bed of his pickup, not connected to the vehicle's electrical system. When it becomes discharged, he either recharges it with a charger or uses jumper cables to temporarily connect it to the vehicle's charging system while the vehicle is parked.

Q I'm using two 12-V deep-cycle batteries, wired in parallel, to power my HF transceiver. I notice that the voltage drops from 13.8 to 12.4 V after only a couple of minutes of operation. I wonder if I could avoid this drop by connecting the batteries in series, then using a regulator to maintain the resulting 24-V total down to 13.8 V?

A That would be some regulator! A voltage regulator works by taking the input voltage and reducing it to a fixed, regulated value. As long as the input voltage is a couple of volts or more greater than the regulated output voltage, the output voltage remains constant for all values of input voltage or current drain. At first, this sounds ideal, but the old adage applies—power gotta' go somewhere. If the input voltage is 24 volts and the output voltage is 12 volts, the other 12 volts is dropped across the regulator. If the current is 20 amps, 12 volts times 20 amps, or 240 watts, is dissipated by the regulator. This could be done, but it would require a hefty regulator with a large heat sink. There are switching-regulator techniques that could be used more efficiently, but, to date, no such regulator has appeared in the amateur press. It is not likely that it will, because you are better off operating your batteries in parallel. Placing them in series and then attempting to regulate the voltage back down to 12 or 13.8 V would result in a horrendous waste of power. Both batteries would discharge very rapidly as they tried to provide 20 A of current that your transceiver requires, delivering 240 watts to the transmitter and wasting 240 watts as heat. Putting them in parallel means that the batteries will take twice as long to discharge, allowing you to have fun longer.

The typical battery voltage during discharge would be about 12.6 V—very close to the 12.4 V that you're observing now. I'd recommend keeping your battery configuration just the way it is now. The reduction in RF output power at 12.6 V is negligible; especially to the guy at the other end of the signal path. The 12.4 volts you measure is actually pretty typical of deep-discharge batteries. The deep-discharge battery will hold that voltage up until the point where it is pretty much discharged. At that point, the voltage will drop pretty quickly. You might gain the extra 200 millivolts with conventional automobile batteries, but auto batteries are *not* designed for slow, deep discharges.

Fig 4-9—This "marine" type battery can be discharged hundreds of times. Although too heavy for most portable use, it can be used to power higher-powered equipment for extended periods of time.

They won't last very long in that use.

MORE INFORMATION

The following information and articles are available on the *ARRLWeb* Technical Information Service batteries page at **www.arrl.org/tis/info/batteries.html**.

Batteries

Articles

Note: Some of the following articles are in Adobe Portable Document Format (PDF) files. To view and print these files, you'll need a copy of Adobe's Acrobat Reader program. (Version 3.0 or later required). More information on Adobe is available from **www.arrl.org/acrorget.html.**

Which Battery Should You Use in Your Equipment? (**www.arrl.org/tis/info/pdf/49940.pdf**) (65,536 bytes). Source: *QST* April 1999, p 40-42.

NiCd, NiMH, Alkaline, etc ... How do they differ from one another, and which is best for your application?

Nickel-Metal Hydride Batteries in Amateur Radio Applications (**www.arrl.org/tis/info/pdf/99438.pdf**) (262,144 bytes). Source: *QST*, Sep 1994, pp 38-39.

Meet the newest power source for portable equipment: the NiMH battery

A NiCd Never Forgets. Or Does It? (622,592 bytes). Source: *QST*, Nov 1994, pp 70-71.

A discussion of memory effect.

A Smart Charger For Nickel-Cadmium Batteries (**www.arrl.org/tis/info/pdf/119470.pdf**) (262,144 bytes). Source: *QST*, Sep 1994, pp 40-42.

Recharge your hand-held's battery pack FAST, with this easy weekend project

The Ubiquitous, Notorious NiCd (**www.arrl.org/tis/info/pdf/69574.pdf**) (131,072 bytes), *QST* Jun 1995, p 74

Technical Correspondence—NiCd battery memory effect

Testing Rechargeable Alkaline Batteries—and More (**www.arrl.org/tis/info/pdf/9604003.pdf**) (759,666 bytes). Source: *QEX*, Apr 1996, pp 3-12.

The ARRL Lab investigates those rechargeable Alkaline batteries.

A Battery-Voltage Indicator (**www.arrl.org/tis/info/pdf/9810050.pdf**) (73,203 bytes). Source: *QST*, Oct 1998, pp 50-51.

Here's a quick and inexpensive project that allows you to keep tabs on your battery's condition.

Contact information for suppliers mentioned in the above articles should first be confirmed using TIS Address Database Search at **www.arrl.org/tis/tisfind.html**.

Web Links

Battery Technology

(**www.battery-index.com/index.shtml**)

How all kinds of batteries work

Frequently Asked Questions—Batteries

(**www.mywebplace.com/batterywholesale/batfaq.html**)

My independent (non-scientific) battery test & review (**scanshack.netfirms.com/batrvw.htm**)

Duracell

Popular alkaline batteries, comprehensive battery guide, battery care

Energizer

A wealth of information on batteries

5 Grounding and Lightning

Ground is not a mysterious hole into which signals disappear. Ground is a circuit concept, whether the circuit is local on a PC board, or much larger, like the ground you use for lightning protection. This chapter answers some of the many questions hams have about ground.

Q How would I know if I have a grounding problem in my station?

A You'll know you have a possible grounding problem if you experience interference to the equipment in your radio room (such as your computer and other gear) whenever you transmit. The display on the computer monitor may jump or flash in sync with your voice or CW keying. You may hear your voice in the speaker of your transceiver, the lights in your TNC may unexpectedly blink, your 2-meter radio may key all by itself, or other strange behavior may occur. In some cases, the metallic parts of your transceiver or microphone will become *hot* when you transmit—giving you a painful *bite* if you get too close!

Q Okay, I have a grounding problem. What should I do?

A The solution is to provide a low-impedance path to ground for all this stray energy. If you are on the first floor, start by improving your basic station ground. Using thick copper braid, connect the chassis of your transceiver, antenna tuner and any other radio gear to a common point. (You can use the braid from an old coaxial cable.) From this point, run more copper braid to a ground rod just outside a nearby window. The rod should be driven six to eight feet into the earth. Keep the length of this braid as short as possible.

If this doesn't cure the problem or if your station isn't on the first floor, there are several alternatives. First, take a look at your antenna system to see if you can make changes there. If you are using an end-fed wire, you might consider switching to a dipole instead.

If you are using a dipole, but your feedline leads away from it at an angle close to one of the wires (perhaps 45 degrees or less), see if you can re-route the feedline to make it more perpendicular. This improves the antenna system balance, ensuring that equal currents flow in both conductors of the feedline (unequal currents can cause the feedline to radiate). If your feedline is coax, you can also try adding a current or choke type balun at the feedpoint, as this may equalize the current flow.

If your antenna system is well constructed, try adding a counterpoise as described later in this chapter.

Q I sometimes get RF burns, despite a good ground system. What gives?

A At high power levels, RF burns are serious. Even at 100 W, they are very unpleasant. At the 100 W level, the nerves in your skin don't always react instantaneously to the stimulus. You usually have enough time to say "What the . . . ?" before you go running for the anesthetic cream.

The reason this can happen even in a station with a by-the-book ground is that antenna systems need a low-impedance ground at the frequencies you transmit on. For dipoles and Yagi driven elements, half of the wire or tubing is connected to the shield side of the coax (or one wire of a ladder line) and that is what gives your antenna system its *RF* ground. In a vertical ground-plane type of antenna, the radial system provides this ground.

With an end-fed wire, however, the RF flowing on the shield side doesn't have any place to go. While some of it will be shunted through the station ground system, some of it can still remain floating on the chassis of your equipment.

One of the ways to cure this problem is to cut a piece of insulated wire and attach one end to the ground connection of your transceiver or antenna tuner. Wrap electrical tape around the other end and lay the wire on the floor leading away from the operating desk. If you can, you should put the wire outside. This wire is known as a *counterpoise*. The length of the wire should be about $^1/_4$ wavelength at your approximate operating frequency (it doesn't have to be exact) on the band you are having trouble with. If you have RF problems on other bands, you'll have to attach additional counterpoises for these bands as well.

A counterpoise is basically part of your antenna system, so it can radiate and with an indoor counterpoise, the RF levels in the shack may still be considerable. Use low power

Figure 5-1—The MFJ-931 Artificial RF Ground can help solve "RF in the shack" problems.

whenever possible in this case.

If you don't have room for these long lengths of wire, you might want to consider an *artificial ground* as an alternative. These devices are basically a single-wire tuning network. You connect a short length of wire (perhaps 20 feet) and then adjust the controls until the combination of the network and the wire is tuned to the frequency you are at. Working together, they become *electrically* the same length as an equivalent counterpoise.

Q How should I ground my equipment, which is located on the first floor right by a window?

A The best way to ground a basic setup like this is with the traditional method. Drive a copper ground rod into the soil right beneath the window and then run a heavy wire (such as a #8 or #6 AWG) or a wide (1-inch or wider) tinned-copper braid or solid strap between the operating desk and the ground rod. Install a heavy copper bus bar (perhaps $^1/_4 \times {}^1/_2$ inch × 3 feet long) or $^1/_2$-inch copper pipe across the back of the desk to provide a convenient place to ground each piece of equipment.

Use individual wires or braid to connect equipment to your bar or pipe. Also, do **not** solder connections in a grounding system! Use hardware such as stainless hose clamps and bolts, washers and nuts. See **Fig 5-2** for an example of this kind of installation.

One note about the ground rod—use a good quality (preferably solid copper-clad steel) rod that is long enough to extend below the frost line in winter. An 8-foot rod is a good length.

Q Can I use a wall-outlet plate screw or water pipe to ground my third-floor amateur station?

A Remember that there are two types of ground, RF ground and safety ground. Safety ground gives you shock hazard protection (for dc and ac, not RF!) and provides some amount of equipment protection. While an adequate safety ground can be had by connecting your station equipment to the wall-outlet screw or water pipe, this will not give you a good ground at RF in your third-floor station.

Additionally, you'll need to make sure that the wall-outlet screw is actually grounded. To do this, turn the circuit breaker for that outlet OFF, then check continuity between the screw that attaches your power plug cover plate and the ground hole in the socket. If you have only two-wire outlets in your apartment, then you'll need to measure between the screw and the breaker-box ground (not very convenient, but your safety is more important than convenience).

If the screw is indeed grounded, then find some $^1/_4$ or $^1/_2$-inch braid (braid from some old coax will do) and use that to make a nice flexible ground strap between your station and the screw. That takes care of the safety ground.

As far as RF ground goes, you have to look at your antenna system to see what your needs are. One way of reducing the need for an RF ground is to use a balanced antenna, such as a dipole or Yagi.

If your antenna is an unbalanced type or if you find that you have problems with RF in the shack or RFI from feedline radiation, you may need to lay out a counterpoise or an artificial ground.

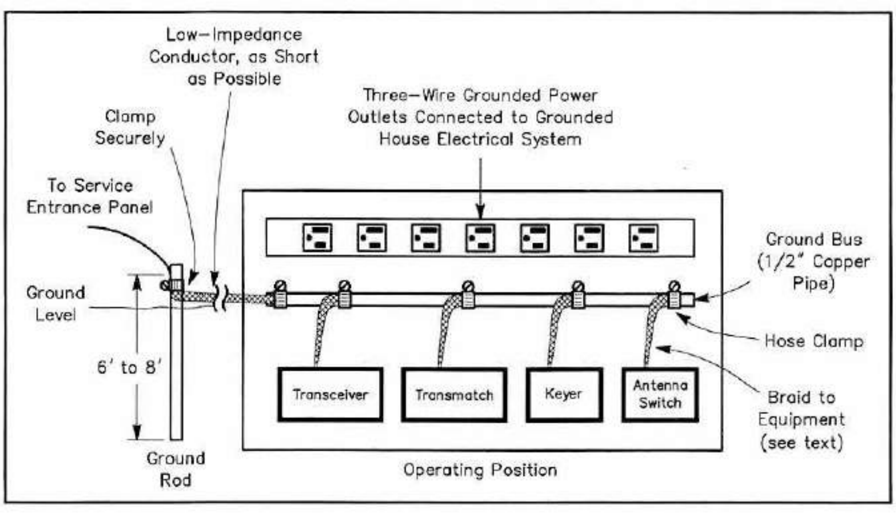


Fig 5-2—An effective station ground bonds the chassis of all equipment together with low-impedance conductors and tied into a good earth ground. Note that the ground bus is in turn bonded to the service entrance panel. This connection should be made by a licensed electrician with #6 AWG (minimum size) copper wire.

Q I've got a problem driving a ground rod deeper than 4½ feet. What should I do?

A This is not a problem. The US Army did a study recently and found that good ground performance was obtained by driving three rods several feet apart to a depth of 4 feet and connecting them together.

Q Can I use the siding of my mobile home as a ground?

A Tying your ground to the trailer siding is definitely out. It is almost certain that the trailer will become part of your radiator—with all the interference problems that implies. Also it is highly probable that the joints on your trailer are not perfect, which would allow arcing and the hazards that that implies—both fire and electric shock.

Your only choice with the vertical is to place as many radials, ¼ wavelength at the lowest frequency, around the antenna. Butternut is correct in saying that, compared to your present location which I assume has good soil, you will be disappointed—but at least you'll be on the air and 20, 15 and 10 shouldn't be too bad.

A better solution would be to put up a dipole or loop at about 30 to 40 feet if possible.

Q Does one 8-foot ground rod provide a good lightning ground for my vertical antenna?

A Safety and RF grounding are fairly simple, but lightning protection is another matter altogether! Effective lightning protection requires a ground of low impedance and a large area in which to dissipate the energy. Additionally, it is important to remember that with lightning protection, the key idea is to keep the lightning energy from harming people and starting fires.

Proper lightning protection can be relatively simple, or quite complex, depending on your antenna and station installation. See **Fig 5-3** for an example of an appropriate installation for a station with a tower.

Note that the various grounds at your QTH need to be connected together to prevent a difference in potential. If the power line down the street from you takes a strike, there would be a temporary difference in voltage between your electrical outlets and your station ground (rod). This difference could cause an arc to jump the gap (even if it is several feet) where these grounds are close (such as in your shack).

The idea behind connecting your station ground to the service entrance is that, in this way, you would keep the energy that flows in this ground connection outside of your home when you have a nearby lightning strike.

In lightning protection, you want to keep the energy outside the house and give it some way to expend itself in a harmless manner. The well-grounded bulkhead-type panel (with feed-through connectors) depicted in Fig 5-3 is appropriate for any installation where lightning is a concern (and that includes most QTHs).

Q For lightning protection, I want to disconnect the antenna when not in use, but I'm concerned about damage to the radio if other family operators forget to reconnect the antenna. Can you help?

A Disconnecting the coax at the rig is a good practice, but one that by itself will not always protect you from a lightning hit. I know of at least one instance where lightning jumped a 5-foot gap between the end of an unattached coaxial cable and a nearby radio. Of course the radio did not survive, but worse than that, a fire could have easily started.

For a station disconnect, the best bet is to use a grounded panel at the entry point to the house and disconnect the station feed at that point. Curing your family's forgetfulness is another matter. You could make a point to also unplug the rig's power cable when the coax is disconnected. A dead radio offers a strong hint that they may have forgotten a step or two!

Q I've read all the literature I could find, including the *ARRL Handbook* and *Antenna Book*, plus I've searched the internet, and I'm still somewhat confused about the right station ground setup to cover both RF grounding needs and lightning protection for my situation. This is apparently a controversial subject and I've discovered a lot of conflicting information. I came up with a design, but before I spend a bunch of money on it, may I please run it by you?

Here's what I have: My shack is in my basement, below grade. All station equipment is grounded to a single bus bar, including an AlphaDelta Delta-4 coax antenna switch that includes an arc element for lightning protection. The bus bar is connected via #6 copper to a single station ground rod about 12 feet away from the house. My antenna ground is a single rod at the base of the tower about 50 feet away, and that is connected to the station ground rod via #6 copper underground. Last, I have also run #6 copper underground from the antenna rod to the existing electric service ground rod, about 75 feet on the other end of the house. So, I have 3 ground rods, all tied together.

Some things I have heard about my proposal are:

1. That I have created ground loops that will result in stray RF currents around the shack, and possible cause RFI.

2. That my system will attract lightning strikes.

3. If lightning actually hits, any protection offered by my Delta-4 will be negated or bypassed through the electric service ground.

What do you think of this?

A Your proposal sounds quite good to me, although I would install ground rods for each tower leg (see Fig 5-3). Now, let me address the concerns your bring up. Ground loops are created when an electrical (dc, ac or RF) current has more than one return path. Since the grounds you are using are not intended to conduct RF under normal circumstances, there is no loop flow. RFI is created by wires that radiate RF flowing through them. Wires underground can not radiate and wires that are above ground, but are of short length will not radiate. Wires that have no RF energy flowing through them normally will also not radiate.

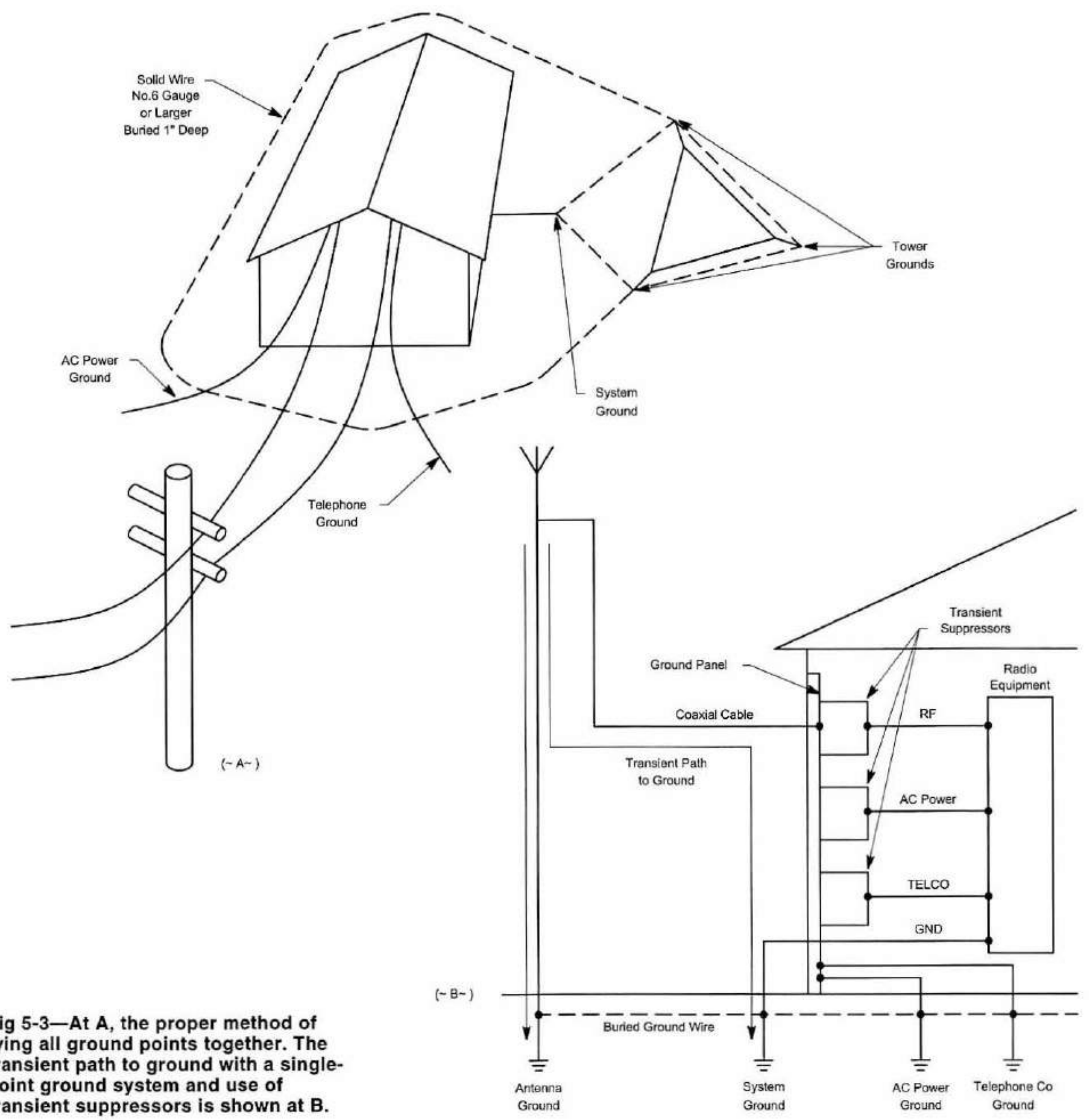


Fig 5-3—At A, the proper method of tying all ground points together. The transient path to ground with a single-point ground system and use of transient suppressors is shown at B.

With regard to the attract lightning comment—there are three schools of thought:

1. If you ground a tall conductor, it will be at the same potential as the surrounding soil, therefore it will be only as likely to get hit as the ground is. (This is the philosophy behind the umbrella-like dissipation array and wire-brush lightning devices.)

2. If you ground a tall conductor, it will be the closest grounded object to the sky, therefore presenting the shortest path, causing lightning to follow that path. There is some truth to this one.

3. Lightning pretty much goes where it wants unless you take steps to make it go where you want (so as to minimize the damage). There is some truth to this one, too.

The fact is that lightning often hits tall objects, grounded or not. The reason is simple—just about any solid material is a better path for lightning than the surrounding air.

The odds of a direct strike in your back yard are quite slim, however, unless you have a mountaintop QTH. Nevertheless, you have to consider what would happen if you did get a direct hit. If your antenna gets hit, it might melt or fry various parts. Your coax might fry also. Although these can be expensive to replace, they are far less so than your home and your family.

One can take steps to construct a system that will take a direct strike without damage. Commercial communications systems are protected in this manner because an equipment loss becomes an income loss. However, the expense of such a system is prohibitive and could easily exceed the cost of new antennas and coax, so there aren't too many hams who go to such lengths.

Lightning protectors for feedlines are not intended to survive a direct strike and offer no protection against them. However, as hams we also have to deal with nearby strikes (induced energy) and static charge build-up (dry winds). Both of these are equipment hazards that these units take care of.

Q What are the facts about lightning and fiberglass vertical antennas?

A I have heard several folks say that someone else told them lightning is attracted by antennas (applies not only to fiberglass ones). This seems to imply that simply having an antenna would cause lightning to strike there (or near there) rather than somewhere else (like the next town over).

The fact is that when an electrical charge builds up high enough to become lightning, it always takes the path of least resistance, which is usually a fairly vertical one. When you consider that clouds are hundreds or thousands of feet above ground, it is pretty easy to see that a projection of 30-50 feet of aluminum (or wire enclosed in fiberglass) isn't going to add anything significant to that situation.

That having been said, if you do have a lightning strike in the vicinity of the antenna (which will happen eventually whether the antenna is there or not), then it is indeed more likely to strike the antenna because that provides less resistance than the surrounding air. This doesn't make it a guaranteed behavior, though—lightning has a tendency to behave in unpredictable ways.

Q How can I provide lightning protection for a balanced feed line? I am going to be constructing a dipole with ladder-line as my feeder. How can I ground my antenna for lightning protection since there is no ground-like conductor such as in coax?

A Although they haven't been widely advertised, there are indeed lightning arrestors for ladder line, just as there are for coax. One type is a simple gap arrangement using common automotive spark plugs with a special mounting bracket for a ground rod. For information on this type, contact:

The Wireman Inc.
261 Pittman Road
Landrum, SC 29356-9544
Phone: 800-727-9473 (Orders)
Technical: 864-895-4195
Fax: 803-895-5811
Email: **n8ug@juno.com**
Web: **thewireman.com/**

The other type uses toroidal inductors with dc continuity on the antenna side to bleed off static charges as well as providing impulse suppression. Contact these folks for info:

Industrial Communications Engineers (ICE)
PO Box 18495
Indianapolis, IN 46218-0495
Phone: 317-545-5412, 800-423-2666
Fax: 317-545-9645
Web: **www.inducomm.net/**

ICE also makes a suppressor for single wires (suitable for end-fed antennas).

Q I've been told that the National Electrical Code requires that antennas be grounded and that the ground must be tied directly into the grounding system for the house's ac system. Why?

A The reason that the NEC requires all grounds be connected together is a matter of personal safety. For the sake of argument, let's say you leave the shack ground separated from the ac mains. If lightning directly strikes the power lines just down the street from you, the voltage of this "ground" may be instantaneously raised by several thousand volts. Earth is not a good conductor—just a persistent one—so it is easily possible for this to happen (and indeed it does).

This ground being at several thousand volts more than your shack ground, the difference in potential could cause an arc to bridge the gap between the two grounds (even if you unplug the rig), possibly resulting in equipment damage or even a fire.

If you tie them together, the voltage of the whole system is raised simultaneously. While the idea of this disturbs some people, they are forgetting that high voltage is only hazardous where there is a potential difference between two points (recall that birds often sit on high voltage wires without suffering any harm).

6 References

Q **I'm just getting started and only have only a single band dipole antenna at this time. What is a good award I can work for?**

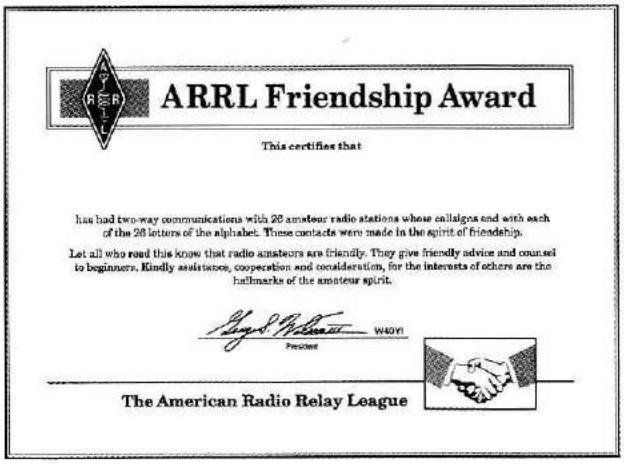
A An award you can earn on your first night on the air with whatever station you have is the Rag Chewers' Club (RCC). This is achieved by having an over the air contact for at least one solid half hour. To get it, just report the QSO to ARRL HQ with a fee of $3.

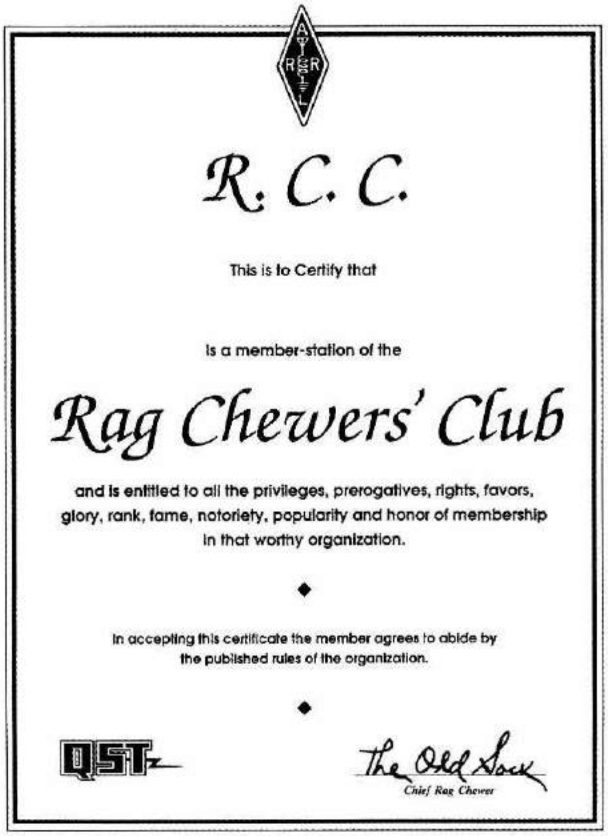
The ARRL Friendship Award is another award attainable by just about anyone in just about any circumstance. Whether using a dipole or a vertical, HF or VHF, or even a mobile station, and is great fun—even repeaters contacts count. Geography is not a factor and rather than just exchange signal reports, you get to know your fellow hams.

This award encourages friendly conversational contacts between radio amateurs (hams) and allows you to discover new friends through personal communication. The ARRL Friendship Award is available to any ARRL member who submits log extracts that show two-way communications with 26 stations whose call signs end with each letter of the alphabet. (For example: W4RA, KØORB, W3ABC ...K1ZZ.) QSL cards are not required. Applications sent to ARRL HQ must include a fee of $5. Other facts about the person contacted might be age, other interests and occupation, etc. Contacts must be made since November 1993 and may be made on any frequency and mode. (Contacts made through repeaters and satellites are both permitted and welcomed.) Completed applications should be submitted to ARRL HQ.

Photocopy the log sheet on page 6.2 or send request including SASE to:

ARRL Awards Desk
225 Main Street
Newington, CT 06111





ARRL Friendship Award

Contact Date	Callsign	First Name	Location	Other Fact
	A			
	B			
	C			
	D			
	E			
	F			
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	H			
	I			
	J			
	K			
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	P			
	Q			
	R			
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	U			
	V			
	W			
	X			
	Y			
	Z			

Place portable indicator of callsign first, for example: HC1/K4ERO

Q **How do I know in which direction to point my beam antenna to work different countries?**

A The Azimuthal Maps (Figs 6-3, 6-4 and 6-5) can be used to determine beam headings. Keeping in mind that a beam's forward lobe is a swath and not a laser beam, these maps should be accurate enough for most amateur work. These maps are also useful for planning fixed antennas such as dipoles.

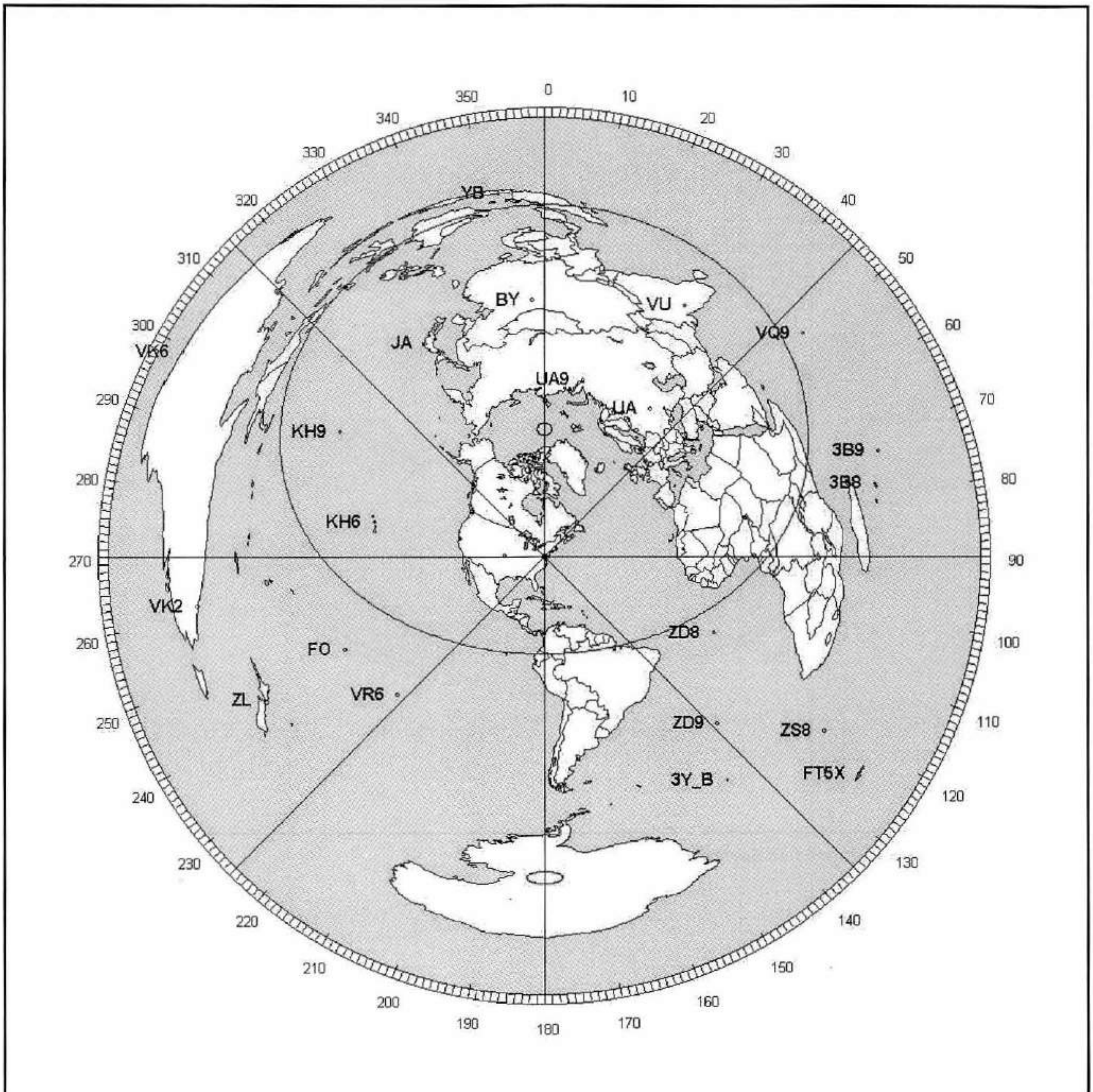


Fig 6-3—Azimuthal map centered on Washington, DC. (Map generated using *GCMWin* version 2.3.)

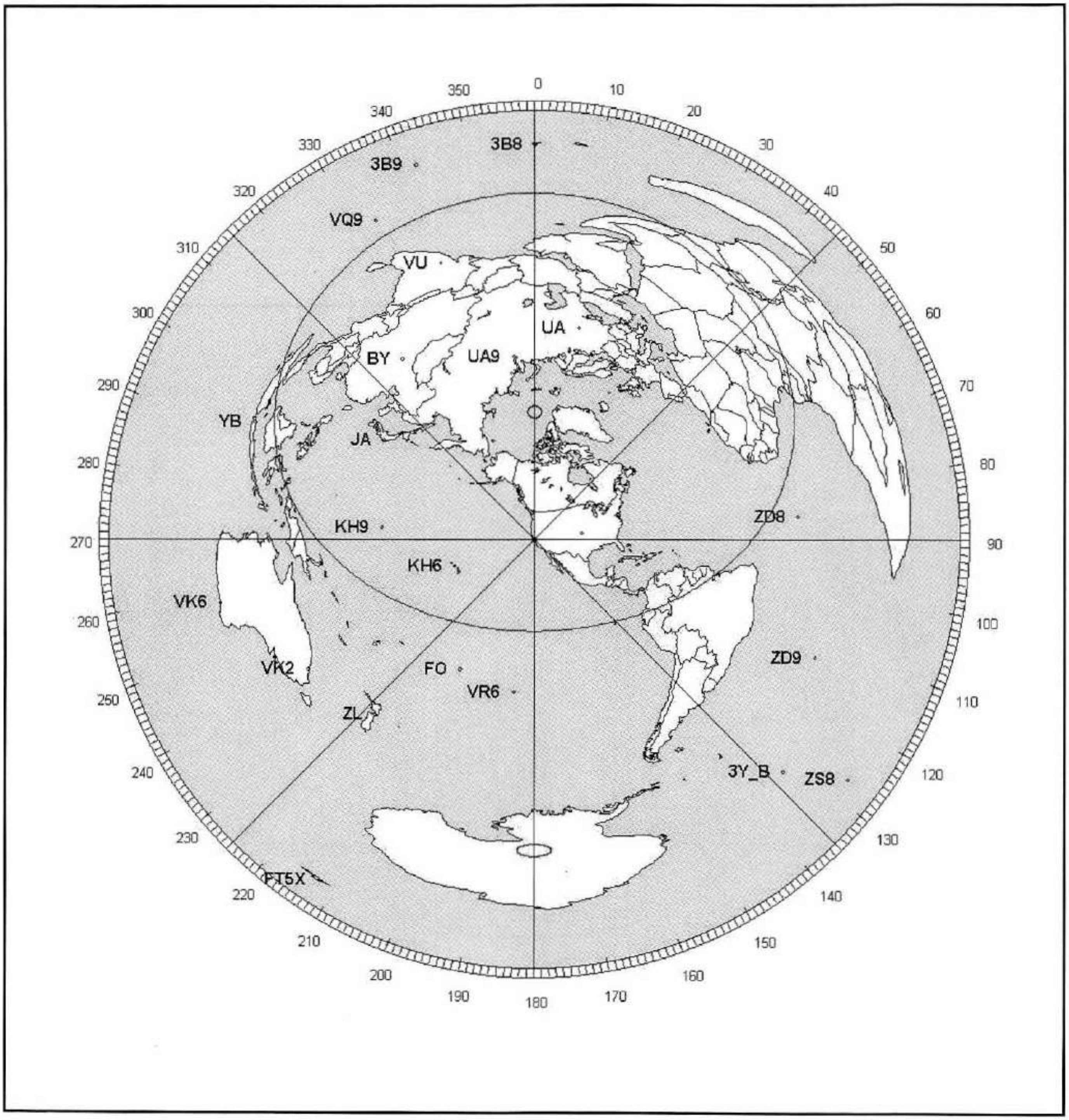


Fig 6-4—Azimuthal map centered on San Francisco, California.

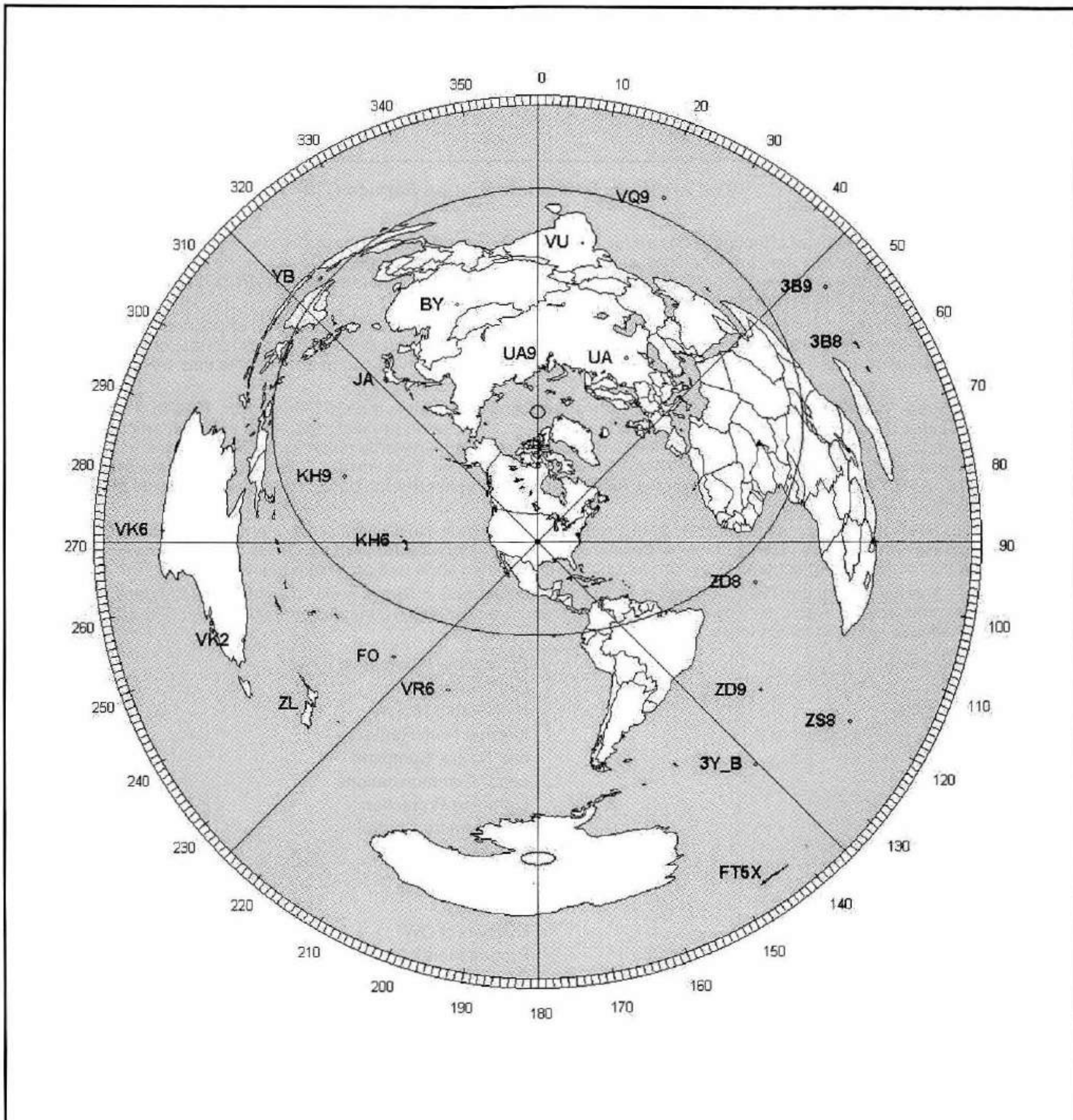


Fig 6-5—Azimuthal map centered on Wichita, Kansas.

Q **Where can I get technical information and answers concerning my particular situation?**

The ARRL Technical Information Service (TIS)

The ARRL answers questions of a technical nature for ARRL members and nonmembers alike through the Technical Information Service. Questions may be submitted via e-mail (tis@arrl.org); phone (860-594-0214); Fax (860-594-0259); or mail (TIS, ARRL, 225 Main St, Newington, CT 06111). The TIS also maintains a home page on *ARRLWeb*: **www.arrl.org/tis**. This site contains links to several technical areas:

TISfind – This search engine contains over 2000 providers of products, services and information of interest to radio amateurs. Before contacting TIS for the address of someone who can repair your radio, or sells antennas, or has old manuals or schematics, look in *TISfind*. Instructions and categories are on the *TISfind* page. This file may be downloaded for use off-line.

ARRL Periodicals Index Search – This **Members Only** search engine contains the *QST* index from 1915 to the present and the *QEX* index from 1981 to the present. For *QST* issues from 1970 to the present, and some selected articles back to 1950, identifying keywords have been added to the database. By entering keywords (such as ANTENNA) or combinations of keywords (such as CONSTRUCTION ANTENNA VERTICAL HF) into the **Title words:** field, you may create dynamic bibliographies. A KEYWORD list is provided on the ARRL Periodicals Index Search page. This replaces the old bibliographies TXT files.

QST Product Reviews — There is a link to a list of Product Reviews from 1970 to the present and for **Members Only** these Product Reviews may be viewed online or downloaded to your computer for printing. There are also links to ARRL book companion software, project templates, product notes, and source code and programs mentioned in *QST* articles.

TIS Pages — The flagship of the TIS Web Page is the Technical Information Pages menu. These articles replace the old TIS Packages that were available only by mail in the past. There are now over 100 topics containing over 500 articles for viewing or download. A list of topics follows:

Access for the Blind

Antennas
- Antenna Projects
- Antenna Gain
- Antenna Ground
- Antenna Theory
- Balloon Antenna
- Grounding
- Indoor
- Receiving Wire Antennas
- Smith Charts
- Transmission Lines/SWR
- Transmatch/Antenna Tuner

Antique/Vintage Radio

Amateur Television
- ATV — Fast Scan TV
- SSTV — Slow Scan TV

Batteries

Buying a Rig

Beginner Ham
- First Steps in Radio
- Your First Antenna

Construction Projects/Techniques
- Antenna Projects
- Building Equipment
- Construction Techniques
- Projects for the Ham Shack
- QRP Projects
- Servicing Equipment
- Surface Mount Technology
- Tube Amplifiers
- VHF Projects
- Tube Transmitters/Receivers

Digital Modes
- AMTOR, APRS, Packet, RTTY, TCP/IP
- Digital Voice
- PSK31
- WEFAX

DSP — Digital Signal Processing

EME — Moonbounce

Emergency/Alternative Power

Grid Squares

Ham Radio History

Internet Ham Radio

Lab Notes, Complete

Laser Communications

Lightning Protection

Link/Remote Control

Mobile
- Marine
- VHF Antennas

Morse/CW
- Coherent CW

Propagation

QRP

Repeaters

RF Exposure

RFI/EMI

Safety
- EDS (Electrostatic Discharge Safety)
- Electrical Safety
- RF Exposure (New!)

Satellites
- General
- Phase 3D

Science Fair/Merit Badge Projects

UHF/Microwave
- UHF/Microwave Projects and Information

Check back often for new and updated TIS pages.

QST and QEX Article Reprints — Reprints are available at nominal cost from the ARRL Technical Secretary by mail (Reprints, ARRL, 225 Main St, Newington, CT 06111), by telephone (860-594-0278), or e-mail (**reprints@arrl.org**). Reprints cannot be e-mailed or attached to an e-mail message. Article copies must be prepaid. The most convenient payment method is via a major credit card.

Q **Where can I find addresses for the major manufacturers, places to get manuals, parts, etc.?**

A These and more and be found in a database called TISfind. It can be found on the ARRL Handbook CD, can be downloaded through the ARRL TIS Web page (**www.arrl.org/tis/**) or accessed on-line from the same Web page.

Here are a few examples:

MAJOR AMATEUR RADIO MANUFACTURERS

(ADI)
Premier Communications Corp.
480 Apollo, Suite E
Brea, CA 92821
USA
Phone: 714-257-0300
Fax: 714-257-0600
Email: premier@adi-radio.com
Web: **www.adi-radio.com/**

Alinco Electronics
438 Amapola Avenue, #130
Torrance, CA 90501
USA
Phone: 310-618-8616
Fax: 310-618-8758
Email: alinco@alinco.com
Web: **www.alinco.com/**

ICOM America, Inc
2380 116th Ave NE
PO Box C-90029
Bellevue, WA 98004
USA
Phone: 425-454-8155
425-450-6088 (literature)
800-858-6252
Fax: 425-454-1509
Email: 75540.525@compuserve.com (tech support)
Web: **www.icomamerica.com/**

Kenwood Communications Corp
2201 East Dominguez Street
PO Box 22745
Long Beach, CA 90801-5745
USA
Phone: 310-639-5300 (customer support)
800-KENWOOD (536-9663 - repair locations/parts)
310-761-8284 (BBS)
Fax: 310-631-3913
Web: **www.kenwood.net/**

Patcomm Corporation
7 Flowerfield St
St James, NY 11780
USA
Phone: 631-862-6512
Fax: 631-862-6529
Email: patcomm1@aol.com
Web: **www.qth.com/patcommradio/index.htm**

Ten-Tec, Inc
1185 Dolly Parton Parkway
Sevierville, TN 37862
USA
Phone: 865-453-7172
865-428-0364 (Repairs)
Fax: 865-428-4483
Web: **www.tentec.com/**

Yaesu U.S.A.
17210 Edwards Rd
Cerritos, CA 90703
USA
Phone: 562-404-2700
Fax: 562-404-1210
Email: yaesu@worldnet.att.net
Web: **www.yaesu.com/**

AMATEUR RADIO KIT SUPPLIERS

EleCraft
PO Box 69
Aptos, CA 95001-0069
USA
Phone: 831-662-8345
Fax: 831-662-0830
Email: radios@elecraft.com
Web: **www.elecraft.com/**

EMTECH
1127 Poindexter Ave W
Bremertom, WA 98312
USA
Phone: 360-405-6805
Email: emtech@steadynet.com
Web: **emtech.steadynet.com/**
Contact name: Scott Gregson, KC7MAS

Oak Hills Research
2460 S. Moline Way
Aurora, CO 80014
USA
Phone: Orders: 800-238-8205
303-752-3382
Fax: 303-745-6792
Email: qrp@ohr.com
Web: **www.ohr.com/**

Ramsey Electronics, Inc
793 Canning Pkwy
Victor, NY 14564
USA
Phone: 716-924-4560
Fax: 716-924-4555
Web: **www.ramseyelectronics.com/**

Red Hot Radio
1717 Andover Lane
San Jose, CA 95124-4744
USA
Phone: 408-390-6805
Fax: 800-881-6120
Email: support@redhotradio.com
Web: **www.redhotradio.com**

S & S Engineering
14102 Brown Road
Smithsburg, MD 21783
USA
Phone: 301-416-0661
Fax: 301-416-0963
Email: n3sad@aol.com
Web: **www.sseng.com**

Small Wonder Labs
80 East Robbins Avenue
Newington, CT 06111
USA
Phone: 860-667-3536
Email: dave@smallwonderlabs.com
Web: **smallwonderlabs.com/**

Ten-Tec, Inc
1185 Dolly Parton Parkway
Sevierville, TN 37862
USA
Phone: 865-453-7172
865-428-0364 (Repairs)
Fax: 865-428-4483
Web: **www.tentec.com/**

Vectronics
1007 Highway 25 South
Starkville, MS 39759
USA
Phone: 800-363-2922
601-323-5800
Fax: 601-323-6551
Email: jshurden@vectronics.com
Web: **www.vectronics.com**

Wilderness Radio
PO Box 734
Los Altos, CA 94023-0734
USA
Phone: 650-494-3806
Email: qrpbob@datatamers.com
Web: **www.fix.net/jparker/wild.html**

ANTENNA MANUFACTURERS AND DISTRIBUTORS

Alpha Delta Communications
PO Box 620
Manchester, KY 40962
USA
Phone: 606-598-2029
Fax: 606-598-4413
Email: jimburns@alphadeltacom.com
Web: **alphadeltacom.com/**

Antenna Specialists Co.
Div. of Allen TeleCom Group
30500 Bruce Industry Parkway
Cleveland, OH 44139
USA
Phone: 440-349-8400
Fax: 440-349-8407
Web: **www.allentele.com/antenna/**

Barker and Williamson Corp (B&W)
603 Cidco Road
Cocoa, FL 32926
USA
Phone: 407-639-1510
Fax: 407-639-2545
Email: custsrvc@bwantennas.com
Web: **www.bwantennas.com/**

(Butternut)
Bencher Inc.
831 North Central Avenue
Wood Dale, IL 60191
USA
Phone: 630-238-1183
Fax: 630-238-1186
Email: bencher@bencher.com
Web: **www.bencher.com/**

Cubex Co.
228 Hibiscus St, #9
Jupiter, FL 33458
USA
Phone: 561-748-2830
Fax: 561-748-2831
Email: ebuchannan@gnn.com
Web: **www.cubex.com/**

Cushcraft Corp
P O Box 4680
Manchester, NH 03108
USA
Phone: 603-627-7877
Fax: 603-627-1764
Email: hamsales@cushcraft.com
Web: **www.cushcraft.com/**

(Diamond Antenna)
RF Parts Co
435 South Pacific St
San Marcos, CA 92069
USA
Phone: 760-744-0700
800-737-2787 (orders only)
Fax: 760-744-1943
Email: rfp@rfparts.com
Web: **www.rfparts.com/**

Dovetron
P.O. Box 6160
Nogales, AZ 85628-6160
USA
Phone: 520-281-1681
Fax: 520-281-1684
Email: w6skc@dovetron.com
Web: **www.dovetron.com/**

Force 12
PO Box 1349
Paso Robles, CA 93447
USA
Phone: 800-248-1985
805-227-1680
Fax: 805-227-1684
Email: Force12@interserv.com.
Web: **www.qth.com/force12/**

GAP Antenna Products
99 North Willow Street
Fellsmere, FL 32948
USA
Phone: 561-571-9922
Fax: 561-571-9988
Web: **www.gapantenna.com/**

High Sierra Antennas
Box 2389
Nevada City, CA 95959
USA
Phone: 888-273-3415
530-273-3415
Fax: 530-273-7561
Email: heath@hsantennas.com
Web: **www.hsantennas.com/**

(Hy-Gain)
MFJ Enterprises
PO Box 494
Mississippi State, MS 39762
USA
Phone: 800-647-1800
601-323-0549 (Tech)
Fax: 601-323-6551
Email: mfj@mfjenterprises.com
Web: **www.mfjenterprises.com/**

Isotron Bilal Company
137 Manchester Dr.
Florissant, CO, 80816
USA
Phone: 719-687-0650

(Larsen)
Radiall/Larsen Antenna Technologies
3611 NE 112th Avenue
Vancouver, WA 98682
USA
Phone: 800-ANTENNA (800-268-3662)
360-944-7551
Fax: 360-944-7556
Fax: 800-525-6749
Email: info@radialllarsen.com
Web: **www.larsenantennas.com/**

M2 Antenna Systems Inc.
7560 North Del Mar Avenue
Fresno, CA 93711
USA
Tel: 209-432-8873
Fax: 209-432-3059
Email: m2sales@aol.com
Web: **www.m2inc.com/**

Mosley Electronics
1325 Style Master Drive
Union, MO 63084
USA
Phone: 800-325-4016 (Orders)
800-9MOSLEY (966-7539)
314-994-7872 (Technical)
Fax: 314-994-7873
Web: **www.mosley-electronics.com/**

Newtronics Antenna Corp. - Hustler
1 Newtronics Place
Mineral Wells, TX 76067
USA
Phone: 877-994-9499
940-325-1386

(Pro-Am)
Valor Enterprises
1711 Commerce Drive
PO Box 601
Piqua, OH 45356-0601
USA
Phone: 513-778-0074
800-543-2197
Fax: 513-778-0259

Wilson Antenna, Inc.
1181 Grier Drive, Suite A
Las Vegas, NV 89119
USA
Phone: 702-896-0399
800-541-6116
Fax: 702-896-0409
Email: wilson@wilsonantenna.com
Web: **www.wilsonantenna.com/**

ACCESSORY MANUFACTURERS

(AEA)
Tempo Research Corp.
1221 Liberty Way
Vista, CA 92083
USA
Phone: 760-598-8900
760-598-9677 (AEA)
Fax: 760-598-4898
Email: tempo@inetworld.com
Web: **www.aea-wireless.com/**

Ameritron
116 Willow Rd
Starkville, MS 39759
USA
Phone: 662-323-8211
Fax: 662-323-6551
Email: 76206.1763@compuserve.com
Web: **www.ameritron.com/**

Astatic Corp./CTI
PO Box 120 - Harbor & Jackson
Conneaut, OH 44030
USA
Phone: 440-593-1111

Astron Corporation
9 Autry
Irvine, CA 92618
USA
Phone: 949-458-7277
Fax: 949-458-0826
Email: astron@linkline.com
Web: **www.astroncorp.com/**

Belden Wire & Cable Co.
PO Box 1980
Richmond, IN 47374
USA
Phone: 765-983-5200
Fax: 765-983-5257
Web: **www.belden.com/**

Bencher Inc.
831 North Central Avenue
Wood Dale, IL 60191
USA
Phone: 630-238-1183
Fax: 630-238-1186
Email: bencher@bencher.com
Web: **www.bencher.com/**

Bird Electronics Corporation
30303 Aurora Rd
Cleveland, OH 44139
USA
Phone: 440-248-1200
Fax: 440-248-5426
Web: **www.bird-electronic.com/**

Heil Sound Ltd.
5800 N Illinois
Fairview Heights, IL 62208
USA
Phone: 618-257-3000, 618-257-3001

(JPS)
Timewave Technology Inc.
58 Plato Blvd East
St. Paul, MN 55107
USA
Phone: 651-222-4858
Fax: 651-222-4861
Email: acaplan@timewave.com, dsp@timewave.com
Web: **www.timewave.com/**

Kantronics
1202 East 23rd Street
Lawrence, KS 66046-5099
USA
Phone: 785-842-7745
785-842-4476 (technical)
Fax: 785-842-2031
Email: purchasing@kantronics.com
Web: **www.kantronics.com/**

MFJ Enterprises
PO Box 494
Mississippi State, MS 39762
USA
Phone: 800-647-1800
601-323-0549 (Tech)
Fax: 601-323-6551
Email: mfj@mfjenterprises.com
Web: **www.mfjenterprises.com/**

Mirage Communications
116 Willow Road
Starkville, MS 39759
USA
Phone: 601-323-8287
Fax: 601-323-6551
Web: **www.mirageamp.com/**

Palomar Engineers
PO Box 462222
Escondido, CA 92046
USA
Phone: 760-747-3343
Fax: 760-747-3346
Email: palomar@compuserve.com
Web: **www.palomar-engineers.com/**

Shure Brothers
222 Hartrey Avenue
Evanston, IL 60202
USA
Phone: 847-866-2200
Fax: 847-866-2279
Email: sales@shure.com
Web: **www.shure.com/**

Timewave Technology Inc.
58 Plato Blvd East
St. Paul, MN 55107
USA
Phone: 651-222-4858
Fax: 651-222-4861
Email: acaplan@timewave.com, dsp@timewave.com
Web: **www.timewave.com/**

The Vibroplex Co., Inc.
11 Midtown Park E.
Mobile, AL 36606-4141
USA
Phone: 800-840-8873 (orders)
334-478-8873
Fax: 334-476-0465
Email: fmitch@maf.mobile.al.us
Web: **www.vibroplex.com/**

MANUALS

(Army Technical Manuals)
Center for Legislative Archives
National Archives
Washington, DC 20408
USA
Phone: 202-501-5350
Fax: 202-219-2176
Email: inwuire@arch2.nara.gov
Notes: Record group 287-US Army Technical Manuals for radio equipment manufactured from 1940 to 1979. Photocopies can be obtained at a cost of 25 cents per page and a $6 minimum mail order fee. A 'Reproduction Service Order' must first be completed by the National Archives to determine the cost of the specific manual you desire. The manual on this form must be identified by its proper Army Technical Manual number. If this number is not known, contact your nearest US Government Depository Library for assistance. These are usually the main public libraries in large and medium sized cities. The National Archives Microfilm Publications Pamphlet describing M1641, also available from the Archives, describes this procedure.

Hi-Manuals
PO Box 802
Council Bluffs, IA 51502
USA
Email: himan@radiks.net
Web: **www.hi-manuals.com/HomePage.htm**
Notes: An extensive collection of manuals for most ham and SWL equipment, covering from the mid 30s to the late 70s, plus

Kenwood manuals to 1983. Send for a current catalog ($2 US, $3 elsewhere) for a complete list of brands, models, prices and ordering information.

The Manual Man
27 Walling Street
Sayreville, NJ 08872-1818
USA
Phone: 732-238-8964
Fax: 732-238-8964
Web: **www.manualman.com/**
Notes: Extensive collection of vintage original or replicated manuals for amateur, audio, and radio-related equipment. Manufacturers include Lafayette, Clegg, Drake, Eico, Hallicrafters, Hammarlund, National, etc. Send two first class stamps for catalog. Also, large supply of new (old stock) parts for many of the Lafayette radio models (send request along with an SASE).

The Raymond Sarrio Company
6147 Via Serena St.
Alta Loma, CA 91701
USA
Phone: 800-413-1129 (orders)
909-413-1129
Fax: 909-484-5125
Email: wb6siv@cyberg8t.com
Web: **www.sarrio.com/**

US Army Military History Institute
Carlisle Barracks, PA 17013-5008
USA
Phone: 717-245-3611
Notes: Technical manuals for military radio equipment. If possible, include the manual number with your request. If this is unknown, include a complete description of the equipment including the model name, model numbers and the time period in which the equipment was in use, if known. Once a specific manual is identified, it may be obtained in one of two ways. If the institute possess three or more copies, one may be borrowed through interlibrary loan procedures. This process must be initiated at the your local library. Up to six items at a time may be borrowed for 60 days. (Noncirculating materials include periodicals, manuscripts, books published before 1940, many unit histories and rare and hard-to-replace books). Please note we are a lender of last resort, which means we do not loan materials that are readily available elsewhere. Alternatively, photocopies can be purchased. Our photocopying charges are $10.00 for the first ten pages of copying and $.25 for each additional page up to 300 pages per patron per calendar year. Checks or money orders should be made payable to the Defense Accounting Officer, but mailed directly to the undersigned. Residents of other nations should pay in U.S. currency with an international money order or a check that will clear through U.S. banks. Selected bibliographies of Institute holdings are available through interlibrary loan.

W7FG Vintage Manuals
3300 Wayside Drive
Bartlesville, OK 74006
USA
Phone: 800-807-6146 (orders)
918-333-3754
Email: w7fg@eigen.net
Web: **www.w7fg.com/**
Notes: W7FG has almost all of the old Collins, Drake, Hallicrafters, Hammarlund, Heathkit, Johnson, National and Swan owner's manuals, plus most others. Manuals for all KDK, Santec and Welz equipment. W7FG also carries telephone filters, books and VHF antennas.

Q **Where can I get parts?**

A Here are a few *free* catalogs you should have. These are companies that have *no minimum order.*

Digi-Key Corporation
701 Brooks Ave S
PO Box 677
Thief River Falls, MN 56701-0677
USA
Phone: 800-344-4539 (800-DIGI-KEY)
Fax: 218-681-3380
Web: **www.digikey.com/**

Jameco Electronics
1355 Shoreway Rd
Belmont, CA 94002
USA
Phone: 800-831-4242
Fax: 800-237-6948
Email: info@jameco.com
Web: **www.jameco.com**

MCM Electronics
650 Congress Park Drive
Centerville, OH 45459
USA
Phone: 1-800-543-4330
Fax: 1-800-765-6960
Web: **www.i-mcm.com/**

Mouser Electronics
2401 Hwy 287 N
Mansfield, TX 76063
USA
Phone: 800-346-6873
Fax: 817-483-0931
Email: sales@mouser.com
Web: **www.mouser.com/**

Q What are the amateur bands?

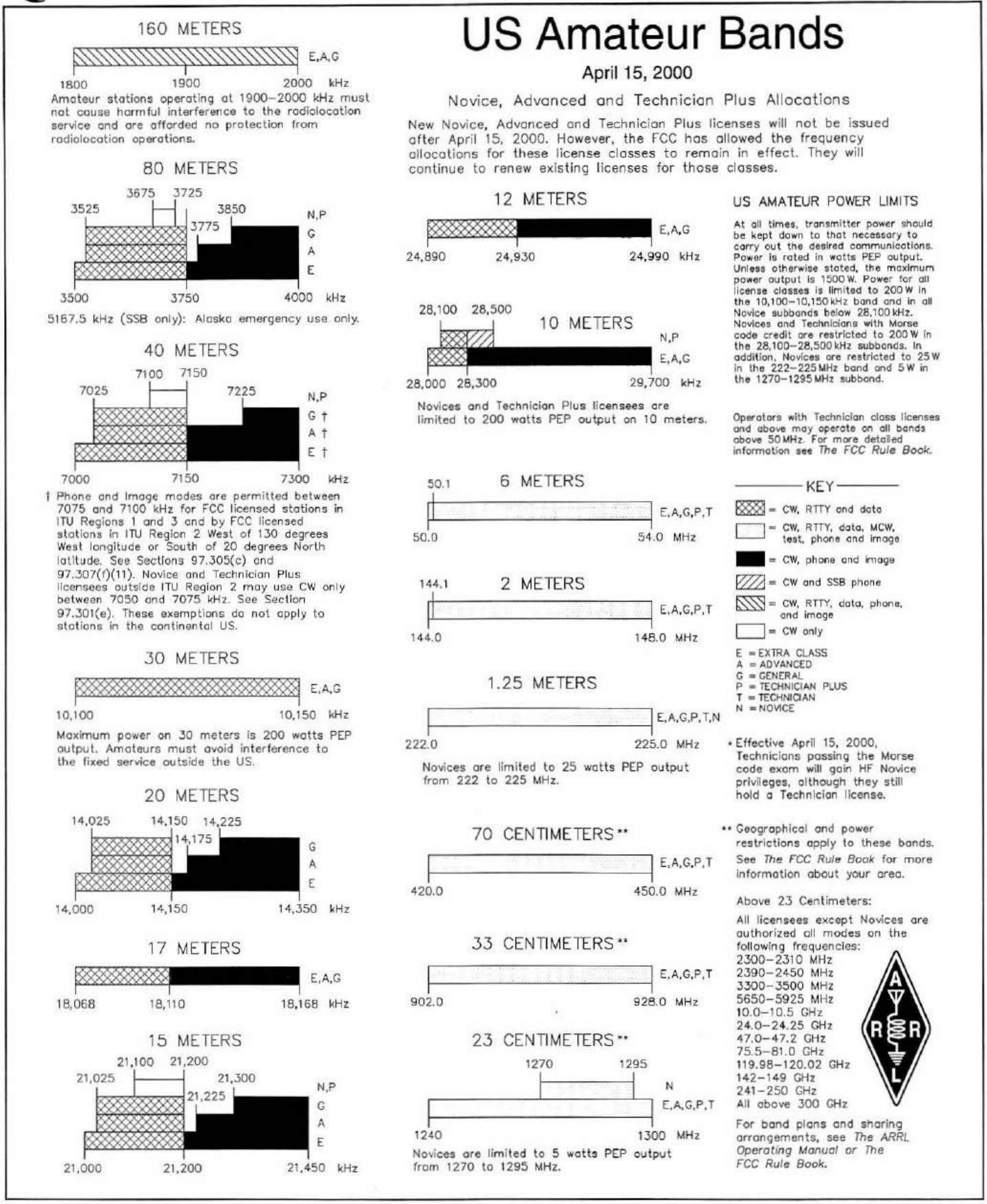


Fig 6-7

Q **Can I get a complete set of the Q signals?**

A Sure, here is as complete a set as you'll need. Remember that to express the Q signal as a question, you will have to follow each one with a question mark.

Q **Can you show me what my dipole's pattern would look like at different heights above ground?**

A Fig 6-8 shows the pattern broadside to the antenna wire. For example, if your wire is running North/South, this is your pattern East/West. The solid-line curves

Q Signals

These Q signals most often need to be expressed with brevity and clarity in amateur work. (Q abbreviations take the form of questions only when each is sent followed by a question mark.)

QRA What is the name of your station? The name of your station is _____.
QRG Will you tell me my exact frequency (or that of _____)? Your exact frequency (or that of _____) is _____ kHz.
QRH Does my frequency vary? Your frequency varies.
QRI How is the tone of my transmission? The tone of your transmission is _____ (1. Good; 2. Variable; 3. Bad).
QRJ Are you receiving me badly? I cannot receive you. Your signals are too weak.
QRK What is the intelligibility of my signals (or those of _____)? The intelligibility of your signals (or those of _____) is _____ (1. Bad; 2. Poor; 3. Fair; 4. Good; 5. Excellent).
QRL Are you busy? I am busy (or I am busy with _____). Please do not interfere.
QRM Is my transmission being interfered with? Your transmission is being interfered with (1. Nil; 2. Slightly; 3. Moderately; 4. Severely; 5. Extremely.)
QRN Are you troubled by static? I am troubled by static _____ (1-5 as under QRM).
QRO Shall I increase power? Increase power.
QRP Shall I decrease power? Decrease power.
QRQ Shall I send faster? Send faster (_____ WPM).
QRS Shall I send more slowly? Send more slowly (_____ WPM).
QRT Shall I stop sending? Stop sending.
QRU Have you anything for me? I have nothing for you.
QRV Are you ready? I am ready.
QRW Shall I inform _____ that you are calling on _____ kHz? Please inform _____ that I am calling on _____ kHz.
QRX When will you call me again? I will call you again at _____ hours (on _____ kHz).
QRY What is my turn? Your turn is numbered _____
QRZ Who is calling me? You are being called by _____ (on _____ kHz).
QSA What is the strength of my signals (or those of _____)? The strength of your signals (or those of _____) is _____ (1. Scarcely perceptible; 2. Weak; 3. Fairly good; 4. Good; 5. Very good).
QSB Are my signals fading? Your signals are fading.
QSD Is my keying defective? Your keying is defective.
QSG Shall I send _____ messages at a time? Send _____ messages at a time.
QSK Can you hear me between your signals and if so can I break in on your transmission? I can hear you between my signals; break in on my transmission.
QSL Can you acknowledge receipt? I am acknowledging receipt.
QSM Shall I repeat the last message which I sent you, or some previous message? Repeat the last message which you sent me [or message(s) number(s) _____].
QSN Did you hear me (or _____) on _____ kHz? I did hear you (or _____) on _____ kHz.
QSO Can you communicate with _____ direct or by relay? I can communicate with _____ direct (or by relay through _____).
QSP Will you relay to _____? I will relay to _____
QST General call preceding a message addressed to all amateurs and ARRL members. This is in effect "CQ ARRL."
QSU Shall I send or reply on this frequency (or on _____ kHz)? Send or reply on this frequency (or _____ kHz).
QSV Shall I send a series of Vs on this frequency (or on _____ kHz)? Send a series of Vs on this frequency (or on _____ kHz).
QSW Will you send on this frequency (or on _____ kHz)? I am going to send on this frequency (or on _____ kHz).
QSX Will you listen to _____ on _____ kHz? I am listening to _____ on _____ kHz.
QSY Shall I change to transmission on another frequency? Change to transmission on another frequency (or on _____ kHz).
QSZ Shall I send each word or group more than once? Send each word or group twice (or _____ times).
QTA Shall I cancel message number _____? Cancel message number _____
QTB Do you agree with my counting of words? I do not agree with your counting of words. I will repeat the first letter or digit of each word or group.
QTC How many messages have you to send? I have _____ messages for you (or for _____).
QTH What is your location? My location is _____
QTR What is the correct time? The correct time is _____
QTV Shall I stand guard for you? Stand guard for me.
QTX Will you keep your station open for further communication with me? Keep your station open for me.
QUA Have you news of _____? I have news of _____.

ARRL QN Signals

QNA* Answer in prearranged order.
QNB Act as relay between _____ and _____.
QNC All net stations copy. I have a message for all net stations.
QND* Net is Directed (Controlled by net control station.)
QNE* Entire net stand by.
QNF Net is Free (not controlled).
QNG Take over as net control station
QNH Your net frequency is High.
QNI Net stations report in. I am reporting into the net. (Follow with a list of traffic or QRU.)
QNJ Can you copy me?
QNK* Transmit messages for _____ to _____.
QNL Your net frequency is Low.
QNM* You are QRMing the net. Stand by.
QNN Net control station is _____. What station has net control?
QNO Station is leaving the net.
QNP Unable to copy you. Unable to copy _____.
QNQ* Move frequency to _____ and wait for _____ to finish handling traffic. Then send him traffic for _____.
QNR* Answer _____ and Receive traffic.
QNS Following Stations are in the net.* (follow with list.) Request list of stations in the net.
QNT I request permission to leave the net for _____ minutes.
QNU* The net has traffic for *you*. Stand by.
QNV* Establish contact with _____ on this frequency. If successful, move to _____ and send him traffic for _____.
QNW How do I route messages for _____?
QNX You are excused from the net.*
QNY* Shift to another frequency (or to _____ kHz) to clear traffic with _____.
QNZ Zero beat your signal with mine.

***For use only by the Net Control Station.**

Notes on Use of QN Signals

These QN signals are special ARRL signals for use in amateur CW nets *only*. They are not for use in casual amateur conversation. Other meanings that may be used in other services do not apply. Do not use QN signals on phone nets. *Say it with words.* QN signals need not be followed by a question mark, even though the meaning may be interrogatory.

are the "perfect-earth" patterns and the shaded curves represent the effects of average earth.

Q How should I install a PL-259 connector and a BNC connector?

A Here is how to attach a PL-259 to both RG-8 and RG-58/59 cable and a BNC connector to RG-58/59.

Fig 6-9 shows how to install the solder type of PL-259 connector on RG-8 type cable. Proper preparation of the cable end is the key to success. Follow these simple steps.

1) Measure back 3/4 inch from the cable end and slightly score the outer jacket around its circumference.

2) With a sharp knife, cut along the score line through the outer jacket, through the braid, and through the dielectric material, right down to the center conductor. Be careful not to score the center conductor. Cutting through all outer layers at once keeps the braid from separating.

3) Pull the severed outer jacket, braid and dielectric off the end of the cable as one piece. Inspect the area around the cut, looking for any strands of braid hanging loose. If there are any, snip them off. There won't be any if your knife was sharp enough.

4) Next, score the outer jacket 5/16 inch back from the first cut. Cut through the jacket lightly; do not score the braid. This step takes practice. If you score the braid, start again.

5) Remove the outer jacket. Tin the exposed braid and center conductor, but apply the solder sparingly. Avoid melting the dielectric.

6) Slide the coupling ring onto the cable. (*Don't forget this important step!*)

7) Screw the connector body onto the cable. If you prepared the cable to the right dimensions, the center conductor will protrude through the center pin, the braid will show through the solder holes, and the body will actually thread itself onto the outer cable jacket.

8) With a large soldering iron, solder the braid through each

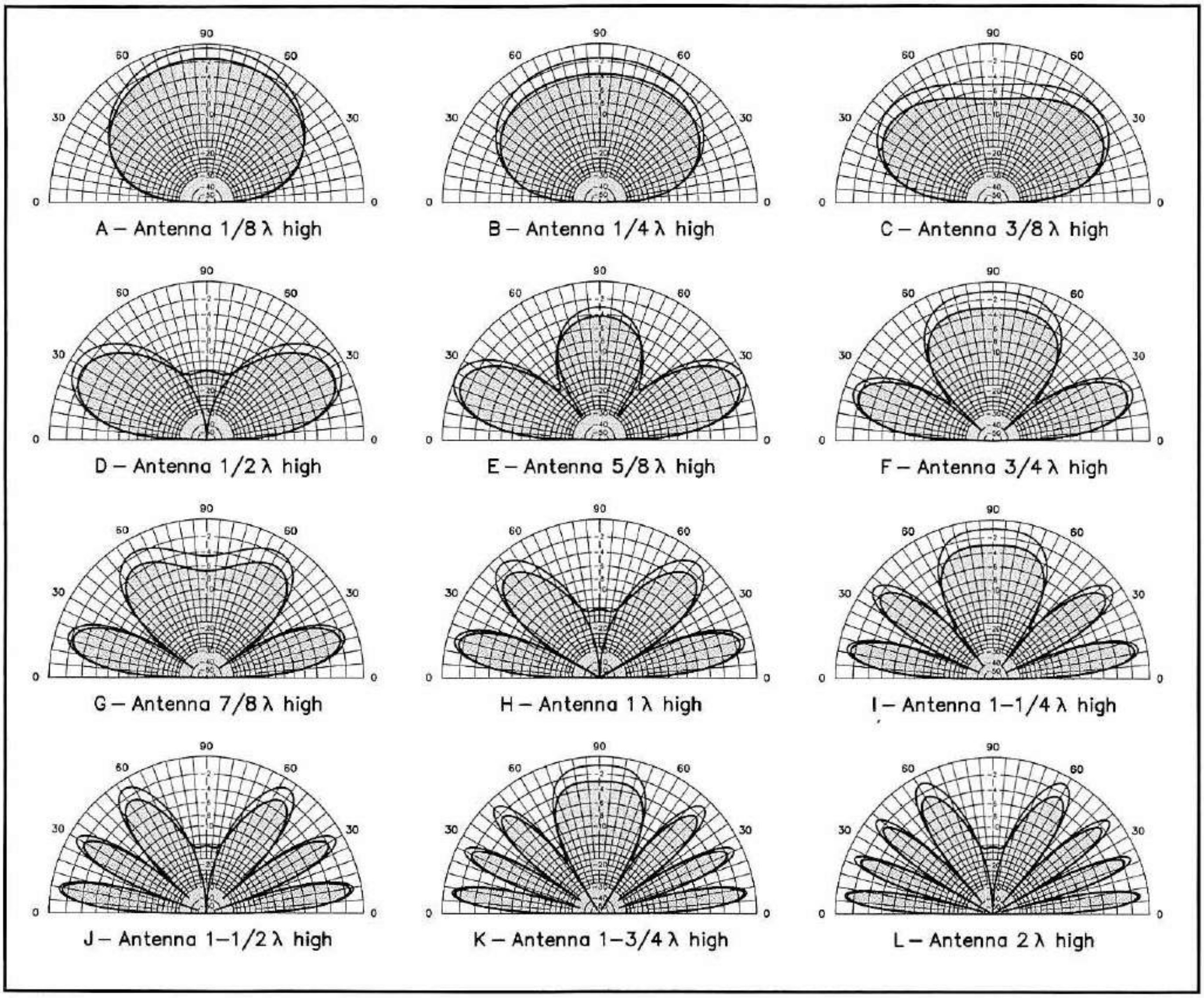


Fig 6-8—Reflection factors for horizontal antennas at various heights above ground. The solid-line curves are the perfect-earth patterns (broadside to the antenna wire); the shaded curves represent the effects of average earth (k=13, G=0.005 S/m) at 14 MHz. Add 7 dB to values shown for absolute gain in dBd referenced to dipole in free space. For example, peak gain over perfect earth at 5/8 λ height is 7 dBd (or 9.15 dBi) at 25° elevation.

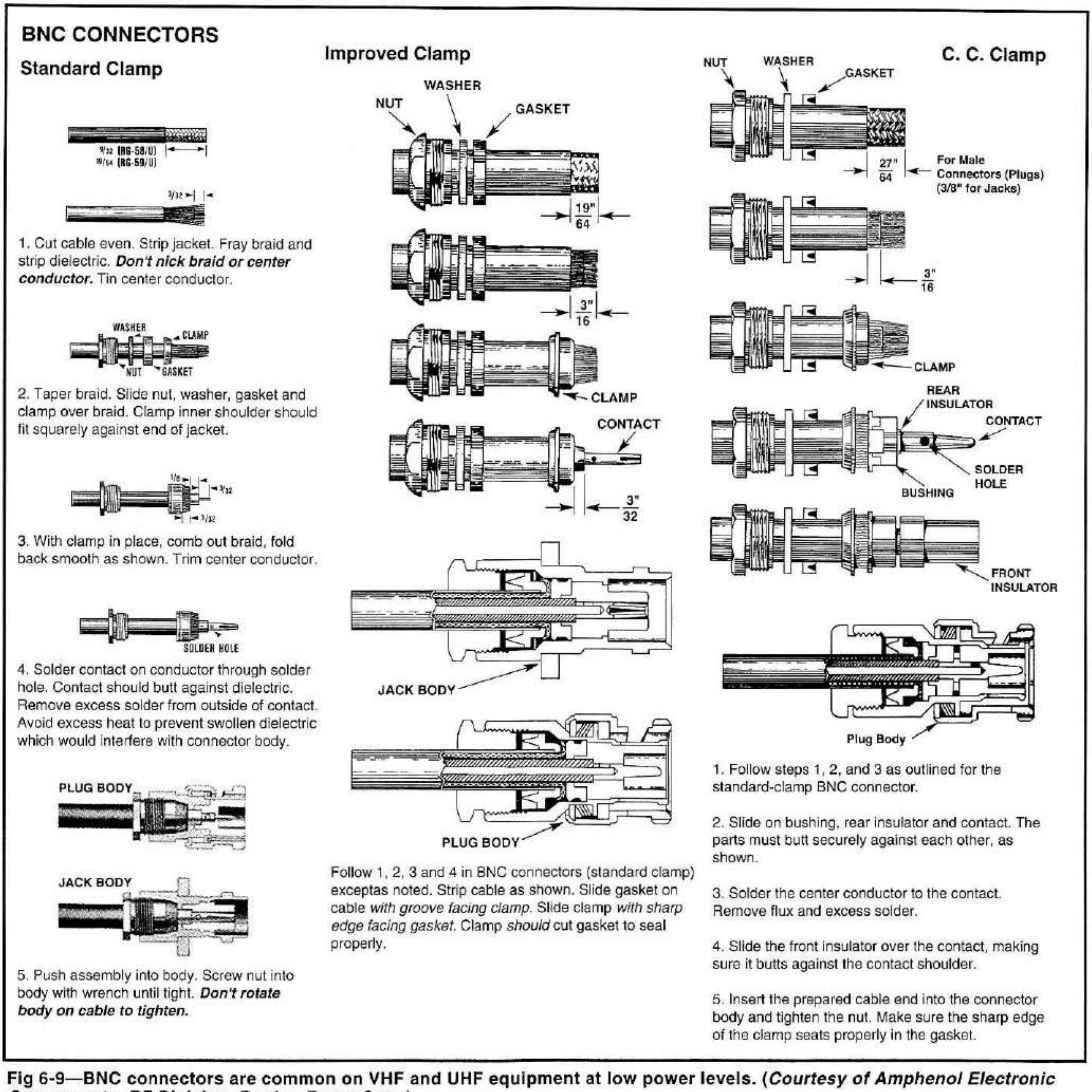


Fig 6-9—BNC connectors are common on VHF and UHF equipment at low power levels. (*Courtesy of Amphenol Electronic Components, RF Division, Bunker Ramo Corp.*)

of the four solder holes. Use enough heat to flow the solder onto the connector body, but no so much as to melt the dielectric. Poor connection to the braid is the most common form of PL-259 failure. This connection is just as important as that between the center conductor and the connector. With some practice you'll learn how much heat to use.

9) Allow the connector body to cool somewhat, and then solder the center connector to the center pin. The solder should flow on the inside, not the outside of the pin. Trim the center conductor to be even with the end of the center pin. Use a small file to round the end, removing any solder that may have built up on the outer surface of the center pin. Use a sharp knife, very fine sandpaper, or steel wool to remove any solder flux from the outer surface of the center pin.

10) Screw the coupling onto the body, and the job is finished.

Q What tools do I need to get started—antenna installation, kit building, general ham shack maintenance and such?

A Here is a list for the *well* stocked ham shack. I have marked the tools you will need to do those tasks that the average ham does around the station. The Dremel tool is marked because it is so handy around the house and it makes a great gift to put on your wish list.

* **tools to start with**

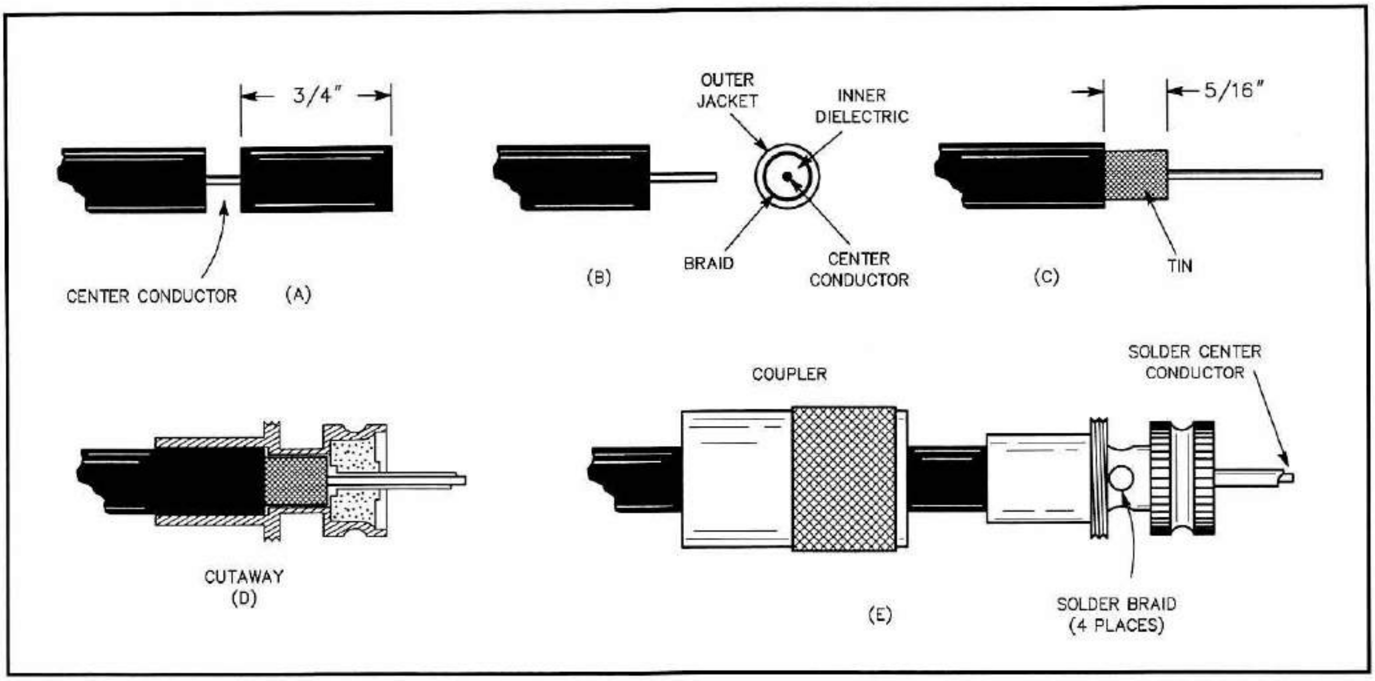
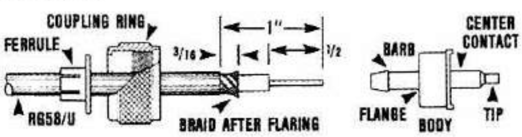
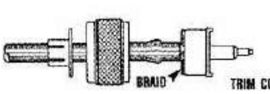


Fig 6-10—The PL-259 or UHF connector is almost universal for amateur HF work and is popular for equipment operating up through the VHF range. Steps for assembly are given in detail in the text.

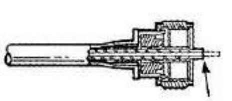
83-58FCP



1. Strip cable - ***don't nick braid, dielectric or conductor.*** Slide ferrule, then coupling ring on cable. Flare braid slightly by rotating conductor and dielectric in circular motion.

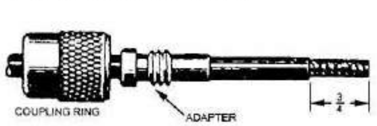


2. Slide body on dielectric, barb going under braid until flange is agains outer jacket. Braid will fan out against body flange



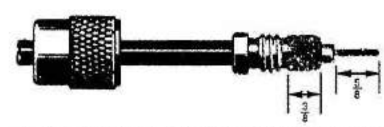
3. Slide nut over body. Grasp cable with hand and push ferrule over barb until braid is captured between ferrule and body flange. Squeeze crimp tip only of center contact with pliers; alternate-solder tip.

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

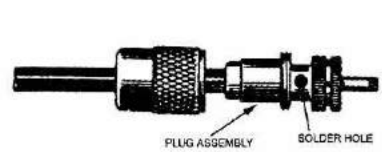


1. Cut end of cable even. Remove vinyl jacket 3/4" - don't nick braid. Slide coupling ring and adapter on cable.

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.

Fig 6-11—Crimp-on connectors and adapters for use with standard PL-259 connectors are popular for connecting to RG-58 and RG-59 coax. (*This material courtesy of Amphenol Electronic Components, RF Division, Bunker Ramo Corp.*)

Simple Hand Tools

Screwdrivers

*Slotted, 3-inch, $^{1}/_{8}$-inch blade
Slotted, 8-inch, $^{1}/_{8}$-inch blade
Slotted, 3-inch, $^{3}/_{16}$-inch blade
*Slotted, stubby, $^{1}/_{4}$-inch blade
Slotted, 4-inch, $^{1}/_{4}$-inch blade
Slotted, 6-inch, $^{5}/_{16}$-inch blade
*Phillips, $2^{1}/_{2}$-inch, #0 (pocket clip)
*Phillips, 3-inch, #1
Phillips, stubby, #2
*Phillips, 4-inch, #1
*Phillips, 4-inch, #2
Long-shank screwdriver with holding clip on blade
*Jeweler's set
Right-angle, slotted and Phillips

Pliers, Sockets and Wrenches

*Long-nose pliers, 6- and 4-inch
*Diagonal cutters, 6- and 4-inch
*Channel-lock pliers, 6-inch
*Slip-joint pliers
*Locking pliers (Vise Grip or equivalent)
Socket nut-driver set, $^{3}/_{16}$ to $^{1}/_{2}$-inch
Set of socket wrenches for hex nuts
*Allen (hex) wrench set
*Wrench set
Adjustable wrenches, 6- and 10-inch
*Tweezers, regular and reverse-action
Retrieval tool/parts holder, flexible claw
*Retrieval tool, magnetic

Cutting and Grinding Tools

File set consisting of flat, round, half-round, and triangular. Large and miniature types recommended
Burnishing tool
*Wire strippers
Wire crimper
*Hemostat, straight
*Scissors
Tin shears, 10-inch
Hacksaw and blades
Hand nibbling tool (for chassis-hole cutting)
Scratch awl or scriber (for marking metal)
Heavy-duty jackknife
*Knife blade set (X-ACTO or equivalent)
Machine-screw taps, #4-40 through #10-32 thread
Socket punches, $^{1}/_{2}$ in, $^{5}/_{8}$ in, $^{3}/_{4}$ in, $1^{1}/_{8}$ in, $1^{1}/_{4}$ in, and $1^{1}/_{2}$ in.
Tapered reamer, T-handle, $^{1}/_{2}$-inch maximum width
Deburring tool

Miscellaneous Hand Tools

Combination square, 12-inch, for layout work
Hammer, ballpeen, 12-oz head
Hammer, tack
Bench vise, 4-inch jaws or larger
Center punch
Plastic alignment tools
*Mirror, inspection
*Flashlight, penlight and standard
*Magnifying glass
*Ruler or tape measure
*Dental pick
Calipers
Brush, wire
Brush, soft
Small paintbrush
IC-puller tool

Hand-Powered Tools

Hand drill, $^{1}/_{4}$-inch chuck or larger
High-speed drill bits, #60 through $^{3}/_{8}$-inch diameter

Power Tools

Motor-driven emery wheel for grinding
*Electric drill, hand-held
Drill press
Miniature electric motor tool (Dremel or equivalent) and accessory drill press

Soldering Tools and Supplies

*Soldering pencil, 30-W, $^{1}/_{8}$-inch tip
Soldering iron, 200-W, $^{5}/_{8}$-inch tip
*Solder, 60/40, resin core
*Soldering gun, with assorted tips
*Desoldering tool
Desoldering wick

Safety

*Safety glasses

Hearing protector, earphones or earplugs

Fire extinguisher

*First-aid kit

Useful Materials

Medium-weight machine oil

*Contact cleaner, liquid or spray can

Duco modeling cement or equivalent

*Electrical tape, vinyl plastic

*Sandpaper, assorted

*Emery cloth

*Steel wool, assorted

Cleaning pad, Scotchbrite or equivalent

Cleaners and degreasers

Contact lubricant

Sheet aluminum, solid and perforated, 16- or 18-gauge, for brackets and shielding.

Aluminum angle stock, $^1/_2 \times {}^1/_2$-inch

$^1/_4$-inch-diameter round brass or aluminum rod (for shaft extensions)

Machine screws: Round-head and flat head, with nuts to fit. Most useful sizes: 4-40, 6-32 and 8-32, in lengths from $^1/_4$-inch to $1^1/_2$ inches. (Nickel-plated steel is satisfactory except in strong RF fields, where brass should be used.)

Bakelite, Lucite, polystyrene and copper-clad PC-board scraps.

Soldering lugs, panel bearings, rubber grommets, terminal-lug wiring strips, varnished-cambric insulating tubing, heat-shrinkable tubing.

Shielded and unshielded wire.

Tinned bare wire, #22, #14 and #12.

Enameled wire, #20 through #30

Q How about a complete list of the RST system?

A The RST system is used to convey the quality and clarity of a signal. All three components are used on CW. However, the Tone is omitted in phone work.

The RST System

READABILITY

1—Unreadable.
2—Barely readable, occasional words distinguishable.
3—Readable with considerable difficulty.
4—Readable with practically no difficulty.
5—Perfectly readable.

SIGNAL STRENGTH

1—Faint signals, barely perceptible.
2—Very weak signals.
3—Weak signals.
4—Fair signals.
5—Fairly good signals.
6—Good signals.
7—Moderately strong signals.
8—Strong signals.
9—Extremely strong signals.

TONE

1—Sixty-cycle ac or less, very rough and broad.
2—Very rough ac, very harsh and broad.
3—Rough ac tone, rectified but not filtered.
4—Rough note, some trace of filtering.
5—Filtered rectified ac but strongly ripple-modulated.
6—Filtered tone, definite trace of ripple modulation.
7—Near pure tone, trace of ripple modulation.
8—Near perfect tone, slight trace of modulation.
9—Perfect tone, no trace of ripple of modulation of any kind.

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