Contents

Chapter 24 — Online Content

Articles
- A Look at Gasoline Powered Inverter Generators by Bob Allison, WB1GCM
- Field Day Towers — Doing it Right by Don Daso, K4ZA and Ward Silver, NØAX

Chapter 24
Assembling a Station

Although many hams might not build a major project, such as a transmitter, receiver or amplifier, they do have to assemble the various components into a working station. There are many benefits to be derived from assembling a safe, comfortable, easy-to-operate collection of radio gear, whether the station is at home, in the car or in a field. The section on Portable Stations was brought up to date by Matt Heere, N3NWV, addressing the style of operating's growing popularity. Alan Applegate, KØBG, expanded the section on Mobile Stations to cover electric vehicles. Configuring and operating a station by remote control is now common and Ken Norris, KK9N, keeps the Remote Stations section up to date. Such topics as station location, grounding and bonding, power sources, station layout, and cable routing are also covered.

Aids for Hams with Disabilities

A station used by an amateur with physical disabilities or sensory impairments may require adapted equipment or particular layout considerations. The station may be highly customized to meet the operator's needs or just require a bit of "tweaking." Each situation must be approached individually based on the operator's particular needs. However, many types of situations have already been encountered and worked through by others, potentially eliminating the need to start from scratch.

An excellent resource is the Courage Kenny Handiham Program. Part of the Courage Kenny Rehabilitation Institute, this program provides a number of services to hams (and aspiring hams) with disabilities. You'll find a wealth of useful information on their comprehensive website, **www.handiham.org**.

24.1 Fixed Stations

Regardless of the type of installation you are attempting, good planning greatly increases your chances of success. Take the time to think the project all the way through, consider alternatives, and make rough measurements and sketches during your planning and along the way. You will save headaches and time by avoiding "shortcuts." What might seem to save time now may come back to haunt you with extra work when you could be enjoying your station.

One of the first considerations should be to determine what type of operating you intend to do. While you do not want to strictly limit your options later, you need to consider what you want to do, how much you have to spend and what room you have to work with. There is a big difference between a casual operating position and a "big gun" contest station, for example.

24.1.1 Selecting a Location

Selecting the right location for your station is the first and perhaps the most important step in assembling a safe, comfortable, convenient station. The exact location will depend on the type of home you have and how much space can be devoted to your station. Fortunate amateurs will have a spare room to devote to housing the station; some may even have a separate building for their exclusive use. Most must make do with a spot in the cellar or attic, or a corner of the living room is pressed into service.

Examine the possibilities from several angles. A station should be comfortable; odds are good that you'll be spending a lot of time there over the years. Some unfinished basements are damp and drafty — not an ideal environment for several hours of leisurely hamming. Attics have their drawbacks, too; they can be stifling during warmer months. If possible, locate your station away from the heavy traffic areas of your home. Operation of your station should not interfere with family life. A night of chasing DX on 80 meters may be exciting to you, but the other members of your household may not share your enthusiasm.

Keep in mind that you must connect your station to the outside world. The location you choose should be convenient to a good power source and an adequate ground. If you use a computer, you may need access to the Ingernert. There should be a fairly direct route to the outside for running antenna feed lines, rotator control cables and the like.

Although most homes will not have an "ideal" space meeting all requirements, the right location for you will be obvious after you scout around. The amateurs whose stations are depicted in **Figures 24.1** through **24.3** all found the right spot for them. Weigh

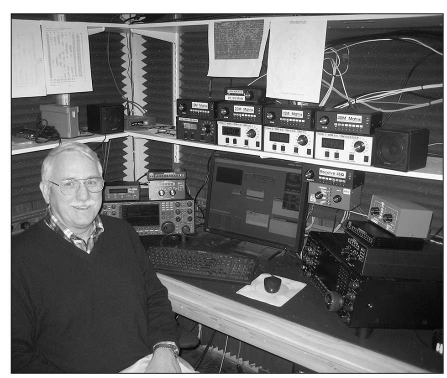

Figure 24.1 — Scott Redd, KØDQ, operated this station at WW1WW in pursuit of top scores in DX contests. Notice that the equipment on the operating desk is laid out logically and comfortably for long periods "in the chair." [Woody Beckford, WW1WW, photo]

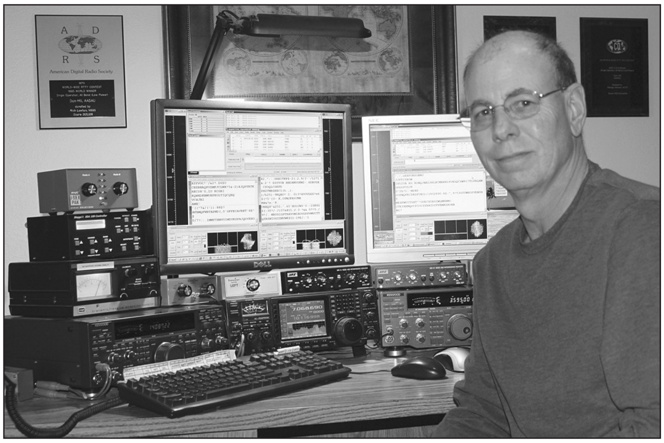

Figure 24.2 — Top RTTY contest operator Don Hill, AA5AU operates with low power from his effective station. RTTY operation emphasizes use of the computer mouse so Don's desk has lots of room for his "mouse hand." [Shay Hill, photo]

Figure 24.3 — Spreading out horizontally, John Sluymer, VE3EJ, has arranged his effective contest and DXing station to keep all of the controls at the same level for easy adjustment. [John Sluymer, VE3EJ, photo]

the trade-offs and decide which features you can do without and which are necessary for your style of operation. If possible pick an area large enough for future expansion.

24.1.2 Station Grounding and Bonding

As discussed in the **Safe Practices** chapter, the station's ground system is very important and serves three purposes: ac safety, lightning protection, and RF management. With some attention to detail and planning, your station can be designed to satisfy all three needs from the start. This section is limited to providing general guidelines for grounding and bonding. Additional information is available from the ARRL's website in the Technology section under the Radio Technology Topics page's group of Safety articles and resources. The ARRL's *Grounding and Bonding for the Radio Amateur* collects a great deal of information into a single book for convenient reference with guidelines for station builders.

AC SAFETY

The **Safe Practices** chapter covers the basic elements of how ac power is configured in residences, including the requirements for grounding and bonding of equipment and earth connections. Make sure your station wiring complies with all ac wiring requirements.

Before building a station or modifying an existing station, start by making sure your existing ac wiring is in good shape. Before you begin, if you are new to ac wiring or uncomfortable around it, get a professional to do the job or have an experienced person show you how to do it. Treated with respect and following simple safety rules, working on ac wiring is safe. This is a good time to read the safety section of any wiring handbook or guide, even if you *think* you know what you're doing.

All branch circuits must have a ground conductor that runs back to the service panel. The ground conductor should be at least as large as the current-carrying conductors so it can handle the same current overloads without causing a fire hazard. The branch circuit ground conductor is almost always one wire in a multi-conductor non-metallic (NM) cable, usually referred to by its trade name, Romex. Inside the cable sheath, the wire is usually bare copper but it can also be have insulation that is green or green-with-yellow-stripes. Make sure the ac service entry ground rod or other earth connection is present and that all wiring to it is sufficiently heavy and that all connecting hardware is in good condition.

Along with the residence's ac service entry ground rod, additional ground rods are often installed for panels where feed lines enter a building, for antennas and towers, and a direct connection to the station's bonding bus. All of these external earth connections must be bonded together using heavy wire or strap.

Although it has been long recommended in amateur radio articles and books, do not use a metal cold water pipe as a ground electrode. Those recommendations were made in an era when copper and galvanized pipe were used for all water service plumbing. Plastic pipe is now the standard and mixed systems of copper and plastic pipe are common. Your local building codes will specify how the pipes inside your home should or shouldn't be connected together for electrical grounding purposes.

A bonding bus is a good way for connecting equipment together and also provides a good way to make ac safety grounding connections. Installed behind or under your equipment, the bus can be any heavy metal conductor — copper or aluminum are both available and relatively inexpensive. Strap, pipe, or even heavy wire will do. Connect the bus to the ac safety ground conductor at a power outlet. Only one connection is needed. Then connect the enclosure of each piece of equipment to the bus using a piece of #14 AWG wire, strap, or flat-weave grounding braid.

The typical amateur station includes a lot of accessory equipment that is itself unpowered but which connects to equipment that is connected to the ac line. Your goal in station building should be to insure that any exposed metal will not present a shock hazard. This requires you to provide a safety ground connection for any unpowered equipment with a metal enclosure, such as an SWR bridge, antenna tuner, or antenna switch. Most larger pieces of this type of equipment will have a ground terminal for you to use. If not, add a screw to the enclosure or use a mounting screw for the connection.

LIGHTNING PROTECTION

Begin by reading about and understanding what lightning is and what protection against its effect consists of. Information about lightning and protection plans are available in the 2002 series of *QST* articles by Ron Block, NR2B (then KB2UYT) available to all at **www.arrl.org/lightning-protection**. Once you have a plan, you can implement it using standard grounding and bonding techniques. The **Safe Practices** chapter covers the basic elements of lightning protection.

Figure 24.4 shows an overview of how station grounding and bonding works together to provide lightning protection. All earth connections such as ground rods and buried conductors must be connected together. Inside

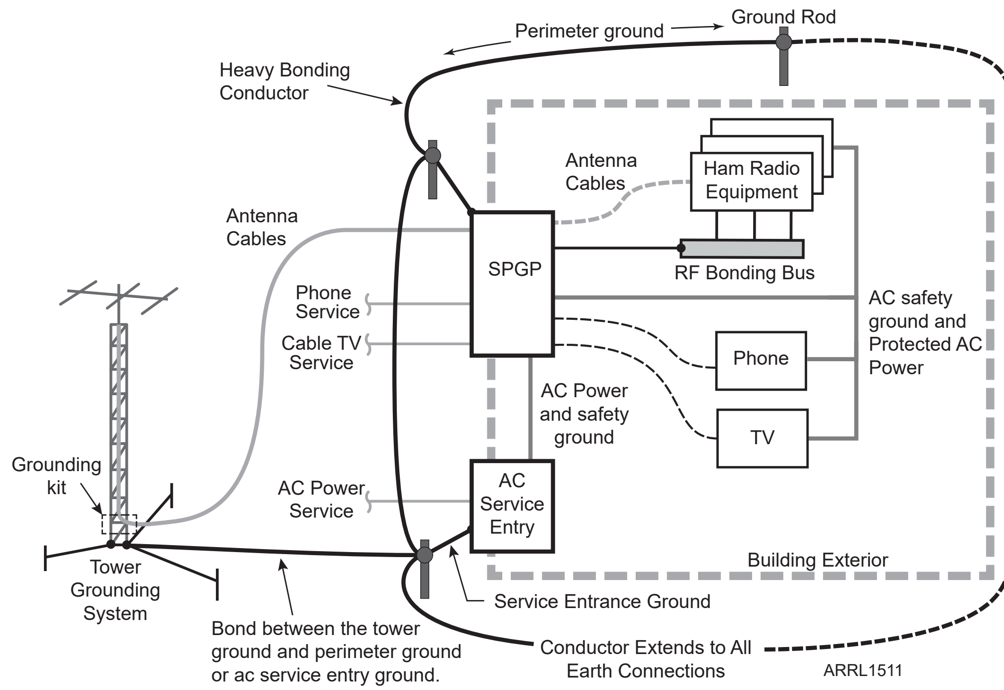

Figure 24.4 — Overview of a station grounding system than incorporates ac safety, lightning protection, and RF management. A single-point ground-panel (SPGP) is used to provide a common bonding connection to equalize voltage during a lightning transient. All ground connections must be bonded together.

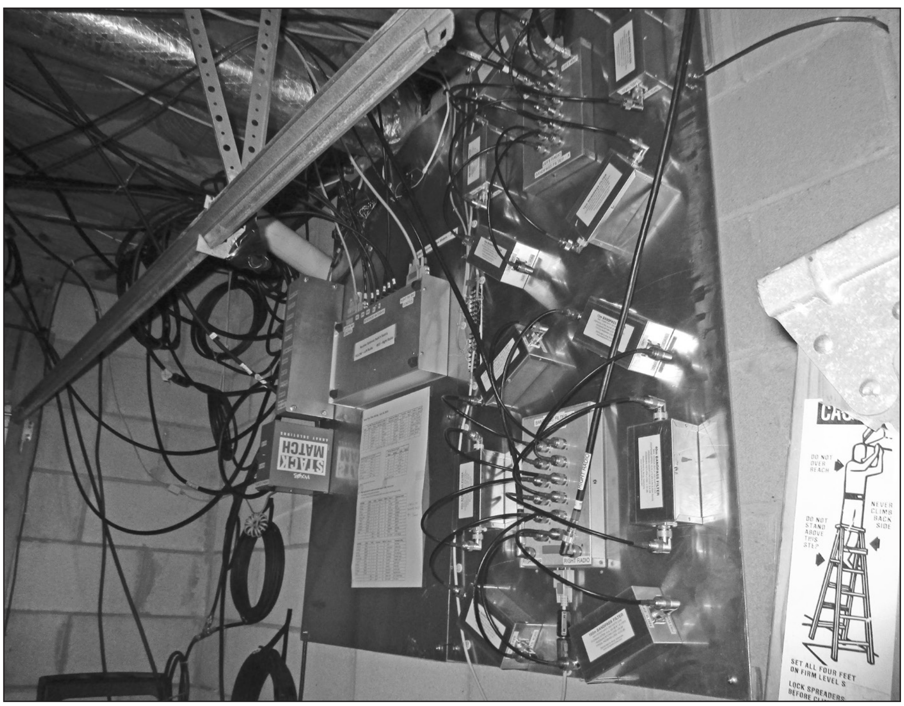

Figure 24.5 — A single-point ground-panel (SPGP) for an active HF station. Mounted on an exterior wall under the station, all filters, switches, and protectors are attached to the aluminum sheet. A heavy ground conductor connects the panel to a ground rod outside. [Kirk Pickering, K4RO, photo]

the station, all equipment is bonded together either directly or through a bonding bus.

Devise a lightning protection plan as instructed in the articles by Block. Remember that every conductor entering or leaving your protected zone must have some means of protection against lightning or lightning-induced transients. **Figure 24.5** shows a single-point ground-panel (SPGP) installed on an exterior wall below the station. **Figure 24.6** shows an example of how to mount lightning protectors on an SPGP. Your circumstances are unique and the exact solution is up to you to design and build.

Don't depend on power strips with simple MOV surge protectors to protect your equipment. You can protect one or two branch circuits with a professional/industrial-quality ac surge protector (see **Figure 24.7**), mounted on your ground panel, and connect your ac power distribution system to that. Whole-house surge protectors will not protect your station equipment from lightning since they are only connected to the residence's incoming ac service. You will still need to create an effective ground system in your station.

Make sure all of your equipment is bonded together so that voltage is equalized between pieces of equipment. Bonding can be done directly between pieces of equipment if you do not have too many individual radios and accessories. An alternative is to use the bonding bus approach as illustrated by **Figure 24.8**. Bonding will also serve to provide ac safety if the bonding includes a connection to the ac safety ground.

RF MANAGEMENT

It is typical for a station to begin with one or two radios, a power supply, and some feed lines to antennas outside. Eventually, more accessories are added, along with a computer, possibly and amplifier, and so on. This eventually leads to "RF in the shack" or RFI to various pieces of equipment. The problem is caused by the numerous interconnections between pieces of equipment. These pick up transmitted signals as common-mode RF current that can affect amateur equipment, just

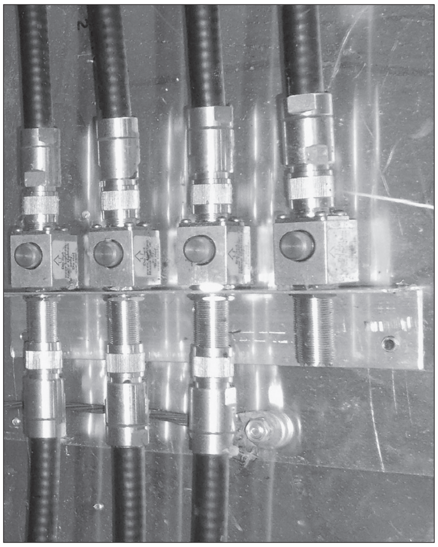

Figure 24.6 — Lightning protectors mounted on a SPGP using an aluminum angle bracket. Some protectors can be mounted directly to panels or as a through-hole using the threaded bulkhead-style connectors. [Ward Silver, NØAX, photo]

Figure 24.7 — An in-line ac power line surge protector suitable for lightning protection. It may be connected to a grounded panel via one of the enclosure screws.

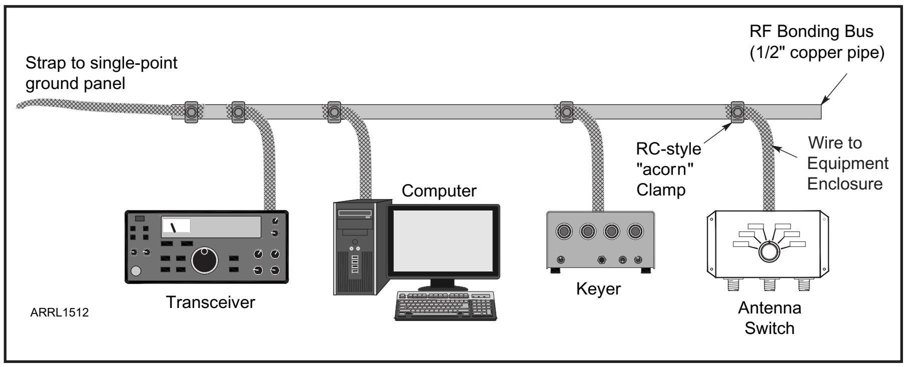

Figure 24.8 — A typical bonding bus for a station with equipment on a table or desk. Connections between the equipment and the bonding bus should be made with heavy wire (#14 AWG is suitable), 20 ga solid strap, or flat-weave grounding braid.

as it can cause RFI to consumer equipment. (See the **RF and EMC** chapter for more information.)

Along with picking up the transmitted signal, all of your station wiring will pick up RF from noise sources, too. There is a surprising amount of noise being radiated by household appliances, consumer electronics, lighting, computers and networking equipment, and power lines. Many opportunities exist for noise on the outside of shields or on unshielded wires to get in to the receiver input where the effect is to raise the station's noise floor, sometimes significantly. Good bonding and careful attention to proper shield connections minimizes those opportunities. For more information about minimizing receive noise, see Jim Brown, K9YC's online paper, "Build Contest Scores by Killing Receive Noise" at **k9yc.com/KillingReceiveNoise.pdf**.

By starting your station with a plan to manage the RF that will be present, you can reduce or eliminate the effects. You will probably not be able to shield your station against RF being picked up by the various cables and enclosures. Instead, use bonding to minimize RF voltage between pieces of equipment so that RF current doesn't flow between them. Bonding can be done by direct connection or by using a bonding bus.

As an added bonus, good bonding between pieces of equipment also minimizes the small audio buzz and hum voltages caused by leakage current and stray magnetic fields. Many stations use low-level audio signals for digital operation. Bonding helps keep unwanted

Figure 24.9 — A simple RF ground plane made of aluminum roof flashing with a copper pipe bonding bus attached at the rear of the table. Equipment is placed on the flashing and attached to the pipe with short jumpers. The ground plane and bus are attached to the station ground system with a heavy wire. [Ward Silver, NØAX, photo]

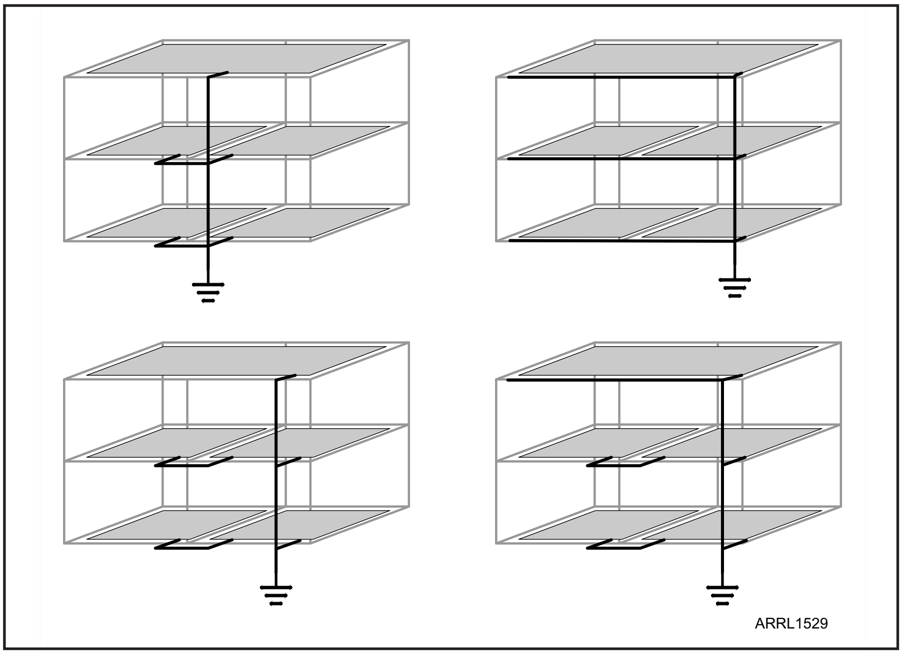

Figure 24.10 — For equipment on shelves, create a ground plane on each shelf. Bond each ground plane segment together (heavy lines) and route cables between the segments along the bonding strap or wire. Several possible examples are shown.

hum and buzz from contaminating these signal paths. Bonding for RF management can satisfy the requirements for ac safety and lightning protection, too.

One technique for helping to equalize RF voltage around your station is the use of an RF *ground plane* or *reference plane*. **Figure 24.9** shows a simple ground plane made from a sheet of aluminum roof flashing attached to a table top. A bonding bus of copper pipe is clamped to the flashing at the back of the table. Sheet metal screws in the pipe are provided for attaching bonding jumpers to each piece of equipment. The ground plane and bonding bus are then connected to the station ground system. A metal desk or table can serve as the RF ground plane, as well. (The RF ground plane is different than a set of ground radials that provide a return path for RF to the feed point of a vertical antenna.) RF voltage differences are kept low by the ground plane. Extra cable length can be coiled up and placed directly on the ground plane to help keep them from picking up common-mode RF.

Portable and temporary stations pose a challenge for RF management. Station configuration usually has to work around various constraints and physical obstacles. Installing a comprehensive ground and bonding system is usually not possible. Under these circumstances, a roll of strap or flexible braid may serve as an effective bonding bus. Screen or even aluminum foil will work as a ground plane. Have plenty of short jumpers and clip leads to connect the equipment enclosures to whatever common connection you can manage.

Many stations have shelving to hold equipment above a desk or table. **Figure 24.10** shows several possible techniques for adding metal sheet or strap to the shelves and connecting it together. You can use metal sheet, screen, or even surplus PC board material as the ground plane. The important thing is to get some metal under the various pieces of equipment to help the bonding connections work at RF.

24.1.3 Station Power

Power supply design and use is covered in the **Power Sources** chapter, and safety issues and station wiring are covered in the **Safe Practices** chapter. A single 20 A, 120 V circuit will provide sufficient power for all of the radio and computer equipment in almost any single-operator amateur station, including most 500 W power amplifiers. A single 20 A, 240 V circuit will provide sufficient power for two legal limit amplifiers that do not transmit simultaneously. A generous number of 120 V outlets should be provided. The 120 V and 240 V outlets should have their equipment grounds bonded together. This simple power arrangement has the major advantage of minimizing problems with audio hum and buzz caused by power system leakage current. Install good quality 20 A outlets and 20 A breakers.

Figure 24.11 shows how you can build your own heavy-duty, high-quality power distribution box. Use metal "back boxes" with high-quality outlets and heavy #12 or #14 AWG wiring. Multiple boxes can be mechanically attached together to support as many outlets as needed. If more than one multi-outlet box is used on the same circuit, use rigid EMT or flexible metal BX conduit between them with all of the metalwork solidly assembled and connected to the ground conductor. A heavy switch can be included to turn the entire package on and off. A GFCI outlet can be included in the box if the branch circuit is not already protected by a GFCI.

Wherever commercial power strips are used in your station, use industrial-quality products with a metal enclosure, heavy wiring, good quality outlets and a built-in switch and circuit breaker (typically rated at 15 A). Avoid inexpensive plastic power strips which cost much less but are of far lower quality.

Using ground fault circuit interrupter (GFCI) circuit breakers or outlets to supply power is not required by the NEC. However, given the many opportunities for stray current in an amateur station and antenna system, GFCI protection is not a bad idea. You can install GFCI breakers in the ac service panel or install GFCI outlets at the station.

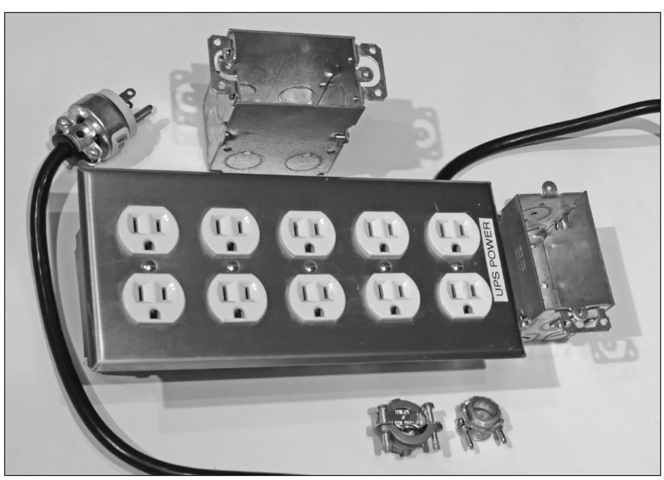

Figure 24.11 — A heavy-duty homemade power distribution box. Several gangable "back boxes" are assembled into a larger box that can hold several duplex outlets. A light switch or GFCI-protected outlet can be included for power control and shock protection. [Jim Brown, K9YC, photo]

24.1.4 Station Layout

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. Computer tables are usually a couple inches lower for a more comfortable keyboard and mouse placement. 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 or a keyboard and mouse toward the front. The length of the top will depend on the amount of equipment being used. An office or computer desk makes a good operating table. These are often about 36 inches deep and 60 inches wide. Drawers can be used for storage of logbooks, headphones, writing materials, and so on. Desks specifically designed for computer use often have built-in shelves that can be used for equipment stacking. Desks of this type are available ready-to-assemble at most discount and home improvement stores. The low price and adaptable design of these desks make them an attractive option for an operating position. An example is shown in **Figure 24.12**.

Figure 24.12 — Mike Adams, N1EN makes the most of his desktop to operate on the HF and VHF+ bands. His laptop and tablet computers are an alternative to the larger desktop systems. He uses a full-size keyboard with the laptop. [Mike Adams, N1EN, photo]

If possible, arrange your operating desk or table so that it is easy to access the rear of the equipment. You may be able to provide a walkway behind the equipment or the desk or table might be moveable. Either way, you will appreciate being able to work behind the equipment without having to get under a table or work in uncomfortable positions. It also helps avoid wiring errors caused by not having a clear view of the equipment. Equipment can also be left in place while connections are made.

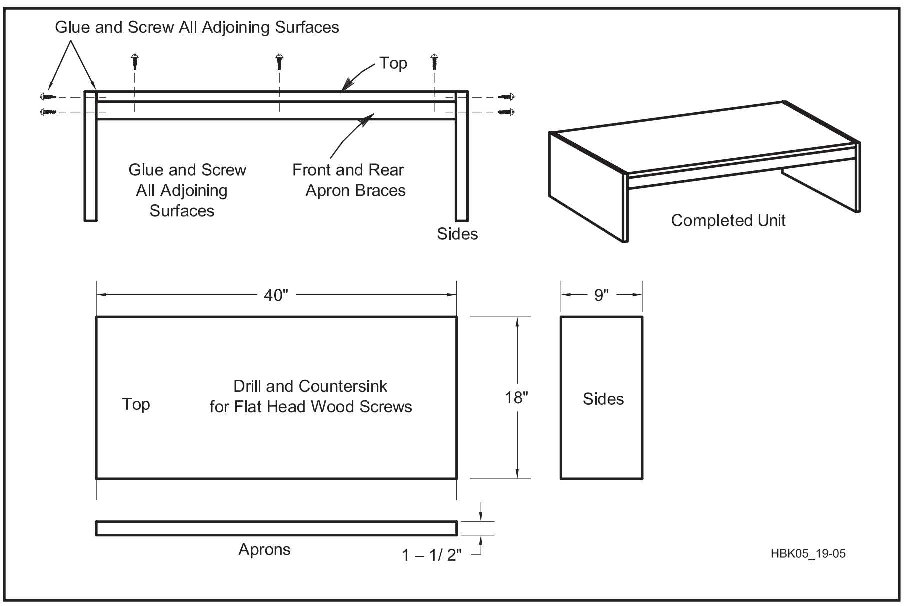

Figure 24.13 — A simple but strong equipment shelf can be built from readily available materials. Use ¾-inch plywood along with glue and screws for the joints for adequate strength.

ARRANGING THE EQUIPMENT

No matter how large your operating table, 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 airflow around it for cooling. A shelf like that shown in **Figure 24.13** can improve equipment layout in many situations. Dimensions of the shelf can be adjusted to fit the size of your operating table.

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 as described in a previous section. Be generous in estimating the number of power outlets for your installation; radio equipment has a habit of multiplying with time, so plan for the future at the outset. Try to obtain power distribution strips or install some outlets with enough space between them to accommodate multiple plug-in "wall-wart" power supplies.

Every station is different and each operator has different preferences so giving “cookbook” instructions for station layout is unrealistic. Even so, there are some general principles that make a station layout effective. Start by looking at the photographs of stations in this chapter, in *QST*, and online. Visit stations of other operators to get ideas and try different arrangements. Think about what equipment you use most while operating and make that easy to reach and use. Consider

Figure 24.14 — This portable 500 W HF station was constructed by W6GJB and K9YC for portable operation during the California QSO Party. [Jim Brown, K9YC, photo]

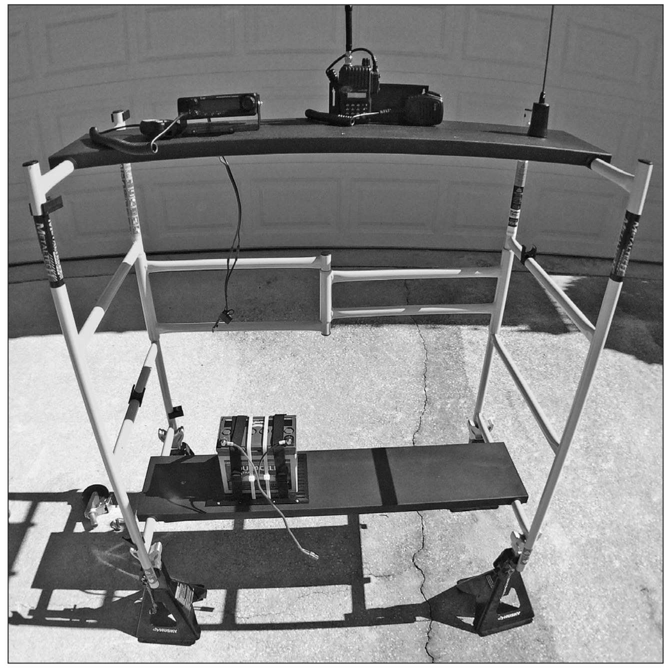

Figure 24.15 — K1CE adapted this portable metal scaffold as a portable operating desk. The top shelf also serves as a ground plane for the mag-mount VHF/UHF antennas. [Rick Palm, K1CE, photo]

Figure 24.16 — Taking advantage of a good opportunity, NØNI adapted this set of metal wire shelving to hold his equipment. The wire shelves also act as an RF ground plane and provide ventilation. [Bob Lee, WØGXA, photo]

making a temporary arrangement to try out different configurations before you settle on a final layout. Make it easy to update your layout as your habits, tastes, and body change. Configure the station to suit your interests, and keep thinking of ways to refine the layout.

Portable stations have the additional requirement to be lightweight and sturdy, often part of a "go-kit" for emergency communication or other public service. **Figures 24.14 and 24.15** show two different solutions for very different sets of circumstances but both are well-considered and appropriate to the need.

You may find yourself taking advantage of non-traditional materials for your station. **Figure 24.16** shows equipment supported by open metal wire shelving used as commercial or industrial shelving. Not only is the shelving strong, since it is metallic, it serves as an RF ground plane and is open to airflow that provides ventilation to the equipment.

ERGONOMICS

Ergonomics is a term that loosely means "fitting the work to the person." If tools and equipment are designed around what people can accommodate, the results will be much more satisfactory. For example, in the 1930s research was done in telephone equipment manufacturing plants because use of long-nosed pliers for wiring switchboards required considerable force at the end of the hand's range of motion. A simple tool redesign resolved this issue.

Considerable attention has been focused on ergonomics in recent years because we have come to realize that long periods of time spent in unnatural positions can lead to repetitive-motion injuries. Much of this attention has been focused on people whose job tasks have required them to operate computers and other office equipment. While most amateur radio operators do not devote as much time to their hobby as they might in a full-time job, it does make sense to consider comfort and flexibility when choosing furniture and arranging it in the station or workshop. Adjustable height chairs are available with air cylinders to serve as a shock absorber. Footrests might come in handy if the chair is so high that your feet cannot support your lower leg weight. The height of tables and keyboards often is not adjustable.

Placement of computer screens should take into consideration the reflected light coming from windows. It is always wise to build into your sitting sessions time to walk around and stimulate blood circulation. Your muscles are less likely to stiffen, while the flexibility in your joints can be enhanced by moving around.

Selection of hand tools is another area where there are choices to make that may affect how comfortable you will be while working in your station. Look for screwdrivers with pliable grips. Take into account how heavy things are before picking them up — your back will thank you.

24.1.5 Interconnecting Your Equipment

Once you have your equipment and get it arranged, you will have to interconnect it all. No matter how simple the station, you will at least have antenna, power and microphone or key connections. Equipment such as amplifiers, computers, TNCs and so on add complexity. By keeping your equipment interconnections well organized and of high quality, you will avoid problems later on.

Often, ready-made cables will be available. But in many cases you will have to make your own cables. A big advantage of making your own cables is that you can customize the length. This allows more flexibility in arranging your equipment and avoids extra cable length that picks up RF. Many manufacturers supply connectors with their equipment along with pinout information in the manual. This allows you to make the necessary cables in the lengths you need for your particular installation.

Always use high quality wire, cables and connectors. Take your time and make good mechanical and electrical connections on your cable ends. Sloppy cables are often a source of trouble. Often the problems they cause are intermittent and difficult to track down. You can bet that they will crop up right in the middle of a contest or during a rare DX QSO! Even worse, a poor quality connection could cause RFI or even create a fire hazard. A cable with a poor mechanical connection could come loose and short a power supply to ground or apply a voltage where it should not be. Wire and cables should have good quality insulation that is rated high enough to prevent shock hazards.

Interconnections should be neatly bundled and labeled. Wire ties, masking tape or paper labels with string work well. See **Figure 24.17**. Whatever method you use, proper labeling makes disconnecting and reconnecting equipment much easier. **Figure 24.18** illustrates the number of potential interconnections in a modern, full-featured transceiver.

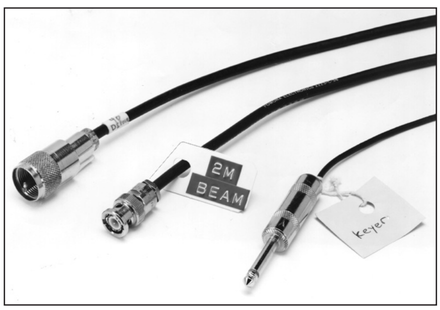

Figure 24.17 — Labels on the cables make it much easier to rearrange things in the station. Labeling ideas include masking tape, cardboard labels attached with string and labels attached to fasteners found on plastic bags (such as bread bags).

WIRE AND CABLE

The type of wire or cable to use depends on the job at hand. The wire must be of sufficient size to carry the necessary current. Use

Figure 24.18 — The back of this Yaesu FT-950 transceiver shows some of the many types of connectors encountered in the amateur station. Note that this variety is found on a single piece of equipment.

Fire Extinguishers in the Amateur Station

Three classes of fire extinguishers are appropriate for amateur stations:

- Class A: Combustible solid materials such as wood or paper
- Class B: Combustible liquid or gases
- Class C: Energized electrical fire

A fixed or portable station should have "ABC" class extinguishers. Mobile stations are most likely to experience class B and C fires.

Most ABC extinguishers contain a solid powder that does not conduct electricity and is safe for electrical equipment. The powder does leave a residue, however. A "clean agent" extinguisher uses a gas, such as Halon, to displace oxygen. The extinguisher contains a liquid form of the agent which changes to a gas on being released. Less common, CO_2 extinguishers use carbon dioxide gas to smother the fire and do not conduct electricity. Gas extinguishers leave no residue.

Liquid water extinguishers or hoses should never be used on an electrical fire because most water is a conductor of electricity and creates an electrical shock hazard. Water mist fire extinguishers disperse de-ionized water in a fog that cools the fire and displaces oxygen. Since the mist is de-ionized, it is safe to use on electrical (Class C) fires.

For use with portable generators, such as at Field Day, keep a fire extinguisher near the generator in case of a fuel spill or other fire. Don't place the extinguisher where it would be in or next to a fuel-related fire — for example, attached to the generator or next to it.

If the fire is caused by an electrical overload or short circuit, remove power before using the fire extinguisher, if possible. This takes away the ignition source and helps keep the fire out once the flames have been extinguished.

The Fire Equipment Manufacturer's Association publishes a number of useful documents on selection and use of fire extinguishers at **femalifesafety.org/fire-equipment/portable-fire-extinguishers**.

the tables in the **Construction Techniques** chapter to find this information. Never use underrated wire; it will be a fire hazard. Be sure to check the insulation too. For high-voltage applications, the insulation must be rated at least a bit higher than the intended voltage. A good rule of thumb is to use a rating at least twice what is needed.

Use good quality coaxial cable of sufficient size for connecting transmitters, transceivers, antenna switches, antenna tuners and so on. RG-58 might be fine for a short patch between your transceiver and SWR bridge, but is too small to use between your legal-limit amplifier and antenna tuner. For more information, see the **Transmission Lines** chapter.

Hookup wire may be stranded or solid. Generally, stranded is a better choice since it is less prone to break under repeated flexing. Many applications require shielded wire to reduce the chances of RF getting into the equipment. RG-174 is a good choice for control, audio and some low-power RF applications. Shielded microphone or computer cable can be used where more conductors are necessary.

For RF connections, #12 – #16 AWG solid or stranded wire or solid strap are preferred. For indoor connections not exposed to the weather, flat-weave tinned braid strap is acceptable. Do not use braid salvaged from coaxial cable for RF connections.

CONNECTORS

Connectors are a convenient way to make an electrical connection by using mating electrical contacts. There are quite a few connector styles, but common terms apply to all of them. Pins are contacts that extend out of the connector body, and connectors in which pins make the electrical contact are called "male" connectors. Sockets are hollow, recessed contacts, and connectors with sockets are called "female." Connectors designed to attach to each other are called "mating connectors." Connectors with specially shaped bodies or inserts that require a complementary shape on a mating connector are called "keyed connectors." Keyed connectors ensure that the connectors can only go together one way, reducing the possibility of damage from incorrect mating.

Plugs are connectors installed on the end of cables and *jacks* are installed on equipment. *Adapters* make connections between two different styles of connector, such as between two different families of RF connectors. Other adapters join connectors of the same family, such as double-male, double-female and gender changers. *Splitters* divide a signal between two connectors.

While the number of different types of connectors is mind-boggling, many manufacturers of amateur equipment use a few standard types. If you are involved in any group activities such as public service or emergency-preparedness work, check to see what kinds of connectors others in the group use and standardize connectors wherever possible. Assume connectors are not waterproof, unless you specifically buy one clearly marked for outdoor use (and assemble it correctly).

Power Connectors

Amateur Radio equipment uses a variety of power connectors. Some examples are shown in **Figure 24.19**. Most low power amateur equipment uses coaxial power connectors. These are the same type found on consumer electronic equipment that is supplied by a wall transformer power supply. Transceivers and other equipment that requires high current in excess of a few amperes often use Molex connectors (**www.molex.com** — enter "MLX" in the search window) with a plastic body housing pins and sockets crimped on to the end of wires.

An emerging standard, particularly among ARES and other emergency communications groups, is the use of Anderson Powerpole connectors (**www.andersonpower.com**). These connectors are "sexless" meaning that any two connectors of the same series can be mated — there are no male or female connectors. By standardizing on a single connector style, equipment can be shared and replaced easily in the field. The standard orientation for pairs of these connectors is shown in Figure 24.19. Using this orientation increases the compatibility of your wiring with that of other hams.

Molex and Powerpole connectors use crimp terminals (both male and female) installed on the end of wires. A special crimping tool is used to attach the wire to the terminal and the terminal is then inserted into the body of the connector. Making a solid connection requires the use of an appropriate tool — do not use pliers or some other tool to make a crimp connection.

Some equipment uses terminal strips for direct connection to wires or crimp terminals, often with screws. Other equipment uses spring-loaded terminals or binding posts to connect to bare wire ends. **Figure 24.20** shows some common crimp terminals that are installed on the ends of wires using special tools.

Audio and Control Connectors

Consumer audio equipment and amateur radio equipment share many of the same connectors for the same uses. Phone plugs and jacks are used for mono and stereo audio circuits. These connectors, shown in **Figure 24.21** come in ¼ inch, ⅛ inch (miniature) and subminiature varieties. The contact at the end of the plug is called the tip and the connector at the base of the plug is the sleeve. If there is a third contact between the tip and sleeve, it is the ring (these are "stereo" phone connectors). Stereo phone connectors are often called TRS (for tip-ring-sleeve) connectors by audio equipment manufacturers.

Phono plugs and jacks (sometimes called RCA connectors since they were first used on RCA brand equipment) are used for audio, video and low-level RF signals. They are also widely used for control signals.

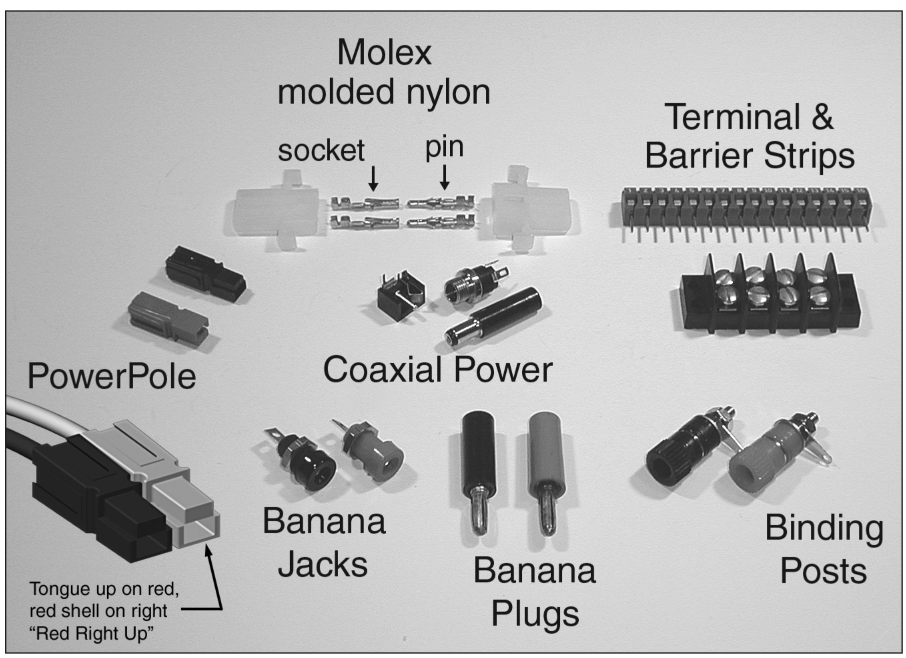

Figure 24.19 — These are the most common connectors used on amateur equipment to make power connections. The proper orientation for paired Powerpole connectors is with the red connector on the right and its tongue on top — "red-right-up." [Courtesy of Wiley Publishing, Ham Radio for Dummies, or Two-Way Radios and Scanners for Dummies]

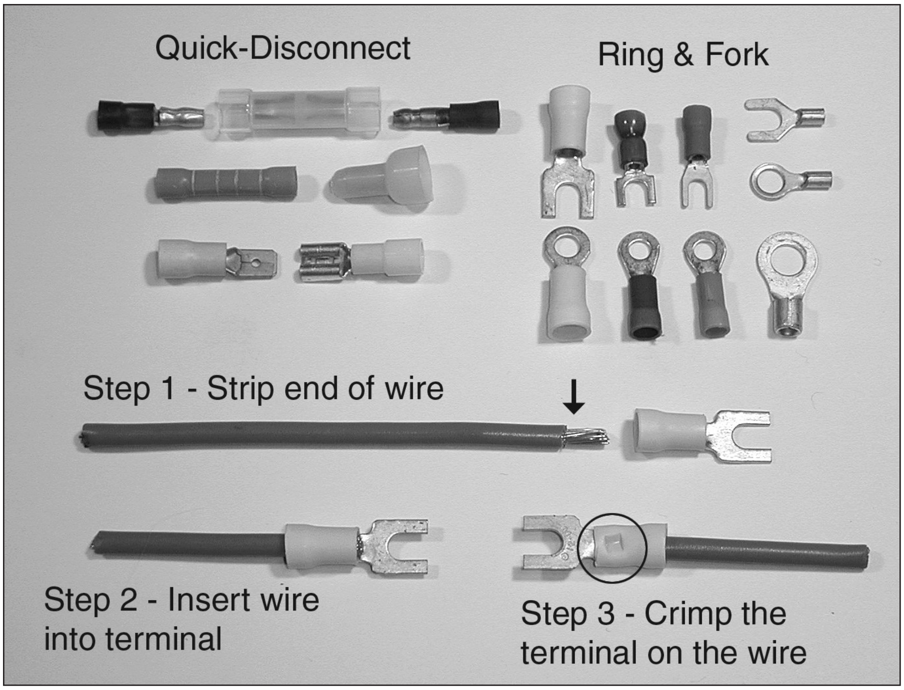

Figure 24.20 — Power connectors often use terminals that are crimped onto the end of wires with special crimping tools. [Courtesy of Wiley Publishing, Ham Radio for Dummies, or Two-Way Radios and Scanners for Dummies]

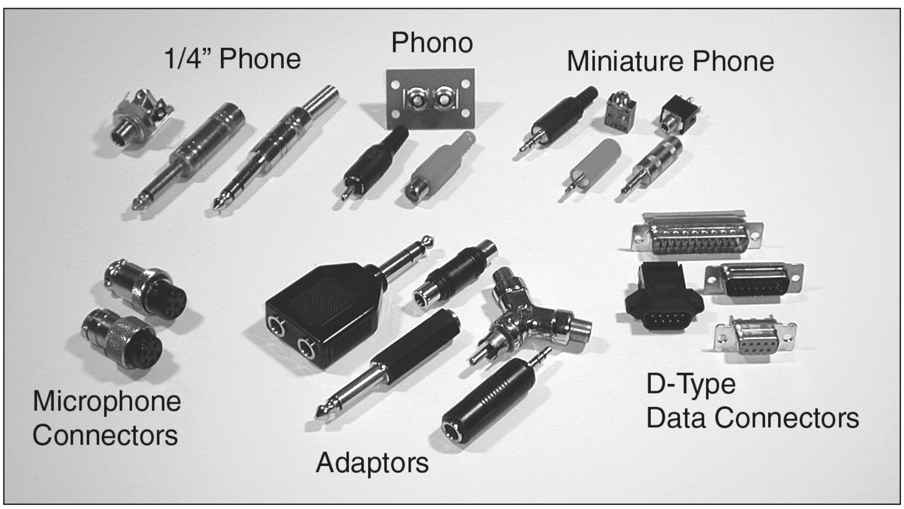

Figure 24.21 — Audio and data signals are carried by a variety of different connectors. Individual cable conductors are either crimped or soldered to the connector contacts. [Ward Silver, NØAX, photo]

The most common microphone connector on mobile and base station equipment is an 8-pin round connector. On older transceivers you may see 4-pin round connectors used for microphones. RJ-45 modular connectors (see the section on telephone connectors below) are often used in mobile and smaller radios.

RF Connectors

Feed lines used for radio signals require special connectors for use at RF frequencies. The connectors must have approximately the same characteristic impedance as the feed line they are attached to or some of the RF signal will be reflected by the connector. Inexpensive audio and control connectors cannot meet that requirement, nor can they handle the high power levels often encountered in RF equipment. Occasionally, phono connectors are used for HF receiving and low-power transmitting equipment.

By far, the most common connector for RF in amateur equipment is the UHF family shown in **Figure 24.22**. (The UHF designator has nothing to do with frequency.) A PL-259 is the plug that goes on the end of feed lines, and the SO-239 is the jack mounted on equipment. A "barrel" (PL-258) is a double-female adapter that allows two feed lines to be connected together. UHF connectors are typically used up to 150 MHz and can handle legal-limit transmitter power at HF.

UHF connectors have several drawbacks including lack of weatherproofing, poor performance above the 2 meter band and limited power handling at higher frequencies. The Type-N series of RF connectors addresses all of those needs. Type-N connectors are somewhat more expensive than UHF connectors, but they require less soldering and perform better in outdoor use since they are moisture resistant. Type-N connectors can be used to 10 GHz.

For low-power uses, BNC connectors are often used. BNC connectors are the standard for laboratory equipment, as well, and they are often used for dc and audio connections. BNC connectors are common on handheld radios for antenna connections. The newest handheld transceivers often use small, screw-on SMA type connectors for their antennas, though.

The type of connector used for a specific job depends on the size of the cable, the frequency of operation and the power levels involved. More information on RF connectors may be found in the **Transmission Lines** chapter.

Data Connectors

Digital data is exchanged between computers and pieces of radio equipment more than ever before in the amateur station. The connector styles follow those found on computer equipment.

D-type connectors are used for RS-232 (COM ports) and parallel (LPT port) interfaces. A typical D-type connector has a model number of "DB" followed by the number of connections and a "P" or "S" depending on whether the connector uses pins or sockets. For example, the DB-9P is used for PC COM1 serial ports.

USB connectors are becoming more popular in amateur equipment as the computer industry has eliminated the bulkier and slower RS-232 interface. A number of manufacturers make USB-to-serial converters that allow devices with RS-232 interfaces to be used with computers that only have USB interfaces.

Null modem or *crossover* adapters or cables have the same type of connector on each end. The internal connections between signal pins are swapped between ends so that inputs and outputs are connected together. This allows interfaces to be connected together directly without any intermediary equipment, such as an Ethernet switch or an RS-232 modem. Severalpractical data interface projects are shownin the **Station Accessories** and **Digital Communications** chapters in this book's online content.

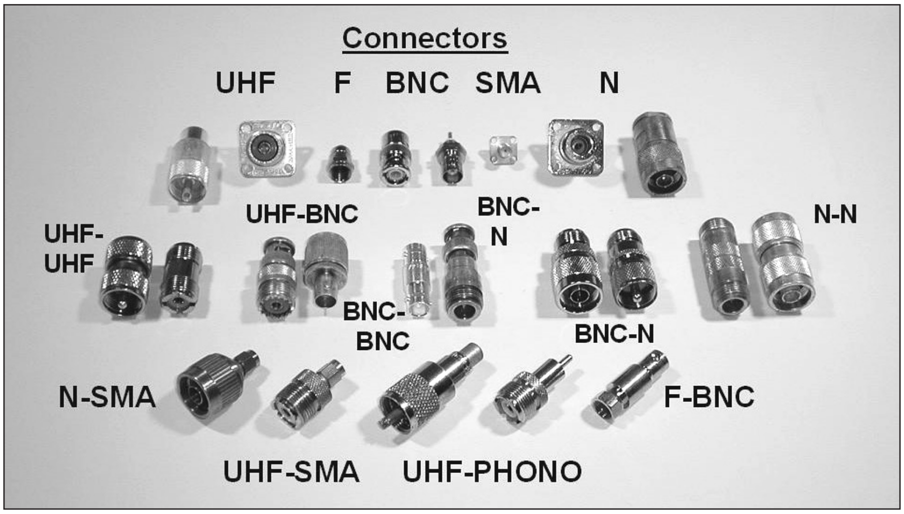

Figure 24.22 — Each type of RF connector is specially made to carry RF signals and preserve the shielding of coaxial cable. Adapters are available to connect one style of connector to another. [Ward Silver, NØAX, photo]

Telephone and Computer Network Connectors

Modular connectors are used for telephone and computer network connections. Connector part numbers begin with "RJ." The connectors are crimped on to multiconductor cables with special tools. The RJ11 connector is used for single- and double-line telephone system connection with 4 or 6 contacts. The RJ10 is a 4-contact connector for telephone handset connections. Ethernet computer network connections are made using RJ45 connectors with 8 contacts.

24.1.6 Documenting Your Station

An often neglected but very important part of putting together your station is properly documenting your work. Ideally, you should diagram your entire station from the ac power lines to the antenna on paper and keep the information in a special notebook with sections for the various facets of your installation. Having the station well documented is an invaluable aid when tracking down a problem or planning a modification. Rather than having to search your memory for information on what you did a long time ago, you'll have the facts on hand.

Besides recording the interconnections and hardware around your station, you should also keep track of the performance of your equipment. Each time you install a new antenna, measure the SWR at different points in the band and make a table or plot a curve. Later, if you suspect a problem, you'll be able to look in your records and compare your SWR with the original performance.

In your station, you can measure the power output from your transmitter(s) and amplifier(s) on each band. These measurements will be helpful if you later suspect you have a problem. If you have access to a signal generator, you can measure receiver performance for future reference.

Coax Connectors — Not as Simple as They Appear

by Hal Kennedy, N4GG

"You get what you pay for" was never more true than when it comes to common UHF connectors, including PL-259s, SO-239s, adapters, and related parts. Every hamfest seems to have at least one vendor selling "mystery" UHF connectors, sometimes for as little as a dollar each. What are you buying when you buy the cheapest PL-259? It's pretty much a guess. For the difference of a dollar or two, "mystery" UHF connectors are a very poor investment.

PL-259s have four parts: the outer sleeve called the "knurled nut," the connector body, the insulator/dielectric and the center pin. All four components can be compromised to the point of making a bargain connector useless.

Problems frequently encountered:

• Finish: Bargain connectors sometimes have a finish you can't solder to! They may have a chrome-like appearance, but the plating may not take solder well and has to be filed down for a good connection.

• Threading: The internal threads at the rear of the body are there to accept a UG-style insert that narrows the connector barrel to accept smaller diameter coax such as RG-8X or RG-58. The threads may be metric! UG inserts also sometimes appear in the US market with metric threads. Either way, the insert will not screw into the body.

• Dielectric: Good connectors use quality phenolic or Teflon insulation between the center pin and the body. Bargain connectors might use anything, including materials such as a thermoplastic material, which will melt when the center pin is soldered.

• Center pin diameter: This is one of the most common and insidious problems in mystery PL-259s. The center pin outer diameter (OD) is almost always slightly smaller than it should be and it's hard to notice. The center pin connection between a PL-259 and an SO-239 or barrel connector depends on the male side pin OD being correct and the matching fingers on the female side being the correct diameter and made of the proper spring material.

• Center socket spring tension: If the SO-239 socket metal relaxes over time and/or temperature, an intermittent connection will be created that can be very hard to track down.

• Mating indentions: The indentations on the end of the SO-239 that mate to a PL-259 (the annulus flange) may only have four indentations to match up with the short prongs on the body of the male connector. A quality SO-239 or barrel connector has indentations all the way around. If the PL-259 and SO-239 don't seat completely, an intermittent connection is likely to develop.

• T and right-angle (elbow) UHF adapters: The center conductor has to make a right-angle turn inside the shell. In poor-quality adapters the right-angle connection is done with a spring contact — these do not hold up. Quality t and right-angle adapters are reliable because the internal conductors are tapped and threaded — the conductors are screwed together within the body at the right angle junction.

How can we tell the good connectors? If the price is too good to be true — well, it is. PL-259s with good silver plating have a dull appearance. Good connectors have a part number and manufacturer's name stamped into them. You can look up the connector's specifications if it's marked. An example is the connectors made by Amphenol — all of which have parts numbers such as 83-1SP (PL-259) or 83-1R (SO-239) stamped into or onto the connector body.

24.2 Mobile Installations

Solid-state electronics and miniaturization have allowed mobile operators to equip their vehicles with stations rivaling base stations. Indeed, it is possible to operate from 160 meters through 70 cm with one compact transceiver. Adding versatility, most designed-for-mobile transceivers are set up so that the main body of the radio can be safely tucked under a seat, with the operating "head" conveniently placed for ease of use as shown in **Figure 24.23**.

Common power levels reach 100-150 W on HF, and 50-75 W on VHF. With proper antenna selection and placement (see the **Antennas** chapter), mobile stations can work the world, just like their base station counterparts. The only real difference between them is that you're trying to drive at the same time you are operating, and safe operating requires attention to the details.

For some of us living in antenna-restricted areas, mobile operating may offer the best solution for getting on the air. For others it is an enjoyable alternative to home-station operation. No matter which category you're in, you can enjoy success if you plan your installation with safety and convenience in mind.

There is a considerable amount of information about mobile operation, both HF and VHF+, online. Many contributions to this section have come from the website of Alan Applegate, KØBG, at **www.k0bg.com**. Specialty groups, such as RVers and off-road groups will have additional perspectives. Your vehicle dealer also has service bulletins regarding the installation of radio equipment. Although the bulletins mainly apply to VHF equipment, they are a valuable source of information about convenient routes and access points for power and other wiring.

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24.2.1 Installation

Installing amateur radio equipment in modern vehicles can be quite challenging, yet rewarding, if basic safety rules are followed. All gear must be securely attached to the vehicle. Unsecured cup holder mounts, mounts wedged between cushions, elastic cords, hook-and-loop tape, magnets, or any other temporary mounting scheme *must be avoided*! Remember, if it isn't bolted down, it will become a missile in the event of a crash. The radio mounting location must avoid SRS (airbag) deployment zones — virtually eliminating the top of the dash in most modern vehicles — as well as vehicle controls (see the sidebar "Air Bags and Mobile Installations).

There are many no-holes-needed mounts available. Some mounts are even designed for a specific transceiver make and model. **Table 24.1** lists some suppliers.

Two other points to keep in mind when choosing a mounting location are convenience and lack of distraction. Microphone and power cabling should be placed out of the way and properly secured. The transceiver's controls should be convenient to use and to view. See **Figure 24.24** for examples.

Mounting radios inside unvented center consoles and overhead bins should also be avoided. Modern mobile transceivers designed for remote mounting allow the main body to be located under a seat, in the trunk, or in another out-of-the-way place (**Figure 24.25**) but be sure there is plenty of ventilation.

If you drive off-road or on rough roads, you may also wish to consider using shock mounts, also known as "Lord Mounts" for their original manufacturer. For more information, see the product information on "Plateform Mounts" from the Astrotex Company at **www.astrotex.com/lord.htm**.

24.2.2 Coaxial Cable

Cable lengths in mobile installations seldom exceed 15 feet, so coax losses are not a major factor except on the 70 cm and higher-frequency bands. Good quality RG-58A or RG-8X size coax is more than adequate for HF and VHF. While there is nothing wrong with using RG-8 size coax (0.405 inch), it is stiffer and has a larger bending radius, making it harder to work with in most mobile applications.

There are some caveats when selecting coax. Avoid solid center conductors such as in standard RG-58. It has a propensity to kink, is susceptible to failure from vibration and can be difficult to solder properly. Both RG-58A and RG-8X use foam dielectric, and care is needed when soldering PL-259 connectors — especially when reducers are being used. The **Transmission Lines** chapter illustrates the correct installation procedure.

24.2.3 Wiring

Proper wiring is an essential part of any mobile installation. Consider the following points when selecting materials and planning the cable routing.

- Wire needs to be correctly sized and fused stranded wire.
- All cables need to be protected from abrasion, heat, and chemicals.
- Wiring needs to be shortened and/or bundled with appropriate wire ties to avoid interaction with passengers and mechanical devices. **Figure 24.26** shows a typical vehicle wiring tray.

Power cables should be connected directly to the battery following manufacturers' recommendations, with the requisite positive and negative lead fuses located close to the battery. **Figure 24.27** shows a typical fuse block. Accessory (cigarette lighter) sockets and power

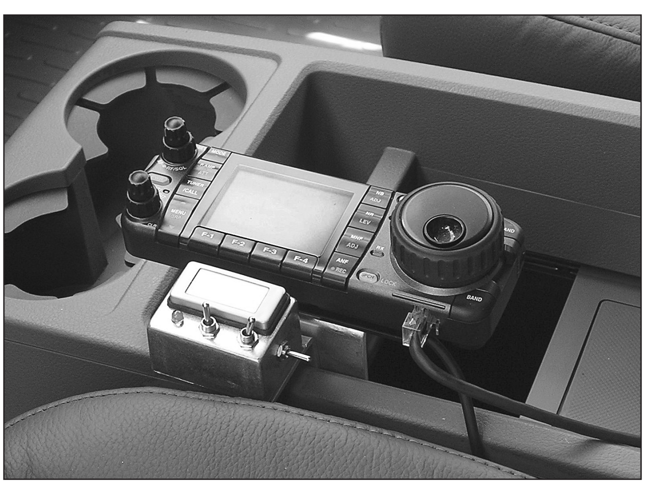


Figure 24.23 — In this mobile installation, the transceiver control head is mounted in the center console, next to a box with switches for adjusting the antenna.

Table 24.1
Mobile Mount Sources

Gamber Johnson — **www.gamberjohnson.com**	
Havis-Shields — **www.havis.com**	
Jotto Desk — **www.jottodesk.com**	
PanaVise Products — **www.panavise.com**	
RAM Mounting Systems — **www.ram-mount.com**	

(A)

(B)

Figure 24.24 — At A, the transceiver control head is attached to one of many available mounts designed for this purpose. Mounts are typically highly adjustable, allowing the control head or radio to be positioned close to the operator. An antenna controller is mounted below the microphone. At B, HF and VHF transceiver control heads and the microphone are all mounted to the dashboard, within easy reach.

Marine Grounding and Equipment Installation

Marine vessels, either fresh- or salt-water, pose challenges to radio and electrical systems. Luckily, there are many online and print references explaining how to do things right, whether the vessel is power or sail, wooden, fiberglass, or metal-hulled. Each type requires certain practices be followed to avoid corrosion and maintain good electrical connections at dc and RF. Your best sources of information can be found through marine outfitters and communication shops that install marine HF and VHF radios.

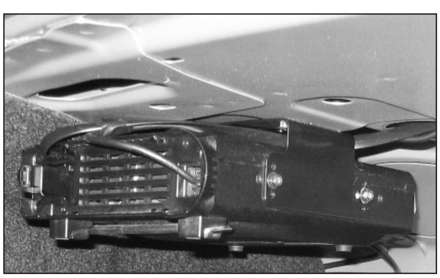


Figure 24.25 — The main body of the radio may be mounted in the vehicle's trunk or other out-of-the-way spot. Allow for plenty of ventilation.

taps shouldn't be used except for very low current loads (<5 A), and then only with care. It pays to remember that a vehicle fire is both costly and dangerous! More information may be found at **www.fordemc.com/docs/ download/Mobile_Radio_Guide.pdf**.

The fuses supplied with most mobile transceivers are ATC style. Most automotive fuses are ATO. The ATC fuse element is completely sealed in plastic and the ATO is not. Since the power cable fuse holders are not waterproof, only an ATC fuse should be used if the fuse holder is exposed to the weather or located anywhere in the engine compartment. If an ATO is used, and water gets into the fuse, the fuse element corrodes and eventually fails.

Proper wiring also minimizes voltage drops and helps prevent ground loops. Modern solid-state transceivers will operate effectively down to 12.0 V dc (engine off). If the voltage drops below 11.6 V under load, some transceivers will reduce power, shut down or operate incorrectly. The vehicle chassis should not be used for ground returns; paint or other insulation can isolate different chassis sections and using a chassis return can create a ground loop.

Running cables through the engine firewall can be easy in some vehicles and nearly impossible in others. Using factory wiring grommets should be avoided unless they're not being used. In some cases, the only alternative is to drill your own hole. If you have any questions or concerns, have your local mobile sound shop or two-way radio dealer install the wiring for you.

Power for ancillary equipment (wattmeters, remotely tuned antennas and so on) should follow the same wiring rules. The use of a multiple outlet power distribution panel such as a RigRunner (**www.westmountainradio.com**) is also recommended. They're convenient, and offer a second level of protection.

WIRE SIZE

The **Construction Techniques** chapter lists the current-handling capabilities of various gauges of wire and cable. The correct wiring size is one that provides a low voltage drop (less than 0.5 V under full load). Don't use wire at its maximum current-current carrying capacity.

Here's the formula for calculating the cable assembly voltage drop (V_d):

$$V_d = [(R_W \times 2\,\ell \times 0.001) + 2\,k] \times I$$

where

R_W = resistance value (Ω per 1000 feet)

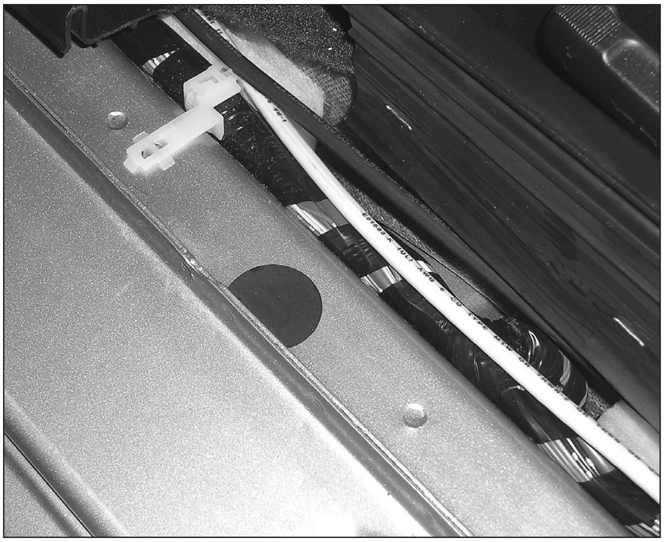


Figure 24.26 — Most vehicles have wiring troughs hidden behind interior body panels.

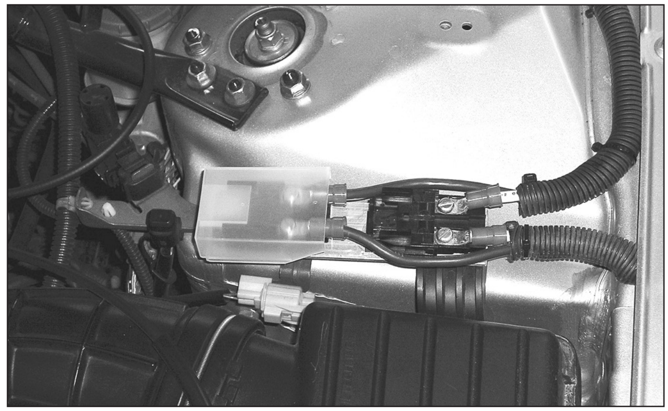


Figure 24.27 — Wiring attached to a fuse block.

from the **Construction Techniques** chapter.

ℓ = overall length of the cable assembly including connectors, in feet.

k = nominal resistive value for one fuse and its holder. Note: Most power cables have two fuses. If yours doesn't, use 1 k in the formula. If you don't know the fuse and holder resistance, use a conservative value of 0.002 Ω.

I = peak current draw in amperes for a SSB transceiver, or steady state for an FM radio.

For example, the peak current draw for a 100 W transceiver is about 22 A, and a typical power cable length is 10 feet. Using the resistive values for 1000 feet of #10 AWG wire (0.9987 Ω), and a conservative value for the fuse resistances (0.002 Ω each), the calculated drop will be 0.527 V.

It's important to reiterate that the wire size should be selected for minimum voltage drop, not maximum power handling capability. The voltage drop is often referred to as "I-squared-R loss" — the current in amperes, squared, times the resistance — and should be held to a minimum whenever possible. In cabling, excessive I^2R losses can cause the wire to overheat with predictable results.

The insulation material of wire used in mobile installations should have a temperature rating of at least 90 °C, and preferably 105 °C. It should be protected with split-loom covering whenever possible, especially under-hood wiring.

Selecting the correct size fuse is also important. The average current draw for any given fuse should not exceed 60% of its rating. Thus, the correct fuse rating for a 22-A load is 30 A. That same 30-A fuse will handle a 40-A load for about 120 seconds, and a 100-A load for about 2 seconds. Therefore, it pays to be conservative when selecting the carrying

Battery Connections

For many years, connecting mobile station power leads directly to the battery (or to the battery positive and ground tie-point) has been the standard recommendation. In vehicles equipped with EIS (Engine Idle Shutoff), however, additional sensing modules in the vehicle electrical system may require alternate connections.

With EIS, as soon as the vehicle stops for a short time, the engine shuts off and the battery voltage drops. To support the additional starting cycles, starters and batteries are more robust, but so are the sophistication of the electrical devices supporting them. The most important device is the ELD (Electronic Load Detector), typically located within the main fuse panel.

ELDs have been in use for many years to measure the current drawn by the accessories (air conditioning, lights, and so on), which allow the engine CPU to more accurately adjust the air/fuel mixture. However, on vehicles equipped with EIS, the ELD is located in battery's negative lead or its connector. (See your vehicle's service manual for the exact location of the ELD.) The ELD is used for *coulomb-counting* to estimate the battery's State of Charge (SoC). Measuring current during starting provides an estimate of the battery's Reserve Capacity (RC). This ensures the battery has enough reserves to restart the engine when the engine has to start again. (See the **Power Sources** chapter for more information on vehicle batteries.)

During engine shutdown, most EIS systems use a dc-to-dc converter to assure that the accessories have a constant voltage source for electric motors that power brakes, air conditioning, transmission servo pressure, fuel pumps, and engine cooling systems. A second trunk-mounted battery may be used, or even super-capacitors (low-voltage capacitors with many farads of capacitance). The converter and accessory operation is under the control of the Battery Monitoring System (BMS) and amateur transceiver wiring must avoid circumventing its operation.

Connecting the transceiver directly to the battery would bypass the BMS which is not recommended, nor is connecting the radio to the dc-to-dc converter, to the trunk-mounted accessory-power battery, or to existing vehicle wiring. In vehicles equipped with a BMS and/or ELD the correct method of connecting the radio is to connect the positive lead directly to the battery, and the negative lead to the battery's chassis grounding point. The negative lead fuse should not be removed! This avoids damage caused by a loose or broken battery connection, which could cause a Load Dump Transient (LDT) to occur. (See the **RFI and EMC** chapter.) Should an LDT occur, the fuse might blow depending on the location of the battery lead failure. Without the fuse, damage to the transceiver could be the result.

If there is any doubt, check with your dealer about how the Battery Monitoring System (BMS) is connected and the recommended connection points for your radio's power leads. Be sure the connections you make are to points adequately rated for the load your radio presents. More information on batteries, alternators, and the newer vehicle power systems is available online at **www.k0bg.com**.

— *Alan Applegate, K0BG*

capacities of both wire and fuses. **Figure 24.28** shows the characteristics of several sizes of automotive fuses.

24.2.4 Amplifiers

Mobile HF amplifiers have been around for many years, and with the advent of high-power solid state devices they are common. However, running high power in a mobile environment requires careful planning. Considerations include, but are not limited to:

• alternator current ratings and battery capacity

• wiring (in addition to safe current ratings, excessive voltage drop will create distortion of the output signal)

• antenna and feed line power ratings

• placement and secure mounting in the vehicle

• wiring and placing of remote controls See **www.k0bg.com/amplifiers.html** for more information on these topics.

Before purchasing an amplifier, take a close look at your antenna installation and make sure it is operating efficiently. Using an amplifier with a poor antenna installation is counterproductive. Here's a rule of thumb applicable to any type of antenna: If the *unmatched* input SWR is less than 1.7:1 on 17 meters or any lower frequency band, then it isn't mounted correctly, and/or you need a better antenna. Whatever antenna you use, it must be capable of handling the amplifier power level — 500 W or more. More information on HF mobile antennas and installation tech-niques may be found in the **Antennas** chapter.

Mobile amplifiers for VHF/UHF operation are not as popular as they once were because most mobile transceivers have adequate output power (about 50 W). Boosting this to 150-300 W or more should be done with caution. Mobile VHF/UHF antennas for high power (>100 W) are rare, so check antenna ratings carefully. Those that are available need to be permanently mounted, and preferably on the roof to avoid inadvertent contact.

With any high-power mobile installation, pay careful attention to RF safety. More information on RF exposure can be found in the **Safe Practices** chapter.

24.2.5 Interference Issues

In a mobile installation, radio frequency interference falls under two basic categories: *egress* (interference from the vehicle to your amateur station) and *ingress* (from your amateur gear to the vehicle). Most hams are familiar with ignition interference as it is the most common form of egress. RF interference to an auto sound system is a common form of ingress.

Both types of interference have unique solutions but they have at least one in common and that is *chassis bonding*. Chassis bonding refers to connecting accessory equipment or assemblies to the frame or chassis of the vehicle. For example, the exhaust system is isolated from the structure of the vehicle and acts like an antenna for the RFI generated by the ignition system. It should be bonded to the chassis in at least three places. **Figure 24.29** shows an example of bonding. More on these techniques is available at **www.k0bg.com/bonding.html**.

Other RFI egress problems are related to fuel pumps, HVAC and engine cooling fans, ABS sensors, data distribution systems and control system CPUs. These are best cured at the source by liberal use of snap-on ferrite cores on the wiring harnesses of the offending

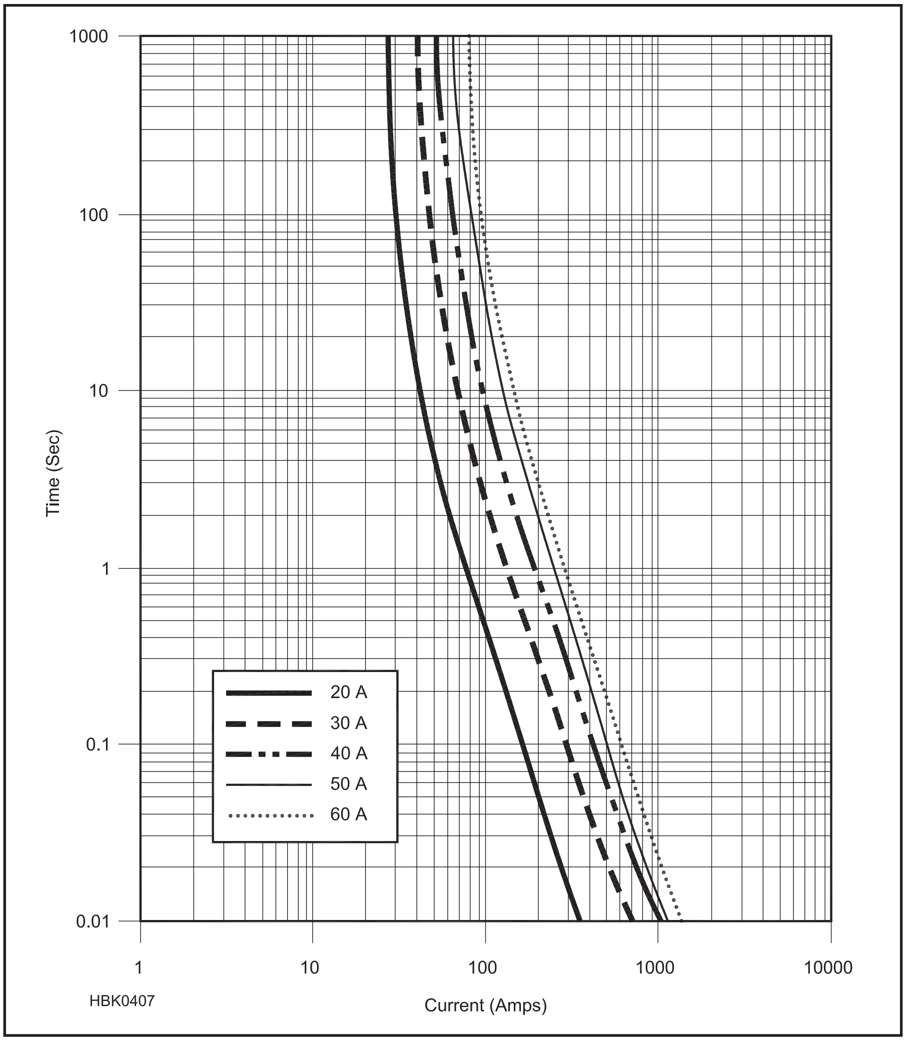


Figure 24.28 — Chart of opening delay versus current for five common sizes of Maxi fuses, the plastic-body high-current fuses common in vehicles. [Based on a chart from Littelfuse Corp]

Figure 24.29 — Bonding vehicles parts — in this case, the trunk lid to the main body — can help reduce interference.

devices. Snap-on cores come is a variety of sizes and formulations called mixes. The best all-around ferrite core material for mobile RFI issues is mix 31. Suitable cores are available from many distributors. Unknown surplus units typically offer little HF attenuation and should be avoided. See the **RF Techniques** and **RFI and EMC** chapters for more information on ferrite cores.

Alternator whine can be another form of RFI egress. It is typically caused by an incorrectly mounted antenna resulting in a ground loop, rather than a defective alternator diode or inadequate dc power filtering as has been the traditional solution. Attempting to solve alternator whine with a dc filter can mask the problem and increases I^2R losses. Additional information on proper antenna mounting is in the **Antennas** chapter.

RFI ingress to the various on-board electronic devices is less common. The major causes are unchecked RF flowing on the control wires and common mode currents flowing on the coax cable of remotely-tuned HF antennas. Again, this points out the need to properly mount mobile antennas.

For more information on RFI issues, see the **RFI and EMC** chapter, *The ARRL RFI Handbook*, and the ARRL Technical Information Service (**www.arrl.org/tis**).

24.2.6 Electric Vehicles

As of 2021, electric vehicles comprise about 6% of all new vehicles sold in the United States and this fraction will increase quickly over the next decade. What is considered an "electric vehicle" includes a number of hybrid variations that use electric motors for a significant amount of their drive power. Here are some examples:

Hybrid Electric Vehicles (HEVs) incorporate a traditional internal combustion engine (ICE), gasoline or diesel, with electric motor and battery (≈5 to 35 kW) subsystems, all integrated into the drivetrain. (Note that for electric vehicles, battery capacity is represented as the ability to deliver power in kW, instead of total energy storage in kW-hr.) The electric motor provides extra power when needed, as well as slow speed, battery-only operation. The batteries are recharged by the ICE, and by using regenerative braking.

Plug-in Hybrid Electric Vehicles (PHEV) are similar to HEVs, except their batteries may also be charged from the electrical grid. PHEVs often have larger capacity batteries

Air Bags and Mobile Installation

Since 1998 all passenger vehicles are required to have Supplemental Restraint Systems (SRS), better known as *airbags*. Side airbags and airbags for rear seat passengers have become commonplace. When used in conjunction with seat belts, they've become a great life saving device, but they do have a drawback — they literally explode when they deploy!

Airbags deploy within 200 ms, expanding at about 200 mph, driven by gas from a controlled explosion. **Figure 24.A** drawing shows a typical vehicle with several air bags deployed in the passenger compartment. Any radio gear within range of an airbag will be ripped free with great force and flung about the interior. This should eliminate from consideration any dash-top mounting scheme including windshield suction cup (mobile phone) mounts, so often employed.

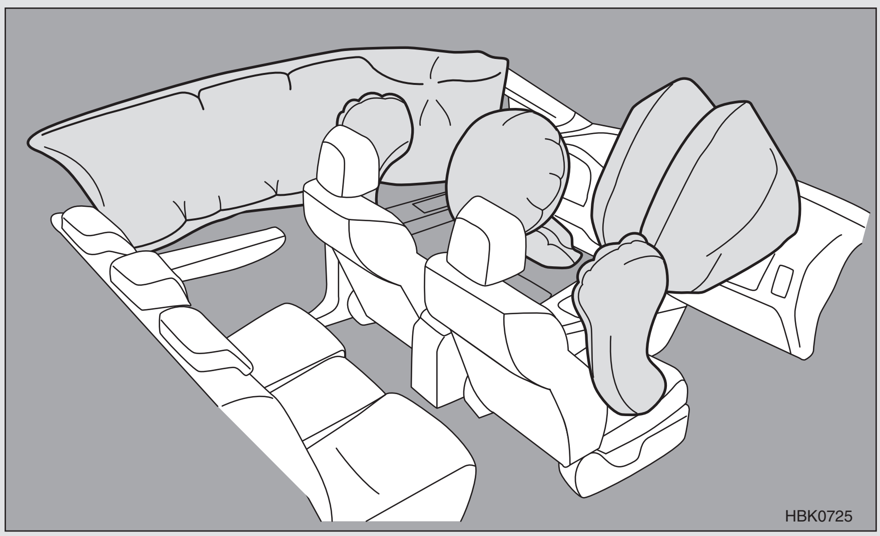


Figure 24.A — Airbag deployment zones in a modern vehicle.

Figure 24.B shows the passenger compartment of a vehicle with airbags deployed after a minor collision that caused less than $300 damage to the bumper. Note the loose piece of dashboard on top of the deflated air bag and the broken windshield. These are typical effects of a deploying airbag, whether from the top or center of the dash. Knowing how airbags deploy, avoid mounting radio gear anywhere near them.

It is always a difficult task finding a suitable mounting location for a transceiver and/or control head that is out of airbag range yet easily seen and operated. One workaround is a gooseneck mount (see **Table 24.1**, page12, for a list of suppliers). These attach via a seat bolt (no hole needed). They're a good alternative as long as they're placed away from the passenger airbag deployment area (the whole right side of the dashboard). The dealer for your make and model may have additional guidelines for mounting radios and control heads in the car.


Figure 24.B — Airbag deployment following a minor collision caused significant disruption inside the passenger compartment.

(≈10 to 70 kW) to allow them to motivate on battery power alone.

All-Electric Vehicles (EV) run solely on battery power. Their batteries are much larger in capacity (up to 760 kW) than HEVs or PHEVs. Although these vehicles employ regenerative braking like their counterparts, the electrical grid is their primary energy source.

The control systems for electric vehicles are complex, using computer-controlled, solid-state electronics to convert battery dc to the ac which drives the motor(s). (See **Figure 24.30** for an example.) As a result, all types of electric vehicles produce prodigious amounts of RFI, well into VHF. Manufacturers do their best to properly filter these switching products, however, the level of RFI may make amateur mobile operation difficult in certain models.

Electric vehicles are classified by the FCC as *incidental radiators*, falling under Part 15 rules. The rules have specific exemptions, such as Part 15.103 (a) which reads: "A digital device utilized exclusively in any transportation vehicle including motor vehicles and aircraft." In other words, vehicles are exempt from Part 15 limits, whether receiving or causing RFI.

Electric vehicle warranties can be a major hurdle to installing third-party amateur radio equipment, as well. Consult the warranty conditions and the vehicle dealer service department about installing radio equipment without voiding the vehicle warranty. The combination of warranty restrictions and RFI can make operating from an electric vehicle a challenge, but it is not impossible.

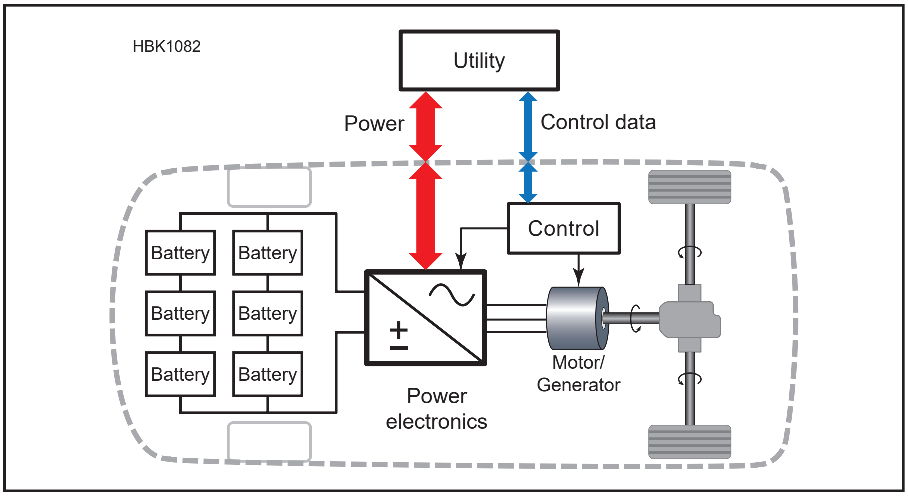


Figure 24.30 — Power system architecture for a typical electric vehicle.

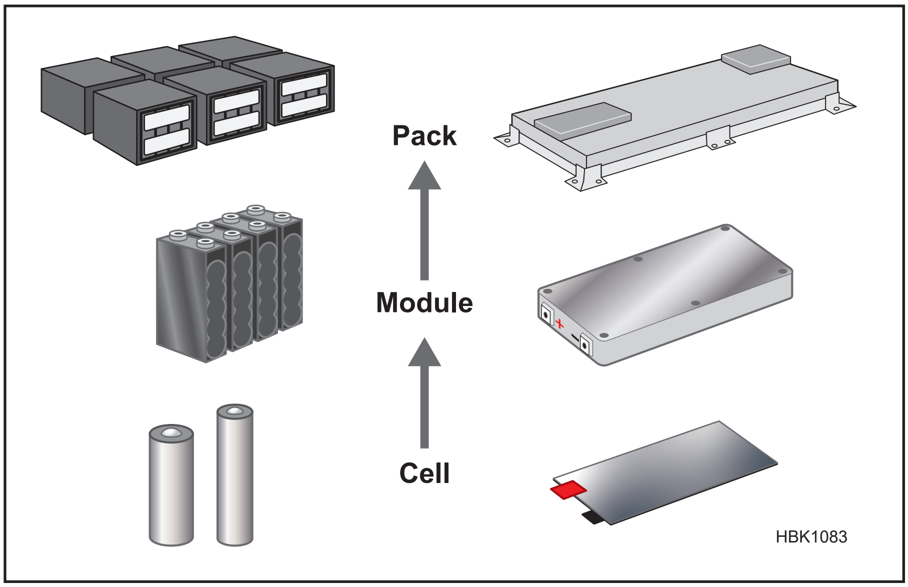


Figure 24.31 – Battery packs are composed of individual cells that are assembled into modules. The modules are then combined to form the overall battery pack.

Hazards from High Voltage

The *propulsion batteries* in most electric vehicles are lithium-ion based (Li-ion), but other types are used. Individual cells are connected in a series/parallel arrangement, so that current and voltage from the overall *battery pack* meet specific performance requirements. A microprocessor-controlled charging circuit insures an equal charge for each cell, and each cell bank.

Battery pack voltages range from 150 volts to as high as 450 volts. Current capability may be as high as 2,000 amps. Once converted to ac, the peak voltage driving the motors may be as high as 650 volts. Needless to say, these are lethal voltages. (See **Figure 24.31**)

Keeping occupants safely isolated from these voltages is a design requisite. However, installing amateur radio equipment in an electric vehicle may place the installer within harm's way of these lethal voltages. Professional help may be required to prevent injury or death.

Power in Electric Vehicles

Some models use a small 12-volt battery to power accessories (lights, radio, etc.) while the vehicle is stopped and the engine isn't running. Others may use inverters to convert the propulsion battery's high voltage to a lower voltage (not necessarily 12 V), to power these accessories. Check to see if your vehicle has a 12-volt system that can power the expected radio equipment. If not, you will have to provide a 12-volt system that is independent of or charged from the vehicle's power system.

Using what are now called *Accessory Sockets* (previously known as cigar or cigarette lighter sockets) to power amateur gear has many caveats. These are used for low power equipment from dash cams to radar detectors and even computers. However, they are not designed to power amateur radio gear, nor should they be used to do so. Regardless of the circuit's fuse size used to feed them power, the electrical harness' wire size is too small (≈ #14 or #16 AWG) for continuous loads larger than 4 amps. Heavier loads may not blow the fuse but can overheat the power wiring bundle, possibly causing a fire or other electrical damage. Built-in USB charging ports may only supply 2 A or less (at 5 V) which is not enough to power mobile-type radios.

Using these sources to power amateur radio gear may also void the vehicle's warranty. Checking with your dealer is the first line of defense in these cases. Even if allowed under warranty provisions, keep in mind that rated current is limited to a few amps and thus one's

Distracted Driving — Don't Do It!

Driver distraction has replaced drunk driving as the number one cause of vehicular crashes and deaths. This has prompted The National Highway Traffic Safety Administration (NHTSA) to address the problem with a nationwide ad campaign (**www.nhtsa.gov/risky-driving/distracted-driving**). Although texting is the number one cause, it isn't the only driver-distraction factor.

Manipulating any vehicular control, especially touch-screen operations, can — and does — cause driver distraction. Automobile manufacturers have partially addressed the issue by equipping vehicles with voice control, but you must still push a button to activate voice control. Even software-driven, self-driving, automatous vehicles, require input from you, the driver.

Please, don't allow amateur radio to become the cause of a distracted crash. When driving conditions warrant your attention, hang up the microphone.

choice of transceivers is also limited.

One exception to these limits is Ford's electric F150 Hybrid pickup truck and the all-electric (EV) F150 Lightning model truck. Both have provisions for providing 120/240 Vac electric power even when in motion. Other manufacturers will no doubt follow suit.

Antennas in Electric Vehicles

As noted elsewhere in this chapter, it is important to minimize common-mode RF current on feed lines. This is important in electric vehicles because of the stronger noise signals that will be picked up by the feed line and conducted to the radio equipment. In addition, radiated RF from the common-mode current may also cause RFI to the vehicle.

Any permanent mobile antenna installation should be directly attached to the vehicle body. This typically requires drilling holes in sheet metal and using common mode-chokes to block common-mode current. Except for temporary operation, mag-mount antennas should be avoided, especially on HF, because the feed line shield will carry much more common-mode current than for a directly-attached antenna in the same location.

Even though the antenna is close to the source of RF noise from the vehicle, you may be able to find mounting locations that pick up less noise. When testing antenna placement, be sure to decouple the feed line by using ferrite chokes. As an added benefit, finding a lower-noise location may also result in less RF pickup by the vehicle wiring.

RFI from Electric Vehicles

The electronics that convert dc battery power to multi-phase ac motor power use switching waveforms with very fast rise and fall times. This generates large amounts of high-frequency noise that covers the entire MF-HF spectrum, well into VHF. (This is the reason most electric vehicles don't have the AM broadcast band on their OEM radios.) Switching noise is the primary source of RFI to amateur radio equipment in electric vehicles.

Electric vehicles also use a lot of the same type of electric motors, solenoids, switches, and control electronics as are found in non-electric vehicles. The same types of noise will be radiated from these devices and any amateur radio equipment is essentially within feet or even inches of the noise source. One difference with electric vehicles is that adding chokes or other RFI remedies may not be permitted under the vehicle's warranty due to the more complex power and control electronics systems. If you do add components to the vehicle wiring to reduce RFI, do it in small steps, testing vehicle and noise performance along the way.

RFI to Electric Vehicles

While all modern vehicles have RF-sensitive electronics on board, electric vehicles have electronics that control every facet of vehicle operation, usually controlled over digital networks such as the CAN (Controller Area Network). These circuits are well-filtered which reduces the chance for stray RF to negatively affect them. However, the vehicle wiring and electronics are very close to the antennas that are radiating a strong signal. As more vehicles adopt partial or complete automated driving, RFI can present serious safety challenges.

We need to be aware that on-board electronics may be susceptible to the high levels of RF generated by amateur transmitters, regardless of the frequency of operation. Even when allowed, proper antenna installation is very important in keeping common-mode RF current pickup by cables and wiring harnesses to a minimum.

If the level of radiated RF is high enough, the digital network signals may be corrupted. This might cause the windshield wipers to operate, or the entertainment system to squeal, which can be annoying. However, it can also cause other circuitry to fail to operate correctly, which can cause unexpected consequences to occur, particularly in safety equipment and systems.

As amateur radio and vehicles use more digital protocols and technology, it should reduce susceptibility to RFI in electric vehicles. In the interim, amateurs will have to remain cautious and be prepared to be flexible in their approach to mobile operating. Amateur operators will still have to contend with RFI, as well, but the future may bring improvements as the digital systems become more tolerant for both the radios and vehicles.

24.2.7 Operating

The most important consideration while operating mobile-in-motion is safety! Driver distraction is a familiar cause of vehicle crashes. While amateur radio use is far less distracting than mobile phones or texting, there are times when driving requires all of our attention. When bad weather, excessive traffic, or a construction zone require extra care, play it safe — hang up the microphone and turn off the radio!

In addition to properly installing gear, a few operating hints can make your journey less distracting. One of those is familiarization with your transceiver's menu functions and its microphone keys (if so equipped). Even then, complicated programming or adjustments are not something to do while underway.

Logging mobile contacts has always been difficult. Compact digital voice recorders have made that function easy and inexpensive. Units with up to 24 hours of recording time are available for less than $50.

For maximum intelligibility at the other end, avoid excessive speech processing and too much microphone gain. Don't shout into the microphone! It's human nature to increase your speaking level when excited or when the background level increases. In the closed cabin of a vehicle, your brain interprets the reflected sound from your own voice as an increase in background level. Add in a little traffic noise and by the end of your transmission you're in full shout mode! One solution is to use a headset and the transceiver's built-in monitor function. Doing so gives you direct feedback (not a time-delayed echo), and your brain won't get confused. Note that headset use is not legal in some jurisdictions and never legal if both ears are covered.

Overcoming vehicle ambient noise levels often requires the use of an external speaker and all too often it is an afterthought. Selecting a speaker that is too small accentuates high frequency noise which makes reception tiresome. Using adapters to interface with vehicle stereo systems isn't productive for the same reason. For speakers that are too large, mounting becomes a safety issue.

For best results, use at least a 4-inch speaker. Rather than mount it out in the open, mount it out of the way, under the driver's seat. This attenuates the high frequency noise, and enhances the mid-range response which increases intelligibility.

Many vehicle audio systems now support audio input from external sources including analog (headphone audio), USB, and Bluetooth. You may be able to route your mobile rig's audio through the vehicle audio system using one of these methods. The audio sounds far better than through a small speaker!

Most modern transceivers contain some form of DSP (digital signal processing) noise reduction as covered in the **DSP and SDR Fundamentals** chapter. Some are audio based and some are IF based, with the latter being preferred. But both types do a decent job of reducing high-frequency hiss, static spikes, and even ignition hash.

24.3 Portable Stations

Many amateurs experience the joys of portable operation once each year in the annual emergency exercise known as ARRL Field Day. All year long, amateurs are operating with portable stations from parks, mountain tops, islands, and more. As lightweight equipment becomes more effective, expect more of this type of activity.

A good portable setup is simple. Although you may bring lots of gear to Field Day and set it up the day before, during a real emergency speed is of the essence. The less equipment to set up, the faster it will be operational. Another benefit of simplicity is that the easier it is for you to collect the equipment and head for the operating site, the more likely you will be to do it!

This section will focus not on the transceiver — so many excellent models are available at all power levels — but power sources and effective antennas for it.

If you expect to frequently operate a portable station, check out some of the online communities that have developed to support popular "on the air" programs like Parks on the Air (POTA; **parksontheair.com**) and Summits On the Air (SOTA; **www.sota.org.uk**). QRP clubs and societies like QRP ARCI (**www.qrparci.org**) publish many helpful projects, equipment reviews, and even sponsor operating events and conventions. There are many helpful videos available online and social media programs, as well.

We'll begin with power sources for field operating. Generators and batteries are by far the most popular. Solar panels are increasing in efficiency and small wind turbines are sometimes used — even human power can be used, such as from a bicycle-powered generator — but nearly always to charge a battery and won't be covered here. The books *Emergency Power for Radio Communications* by Mike Bryce, WB8VGE, and *Energy Choices for the Radio Amateur* by the late Bob Bruninga, WB4APR are good resources for information about off-grid power sources.

24.3.1 AC Generators

Essentially, a generator is a motor that's operating "backward." When you apply electricity to a motor, it turns the motor's shaft (allowing it to do useful work). Take the same motor, physically rotate its shaft, and it generates electricity across the same terminals used to supply power when used as a motor. Turn the shaft faster and the voltage and frequency increase. Turn it slower and they decrease. To some degree, all motors are generators and all generators are motors. The differences are in the details and in the optimization for specific functions. Consumer-class ac generators are classified as *home backup* (for powering an entire home during power outages), *portable* (basic gas-powered generators for tools and appliances), *inverter* (generators coupled to solid-state inverters), and *portable power stations* (batteries packaged with an inverter, discussed in the battery section below).

PORTABLE GENERATORS

A "motor" that is optimized for generating electricity is an alternator — just like the one in your car. The most basic generators use a small gas engine directly coupled to an ac alternator, so the output voltage and frequency depend on the engine speed. If the engine is running too fast or too slow, the voltage and frequency of the output will be off. If everything is running at or near the correct speed, the voltage and frequency of the output will be a close approximation of the power supplied by the ac mains — a 120 V ac sine wave with a frequency of 60 Hz. These are referred to as *constant-speed generators*. Most consumer models use two-pole armatures that run at 3,600 RPM to produce a 60 Hz sine wave.

Remember, a standard generator *must* turn at a specific speed to maintain output regulation, so when more power is drawn from the generator, the engine must supply more torque to overcome the increased physical/magnetic resistance in the generator's core — the generator *can't* simply spin faster to supply the extra power.

Most generators have engines that use mechanical or vacuum "governors" to keep the generator shaft turning at the correct speed. If the shaft slows down because of increasing generator demand, the governor "hits the gas" and draws energy stored in a heavy rotating flywheel, for example, to bring (or keep) the shaft speed up to par. The opposite happens if the generator is spinning too fast.

In addition to mechanical and vacuum speed regulating systems, generators that are a step up in sophistication additionally have electronic automatic voltage regulation (AVR) systems that use special windings in the generator core (and a microprocessor or circuit to monitor and control them) to help keep things steady near 120 V and 60 Hz. AVR systems can respond to short term load changes much more quickly than mechanical or vacuum governors alone. They are mostly used in higher quality 5 to 15 kW "home backup systems" and in many recreational vehicles.

INVERTER GENERATORS

Inverter generators produce high-voltage, multiphase ac that is rectified to dc — similar to an automobile alternator. The dc power is then converted back to very clean and consistent ac power by a microprocessor-controlled solid-state power inverter. Unlike the constant-speed generators, inverters can run at idle while still providing power, increasing speed to meet additional demand. This improves economy and reduces emissions. The most common models are available with capacities to approximately 2000 W output and some can be paralleled with special cables for higher capacity. The June 2012 *QST* Product Review "A Look at Gasoline Powered Inverter Generators" compares several popular models available at that time and is provided with this book's online content.

Basic portable generators are intended to power lights, saws, drills, ac motors, electric frying pans and other devices that are not dependent on clean sine-wave power. If you want the highest margin of protection when powering computers, transceivers and other sensitive electronics, an *inverter generator* is the best way to go. Some popular examples are shown in **Figure 24.32**, and their key specifications are shown in **Table 24.2**. Available in outputs ranging from 1 to 5 kW, these generators use one or more of the mechanical regulation systems mentioned previously, but their ultimate benefit comes from the use of a built-in ac-dc-ac inverter system that produces clean 60 Hz sine waves at 120 V ac, with a 1% to 2% tolerance, even under varying load conditions.

Instead of using two windings in the generator core, an inverter generator uses 24 or

Things to Consider for Operating Portable Stations

Safety

• Being the cause of a medical emergency will not ingratiate you or any future amateur operators with the public or the facility administration. Think ahead!

• RF Safety: Ensure that your personal RF exposure and the RF exposure of anyone who happens by will be within published safety limits. Have some idea of safe distances before setting up and flag areas of caution.

• Physical Safety: Radial wires, coaxial cable, power cords, and guy lines are all trip hazards. Antennas and masts are often top heavy. Generators must be well-ventilated and fuel supplies secured. Have a basic first-aid kit with you.

• Electrical Safety: High RF voltages exist in many antenna systems and batteries usually contain significant electrical energy. Use high-quality power distribution cables and boxes and keep them dry!

Permission and Permits

• Whether public or private, almost all property is covered by some set of rules. You need to ensure that access to the location is authorized during the hours you expect to be there and that the operation of an amateur radio station is allowed.

• Have a copy of any necessary permits. The use of trees for supporting antennas or driving stakes in the ground may not be allowed.

• RF emissions are restricted around certain research and medical facilities.

• Be 100% certain that your operation will be allowed.

Physical Presence

Being seen and not heard is great advice for operating in a shared public space. Avoid needlessly annoying other visitors. Loud generators, noisy static-CW-garbled voices, and shouting into a microphone are all bad ideas around non-hams.

• Taking up an entire pavilion or most of an open area with antennas will not impress other park patrons and staff, whether you have a permit to operate or not.

Practice Before you Go

• Set up your station outside at home to be sure you have all the parts and pieces and connections. Whatever you need to complete the station will be close at hand.

• Operate the station and make a few contacts to ensure that you really do have everything. You'll find all sorts of things to learn or adjust or fix before doing it "for real." This is the time to solve any RFI problems or intermittent problems.

• Assess what spares, supplies, and tools you needed or are likely to need. Unless you are going with a bare minimum setup; a roll of electrical tape, a multi-tool of some kind, and a spare length of coax are essentials, for example.

• As you take the station apart afterwards, make a checklist of all equipment. Note the individual pieces of gear and also the containers into which stuff has been packed. Include the non-radio equipment in your list: chair, bug spray, cell phone power bank, water and sunscreen, hat and gloves, etc. Include everything you were using when you were outside at home.

• After the actual operation, supplement your checklist with things you noticed on-site. What worked well and what didn't, things forgotten or needed, and improvements for next time are all part of what public service teams call a "hot wash." The time for this is right away while your memory is still fresh.

Preparing Yourself

• Make a plan for food and have plenty of water. If you have any health issues, plan to compensate for them and mitigate any risks.

• Dress appropriately for the climate and be prepared for changes in the weather.

• Get experience in operating with the modes you plan to use. In the field is not the time to learn new tactics.

• If participating in an "on the air" program (POTA, SOTA, IOTA, etc.) or competition – be sure you know the rules and any requirements for logging contacts.

• Be sure to tell someone your plans, including where you are going and when you'll be home!

Interacting With the Public

Assume you will have visitors. Bring a printout of some kind to explain what ham radio is and where they can go for more information. Someone curious enough to stop and ask you a question is a good prospect for amateur radio. A minute or two to be friendly and courteous won't cost you many contacts, and who knows what you will gain!

Figure 24.32 — Modern inverter generators from Honda and Yamaha. See Table 24.2 for a partial list of specifications.

more windings to produce a high frequency ac waveform of up to 20 kHz. A solid-state inverter module converts the high frequency ac to smooth dc, which is in turn converted to clean, tightly regulated 120 V ac power. Most inverter generators are compact, lightweight and quiet. Low-noise operation is important if you plan on operating at a site where other people might be present.

GENERATOR CONSIDERATIONS

In addition to capacity and output regulation, factors such as engine type, noise level, fuel options, fuel capacity, run time, size, weight, cost, or connector type, may factor into your decision. Consider additional uses for your new generator beyond Field Day or other portable operation.

Power Rating

Your generator must be able to safely power all the devices that will be attached to it. Simply add up the power requirements of *all* the devices, add a reasonable safety margin (25 to 30%) and choose a suitably powerful generator that meets your other requirements.

Some devices — especially electric appli-

Table 24.2
Specifications of the Inverter Generators Shown in Figure 24.32

Make and Model	*Output (W) (Surge/Cont)*	*Run Time (h) Full / 25% Load*	*Noise Range (dBA@21 feet)*	*Engine Type*	*Weight (Pounds)*	*Notes**
Honda EU2000i	2000 / 1600	4 /15	53-59	100 cc, OHC	46	a,b,c,d
Yamaha EF2400iS	2400 / 2000	N/A / 8.6	53-58	171 cc, OHV	70	a,b,c

*a — has 12 V dc output; b — has "smart throttle" for better fuel economy;
c — has low oil alert/shutdown; d — replaced by EU2200i with similar specifications

ances — take a lot more power to start up than they do to keep running. A motor that takes 100 W to run may require a surge of 200 W or more for a brief period when started. Many items don't require extra start-up power but be sure to plan accordingly.

Always plan to have more capacity than you require or, conversely, plan to use less gear than you have capacity for. Running close to maximum power is bad for your generator *and* your gear. Some generators are somewhat overrated, probably for marketing purposes. Give yourself a margin of safety and don't rely on built-in circuit breakers to save your gear during overloads. When operating at or beyond capacity, a generator's frequency and voltage can vary widely before the current breaker trips.

Size and Weight

Size and weight vary according to power output — low power units are lightweight and physically small. Watt for watt, however, most modern units are smaller and lighter than their predecessors. Models suitable for ham radio typically weigh between 25 and 125 pounds.

Engines and Fuel

Low-end portable generators are typically powered by low-tolerance, side valve engines of the type found in discount store lawnmowers. They're noisy, need frequent servicing and often fail relatively quickly. Better models have overhead valve (OHV) or overhead cam (OHC) engines, pressure lubrication, low oil shutdown, cast iron cylinder sleeves, oil filters, electronic ignition systems, and even fuel injection. These features may be overkill for occasional use but are desirable for more consistent power needs.

Generators used for emergency power are frequently left idle for long periods of time. Running the generator up to 30 minutes every so often — six months is frequently suggested — is a good way to keep it ready. After you use the generator for an emergency or to keep it in good condition, run it until the gas tank and carburetor are completely dry. Another option is to just close the fuel shut-off valve and run the generator until the carburetor is dry. This prevents the build-up of films known as "varnish" in the carburetor.

If you store the generator with fuel in the tank, use a fuel stabilizer additive to prevent varnish build up and to absorb any condensation that may occur. Ethanol-free gasoline, if available, holds up better for long storage periods. Generator shops, powersports dealers, power equipment dealers, and RV websites are good sources of recommendations for additives and sources of ethanol-free gas. Gasoline stored in a container should also be regularly rotated out by using it in a vehicle and refilling the container or an additive for storing gasoline should be added.

Run Time

Smaller generators usually have smaller gas tanks, but that doesn't necessarily mean they need more frequent refueling. Some small generators are significantly more efficient than their larger counterparts and may run for half a day while powering small loads. Some generators offer separate gas tanks as an accessory.

As with output power, run times for many units are somewhat exaggerated and are usually specified for 50% loads. If you're running closer to maximum capacity, your run times may be seriously degraded. The opposite is also true. Typical generators run from three to nine hours on a full tank of gas at a 50% load. Make a practice run with a typical load (electric lights are good test loads) to see what the actual gas consumption is and use that information to plan for your actual portable operation.

Noise

Portable generators for tools, pumps, and appliances are almost always loud. Noise levels for many models are stated on the box, but try to test them yourself or talk to someone who owns the model you're interested in before buying. Environmental conditions, distance to the generator, and the unit's physical orientation can affect perceived noise levels. Inverter generators are much quieter.

Generators housed in special sound dampened compartments in large boats and RVs can be much quieter than typical "outside" models. However, they are expensive and heavy, use more fuel than compact models, and most don't have regulation specs comparable to inverter models. If you are concerned about noise levels, consider building a small plywood enclosure with at least one open side to direct sound away from people. Be sure the enclosure has adequate ventilation.

Regulation

For hams, voltage and frequency regulation are very important since most ham equipment is designed to be operated directly or from a power supply using ac line power. AVR units with electronic output regulation (at a minimum) and inverter generators are highly desirable and should be used exclusively, if only for peace of mind.

Unloaded portable generators can put out as much as 160 V ac at 64 Hz. As loads increase, frequency and voltage decrease. Under full load, output values may fall as low as 105 V at 56 Hz. Normal operating conditions are somewhere in between.

Some have tried inserting uninterruptible power supplies (UPSs) between the generator and their sensitive gear. These devices are often used to maintain steady, clean ac power for computers and telecommunication equipment. As the mains voltage moves up and down, the UPS's regulator system adjusts the output voltage accordingly. The unit's internal batteries provide power to the loads if the ac mains (or your generator) go down.

In practice, however, most UPSs can't handle the variation in frequency and voltage of a generator powered system. When fed by a portable generator, most UPSs constantly switch in and out of battery power mode — or won't switch back to what is perceived to be ac power. When the UPS battery goes flat, the unit shuts off. Not every UPS and every generator interact like this, but an inverter generator is a better solution.

RF Noise

Some generators create RF noise in the HF bands as common-mode current on connected power cords. Glen Brown, W6GJB, built and Jim Brown, K9YC, designed the choke in **Figure 24.33** to suppress the noise. The assembly consists of a pair of chokes in series, each consisting of 8 turns of #14 AWG Romex-type cable wound on type #31, 2.4-inch OD ferrite toroids. One choke is wound

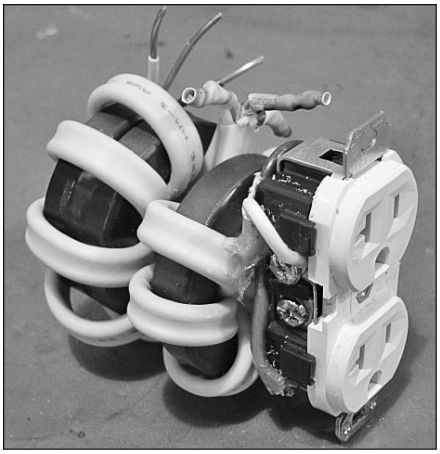


Figure 24.33 — A heavy-duty common-mode RF choke wound on Type 31 ferrite cores for ac generators. K9YC and W6GJB use this choke during portable operating. See the text for construction details.

on two cores for 80- and 40-meter coverage. The second choke is wound on one core for 10 MHz and above. (Figure 24.33A) The chokes are attached directly to a duplex outlet installed in an electrical enclosure (Figure 24.33B). A heavy-duty extension cord connects the choke to the generator.

DC Output

Some generators have 12 V dc outputs for charging batteries. These range from 2 A trickle chargers to 100 A quick-charge outputs. Typical outputs run about 10 to 15 A. As with the ac outputs, be sure to test the dc outputs for voltage stability (under load if possible) and ripple. Large batteries can tolerate some ripple in the charging circuit, but your radio might not tolerate it at all! Be sure your battery can be charged with the type of charging output from the generator. SLA batteries are very tolerant but lithium-chemistry and nickel-metal-hydride batteries require special chargers.

Miscellaneous

Other considerations include outlets (120 V, 240 V and dc output), circuit breakers (standard or ground fault interrupter type), fuel level gauges, handles (one or two), favorite brands, warranties, starters (pull or electric), wheels, handles or whatever you require for your expected operating conditions.

SETUP, SAFETY, AND TESTING

Before starting the engine, read the user manual. Carefully follow the instructions regarding engine oil, throttle and choke settings (if any). Be sure you understand how the unit operates and how to use the receptacles, circuit breakers and connectors. If there is a fuel tank shutoff valve, be sure it is open before attempting to start the engine.

Make sure the area is clean, dry, and unobstructed. Generators should *always* be set up *outdoors*. Do not operate gas powered engines in closed spaces, inside vans, or covered pickup beds, etc. If rain is a possibility, set up an appropriate canopy or other *outdoor protective structure.* Operating generators and electrical devices in the rain or snow can be dangerous. Keep the generator and any attached cords dry.

Exhaust systems can get hot enough to ignite certain materials. Keep the unit several feet away from buildings and keep the gas can (and other flammable stuff) at a safe distance. Don't touch hot engines or mufflers.

When refueling, shut down the generator and let things cool off for a few minutes. Don't smoke, and don't spill gasoline onto hot engine parts. A flash fire or explosion may result. Keep a small fire extinguisher nearby. If you refuel at night, use a light source that isn't powered by the generator and can't ignite the gasoline. Generators with separate fuel tanks can be refueled with the generator running if the tank is located away from the generator.

Testing

Before starting (or restarting) the engine, disconnect or turn off all electrical loads. Starting the unit while loads are connected may not damage the generator, but transients or voltage over-shoot may damage solid-state devices. The engine will be much harder to start under load, as well. After the engine has warmed up and stabilized, test the output voltage (and frequency), if possible, *before* connecting loads.

Because unloaded values may differ from loaded values, be sure to test your generator under load (high wattage quartz lights or electric heaters are good high-power loads). Notice that when you turn on a hefty load, a portable generator will "hunt" a bit as the engine stabilizes. An inverter generator should always output regulated ac. Measure ac voltage and frequency again to see what the power conditions will be like under load. See your unit's user manual or contact the manufacturer if adjustments are required.

Safety Grounds and Field Operation

The NEC addresses safety grounding for this type of generators in section 250.34. The NEC considers "portable" to describe a generator that is easily carried from one location to another by a person. "Mobile" applies to generators that are capable of being moved on wheels or rollers and includes generators mounted in a vehicle.

A ground rod or other direct earth connection is not required for portable generators as long as the generator has receptacles mounted on the generator panel and the receptacles have equipment grounding terminals (i.e., the third ground pin of an ac receptacle) that are bonded to the frame of the generator. Equipment must be connected to the generator through a suitable cord and plug, such as the usual extension cord. Any exposed metal surface of the equipment must be connected through the ground wire of the power cord to the receptacle ground terminal, as well. If the generator is mounted in a vehicle the same rules apply as long as the equipment supplied by the generator is mounted on the vehicle and the frame of the generator is bonded to the frame of the vehicle. In both cases, it is OK to use a ground rod connected to the generator frame but you don't have to.

Ground rods may be used if desired. If the generator is more than a short distance from the station or if more than one separate station is powered by the same generator, a ground rod at the generator and at each station may be prudent. Bond all ground rods together and don't depend on ground conductivity.

Regardless of the grounding method you choose, a few electrical safety rules remain the same. Your extension cords *must* have intact, waterproof insulation, three "prongs" and three wires, and must be sized according to loads and cable runs. Use #14 to #16 AWG, three wire extension cords for low wattage runs of 100 feet or less. For high wattage loads, use heavier #12 AWG, three-wire cords designed for air compressors, air conditioners or RV service feeds. Try to position extension cords so they won't become a trip hazard (particularly at night) or run over by vehicles. Secure long cords to stakes so if someone does trip, the cord does not pull equipment off an operating position or disconnect from the generator. Never run electrical cords through standing water.

During operations, try to let all operators know when the generator will be shut down for refueling so radio and computer gear can be shut down in an orderly manner. Keep the loads disconnected at the generator or powered down until the generator has been refueled and restarted.

24.3.2 Battery Power Sources

If a generator is not available to supply ac voltage for portable operation, batteries are often used for portable or Field Day operation. (See the **Power Sources** chapter for complete information on batteries, including charging.) Alternative energy sources such as solar panels and wind generators can be used to charge batteries, as well.

Battery technology has advanced considerably in the past few years in support of alternative energy and electric vehicle applications. *Lithium-Iron-Phosphate* (LiFePO4 or LFP) and *lithium-polymer* (LiPo) batteries in particular have become widely used for portable operation, including ultra-light backpacking. (LiPo refers to the method of battery construction using polymer separators between the anode and cathode and can use any lithium chemistry.) The *sealed lead-acid* (SLA) battery is rapidly being displaced for portable stations that are not in a vehicle or marine vessel. **Table 24.3** is a comparison of the lead-acid and LiFePO4 battery types with data excerpted from the more complete table in the Batteries section of the **Power Sources** chapter. See that chapter's sections on battery selection for a more complete comparison of battery chemistries in mobile and portable stations.

Battery technology will continue to evolve rapidly. While the LFP chemistry is currently the most popular choice for portable operating, other variations and completely different chemistries and physical form factors are likely to appear in the coming years.

Table 24.3 Lead-Acid and LiFePO4 Comparison

Specification	*Lead-Acid*	*LiFePO4*
Specific energy (Wh/kg)	30-50	90-120
Cycle life (1,2)	200-300	1000-3000
Fast-charge time	8-16 hr	1 hr or less
Overcharge tolerance	High	Low
Trickle charge	Yes	No
Safety requirements	Thermally stable	Protection circuit mandatory (3)
Toxicity	Very high	Low

1 — Based on depth of discharge (DoD). Shallow DoD improves cycle life.
2 — Based on current (Feb 2022) manufacturer information
3 — Usually built-in to battery packs

VOLTAGE STABILITY

Voltage stability is a significant concern for battery-power operation. Most solid-state transceivers are designed to operate at a nominal 13.8 V from a lead-acid battery being charged by a vehicle's engine. As battery voltage drops during use, transmit signal quality begins to drop, sometimes drastically, and output power drops off as well. Further, most transceivers will simply shut themselves off once their input voltage drops to approximately 11.6 V. Even for a partially charged battery, voltage drops in power cables and connectors when transmitting can cause the radio to shut off intermittently or operate improperly.

Several manufacturers and distributors sell "battery boosters" that provide a regulated output of 13.8 V as battery voltage varies. Booster efficiency varies with the input voltage and current draw but is typically around 80%, a significant loss of capacity.

Another option is a dc-to-dc converter which runs from a nominal input of 24 or 48 V, providing a regulated output of 13.8 V. In this case, two (or more) 12 V batteries are wired in series or in series-parallel to extend operating time. Converter efficiency is typically greater than 88%. Both ground-isolated and non-isolated models are available. The latter units use a common bus for the negative connection between power source batteries and output connections.

LEAD-ACID BATTERIES

Most lead-acid batteries used today are "maintenance-free" types in which the liquid electrolyte (sulfuric acid) is sealed in the battery as a liquid or gel. Batteries used in vehicle systems are called *starter-lights-ignition* (SLI) or just *starter* batteries and are designed to supply momentary power surges with continuous charging while the engine is running. *Deep-cycle* batteries are designed to supply power continuously. S*ealed lead-acid* (SLA) batteries are completely sealed with a gelled electrolyte and can be operated or stored in any orientation. *Absorbent Glass Mat* (AGM) batteries are spill-proof with the electrolyte stored in mats of glass fibers. For portable operation, any of these types can be used if they can be transported to the operating site. Of these types, SLA is the one most likely to be used for portable stations.

As the battery's state of charge (SoC) is reduced, so is the voltage, especially under load. Battery voltage should be monitored to assure long battery charge-cycle life. For example, a nominal 12 V SLA battery is considered 100% discharged when the voltage under load reaches 10.5 V. Below this level the charge-cycle life is reduced. Even a deep-cycle lead-acid battery will be severely damaged by repeated discharge below 50% of its rated capacity.

Multiple SLA batteries wired in parallel may be used to extend operating time. The SLA battery terminal voltage when not being charged is still around 12 – 12.2 V, well below the radio's design voltage.

An advantage of using lead-acid batteries of any type (except for very small batteries) is that they can be charged directly from a vehicle charging system without a special charger. If a vehicle is available, a pair of medium-capacity batteries can be rotated, with one battery powering the radio while the other charges. Charging requires the vehicle engine to be running on occasion throughout the operation.

LFP AND LIPO BATTERIES

LFP is the most common type of lithium-chemistry battery used for 100 W portable stations. LiPo battery packs using LFP or similar chemistries are much smaller and used for lightweight and ultra-lightweight QRP operation. A lithium-chemistry battery will be half the size and a quarter (or less) the weight of a comparable capacity lead-acid battery. For a more complete discussion of LFP and LiPo batteries, see the Bienno Power web page at **www.bioennopower.com/pages/faq-lifepo4-batteries**. LFP in the remainder of this section refers to both LFP and LiPo battery types.

The LFP battery is very well suited for portable use, providing a nearly constant 12.8V output over its discharge cycle. When fully charged, LFP batteries will output around 13.5V with no load. As the reach depletion, voltage will drop to about 10 V. However, for 95% of the total range the voltage will stay between 12.6 and 12.9 V. This is within 10% of the 13.8V design voltage of most amateur radio gear. If a LFP battery is rated for 25 A-hr, it will supply 25 usable ampere-hours when new.

The LFP is tolerant of deep discharge without damage. Typically, an LFP battery will support 10 times the number of cycles available from an SLA battery of equivalent capacity. In other words, a single LFP battery would replace 10 lead-acid equivalents over its useful life. Total cost of ownership for LFP batteries is therefore much lower even though the initial purchase price is higher.

Two issues with LFP batteries require consideration:

• They require an appropriate charger and a vehicle charging system is NOT an appropriate charger. Recharging a LFP battery in the field will be more complicated and cost more than charging a lead-acid battery. Chargers cost more for lithium chemistries than for lead-acid.

• The usable capacity of a LFP battery drops considerably as the battery gets colder and charging when it is cold can easily damage the battery. LFP batteries can be used down to 0 °F (–20 °C) but should not be charged below freezing.

PORTABLE POWER STATIONS

These integrated power sources combine a large battery, an inverter, and electronics to allow charging from ac, solar panels, and other sources. Having the entire system in one package makes them very convenient. They are completely silent because there is no engine. Because there is no engine, they are also safe to use indoors. See **www.cnet.com/home/energy-and-utilities/best-portable-power-stations** for more information about these devices.

These units are rated in watt-hours (W-hr) with peak power up to around 1,500 W. To compare with battery-only capacity, you'll have to convert W-hr to amp-hour (A-hr) by dividing by 12 V. To account for an estimated 10% loss and other inefficiencies in the electronics, multiply the resulting A-hr value by 0.9. For example, a 500 W-hr station would be roughly equivalent to a 500 / 12 = 41.7 A-hr × 0.9 = 37.5 A-hr battery-only capacity. Remember that there will be additional losses when the ac power is converted back to dc for powering a radio.

Output ac waveforms are clean and there are usually several accessory dc outputs to run 12 V electronics and USB-charging ports. The ac outlets are typically limited in the amount of power that can be drawn from them so check the specifications to be sure they can supply enough power for your electronics. To let you know the state of charge for the internal battery, a display of voltage and charge remaining is included. Complete packages that include solar panels are available.

BATTERY CAPACITY REQUIREMENTS

Watts (W) is the unit of power and the watt-hour (W-hr) is the unit of energy and battery capacity. Most batteries are rated in ampere-hours (A-hr). This is the battery's ability to supply a certain level of current at a nominal output voltage. The battery's energy storage capacity is the product of A-hr and nominal voltage. (A more detailed procedure for evaluating the energy needs of a complete portable station is supplied in the section "Choosing a Battery for Portable Operation" in the **Power Sources** chapter.)

If capacity is not specified for a battery, multiply the battery's A-hr rating by its nominal voltage. For example, an 8 A-hr, 1.5-V D-cell battery has an 8 × 1.5 = 12 W-hr capacity. A typical 3 A-hr, 12.8-V LFP battery would have a capacity of 3 × 12.8 = 38.4 W-hr.

The following method produces a rough estimate of required capacity for operating with a 100 W HF transceiver:

• For SSB operation, assume that energy consumption is 100% of the value of peak output power in watt-hours. For example, if peak output power is 50 W, assume 50 W-hr per hour of operation.

• For other modes, assume 200% of peak output power. For example, if peak output power is 35 W for CW or FT8, assume 35 × 2 = 70 W-hr per hour of operation.

Multiply the energy consumption by duty cycle (the percentage of time transmitting). For casual operation this is generally assumed to be 0.25 or 25% of total operating time. For POTA/SOTA, Field Day, or contesting, assume 0.50 or 50%. Then multiply by the number of hours of operation. This is the total required capacity.

For example, a 5-hour SSB POTA operation at 100 W PEP requires (100 W-hr per hour) × 50% duty cycle × 5 hours = 250 W-hr capacity. If using a LFP battery that can be nearly fully depleted, 250 W-hr / 12.8 V = 19.5 A-hr and a 20 A-hr battery is sufficient. An SLA battery has a lower nominal voltage (12 V) and can only be discharged 50% without damage, so a rating of 20 A-hr × (12.8 V / 12 V) × (1 / 50%) = 42 A-hr is required.

24.3.3 Antennas for Portable Stations

An effective antenna system is essential to all types of operation but is likely the most important part of a portable station. Strive for the best antenna system possible because operations in the field are often restricted to low power by power source and equipment considerations. An effective antenna makes the difference between success and frustration.

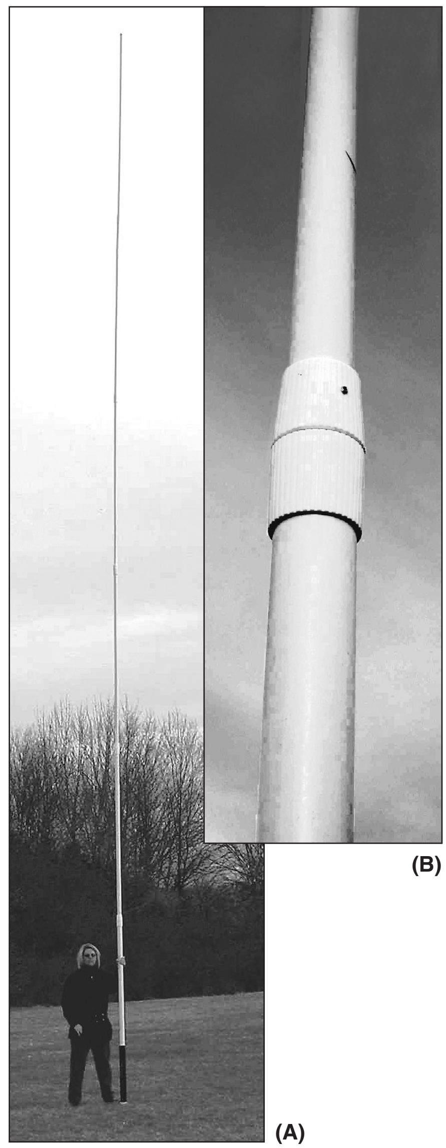
Effective antennas are more challenging for portable stations than for permanent stations. A portable antenna must be light, compact, and easy to assemble. Portable station antennas need to go up and come down quickly, in just minutes. If you only have four hours to spend at a park, for example, and the antenna takes two hours to setup and an hour to tear down, three-quarters of the available time is lost. It is also important to remember that the antenna will be erected at a variety of sites, not all of which will offer ready-made supports.

This section will cover supports for the antenna, review a few basic types of popular full-size and compact antennas, and antennas for VHF/UHF operation that are popular for mountain-top operating (mentioned above, the SOTA program encourages activity on these bands). More information about the design and construction of these antennas is available in the **Antennas** chapter and there is an entire chapter on portable antennas in the *ARRL Antenna Book*.

ANTENNA SUPPORTS

The simplest support is no support, or more accurately an antenna that supports itself. Vertical antennas which use steel or telescoping whip radiating elements often need no external support if they are attached to a substantial base. Mobile antennas, attached to a vehicle, are the best-known example of this type of antenna, and they represent a very reasonable option for some types of portable use.

Another relatively simple option is to use a support which already exists at the location. Usually this means trees, although creative amateurs have pressed observation towers,



(B)

(A)

Figure 24.34 — Telescoping fiberglass poles can be used to support a variety of wire antennas or small VHF/UHF Yagis. The one shown in A is 40 feet long, yet collapses to 8 feet for storage. At B, a typical twist-lock mechanism secures the sliding sections in place.

Figure 24.35 — The K5ND/r push-up mast (a painter's pole) on a drive-on base with a stabilizing brace attached to the roof rack.

telephone or light poles (never power poles!), and even buildings into service. Make 100% certain that you have permission to use the desired structure. Even with trees, you need to be certain that park or other green space regulations allow you to use them as part of an antenna system.

The complexity of getting an antenna onto or held up by one of these supports will vary, but the tools used by arborists are the best and safest bet for use in a public space. Arborist rope and "throw bags" are effective, will not damage delicate trees, and work quickly and easily. Tennis ball launchers (the manual ones for throwing a ball a long way) can also be quite effective at getting a light line over tree branches. Avoid using slingshots or compressed-air launchers. These devices are often not allowed in parks or public spaces and are considered weapons under a number of ordinances. Their use, other than on private property, is not advised and may lead to a visit from public safety officers.

The telescoping fiberglass mast (see **Figure 24.34**) is a popular choice to provide a portable support solution. Multiple heights and weights are available from nearly 20 meters tall down to systems that are intended more for fishing than holding up antennas. Consider the operating requirements for height, weight capacity, and cost to select the correct mast. Remember that carbon fiber, despite its strength to weight benefits, is conductive and can affect antennas in unpredictable ways.

A fiberglass mast will not hold up even a small HF triband beam made of aluminum tubing. Wire antennas or a lightweight rotary dipole, a 2-element, 6 meter beam or loop, or a 2 meter / 70 cm beam is about the limit for the heavy-duty versions of these masts. To support bigger antennas, a traditional push-up mast such as the 30-foot Rohn H30 is required. These thin-wall steel masts are sturdy, but they are much heavier than fiberglass.

Do not attempt to "walk-up" an extended mast with a significant load attached to the top. A fiberglass mast section may snap, or a steel push-up mast can fold over, ruining them. The collapsing support can also be dangerous. With the mast vertical, extend one section at a time with the load attached. If the sections slip from the weight of the load, a small hose clamp at the bottom of the section can act as a stop.

Securing a mast is important as they can be tall enough to cover a lot of ground if they happen to fall, and damage to the mast itself is almost certain in an unplanned crash. If a vehicle is available, popular methods of supporting these masts involve "flagpole" holders which either mount on a trailer-hitch receiver or consist of a solid plate base onto to which you drive one wheel of the vehicle. **Figure 24.35** shows the VHF/UHF rover antenna setup of K5ND with a heavy-duty fiberglass mast in a drive-on mount. A brace attached to the vehicle roof rack keeps the mast vertical.

Figures 24.36 shows a drive-on base built by W7NS for small towers. A 3-foot section of Rohn 25 tower is welded to a pair of large hinges, which in turn are welded to a steel plate measuring approximately 18 × 30 inches. One of the rear wheels of a vehicle is driven onto the plate. Additional tower sections are then attached with the base horizontal and antennas added to the tower. The

(A)

(B)

Figure 24.36 — The portable tower mounting system by W7NS at A. A short section of Rohn 25 is welded to a metal base plate and a truck is driven on to the plate to weigh it down. The tower can be attached to the roof of the truck or guyed. Do not attempt to climb a temporary tower installation. At B is the portable tripod mount by W7NS. The tripod is clamped to stakes driven into the ground. The rotator is attached to a homemade pipe mount.

Field Day Tower Safety

In the haste to get a Field Day station on the air, safety can be overlooked when raising a tower or mast. The *QST* article "Field Day Towers — Doing It Right" by K4ZA and NØAX addresses many common situations and illustrates ways to put up small towers safely in temporary installations. The article is included in the *Handbook's* online information.

loaded tower is then walked up and secured to the truck or guyed. Do not climb a temporary tower.

Without a vehicle, a tall mast will require either a solid attachment to an existing structure or a set of guy lines. Lashing or tying fiberglass masts to picnic tables, water spigots, or signposts can avoid the need for guying. Remember that a guy line is only as strong as the anchor to which it is attached and, like using trees, permission is usually required to drive things like tent stakes into public ground. Whenever guying an antenna or mast in a public place, be sure to tie strips of caution tape to the guys to help people avoid walking into them.

Another method of supporting portable beams is shown in **Figure 24.37**. Also built by W7NS, this support is intended for use with small HF or medium-sized VHF/UHF beams. The tripod is available from any dealer selling television antennas; tripods of this type are usually mounted on the roof of a house. Open the tripod to its full size and drive a pipe into the ground at each leg. Use a U-bolt to anchor each leg to its pipe.

The rotator mount is made from a 6-inch-long section of 1.5-inch-diameter pipe welded to the center of an "X" made from two 2-foot-long pieces of concrete reinforcing rod (rebar). The rotator clamps onto the pipe, and the whole assembly is placed in the center of the tripod. Weights placed on the rebar hold the rotator in place, and the antennas are mounted on a 10- or 15-foot mast section. This system is easy to make and set up.

A base-loaded whip antenna is shown mounted on its own miniature tripod in **Figure 24.37A**. Camera tripods are another excellent option for compact antennas as shown in Figures 24.37B and C. Antennas make the assembly top-heavy, and wind can easily blow them over. Either secure the legs as for the heavy-duty tripod described above or add guys to the antenna.

WIRE ANTENNAS

Wire antennas are very popular for portable operation because they are simple and inexpensive while being fairly effective radiators. Quarter-wave vertical antennas and half-wave dipoles of all sorts find their way into the field so often because they do well in addressing the basics of portable stations:

• **Footprint** — How much room is required for this antenna?

• **Deployment effort** — How long will it typically take to deploy or take down this antenna?

• **RF Performance** — How efficient is the antenna and what does its radiation pattern look like?

• **Cost** — What investment is required to either build or buy this antenna?

Wire antennas for portable use can be made using smaller wire than is typically used in permanent installations. Larger wire offers

(A)

(B)

(C)

Figure 24.37 (Figures 24.37A, B, and C) – Three examples of small tripod-antenna combinations: a based-loaded vertical whip; two helically-wound whips and loading coils form a dipole; a portable mag-loop antenna.

better physical strength, but even #30 AWG magnet wire can easily handle 100 W. The lighter carry weight is well worth the effort to handle a portable antenna with a little care and the low cost of small wire makes replacements fairly painless.

Quarter-Wave Vertical

At HF operating frequencies, the ¼-λ vertical is one of the few antennas designs that does not require elevation for good performance. Only the center radiating element (or elements if you build a multiband version) needs vertical support. Supports which are too short to be of any use for horizontal dipoles can work well with a ¼-λ vertical.

¼-λ verticals also operate across a relatively wide bandwidth and typically do not require impedance matching. This represents a significant size and weight savings for the entire station, as well as simplified operation. This is especially true if higher power operation is to occur.

The ¼-λ ground-plane vertical requires a ground plane of radial wires that increases its footprint. If you get a total of two wavelengths of wire down on the ground in eight different radial elements, you've accomplished 90% of what can be done. The length of any one radial is almost irrelevant. All else being equal, more numerous and shorter radials are easier to deal with than are longer ones and the shorter ones work just fine. Put your radials out in a circle if you can, but if that is not possible, just lay them out where you can. Remember to use caution tape to help people avoid walking over the radials. Rolls of chicken wire or hardware cloth at the base of the antenna are also very effective.

Center-Fed Half-Wave Dipole

Dipoles are very popular and present two potential advantages over the ¼-λ vertical. First, less wire is needed to construct a dipole when compared to a radial field. This means far less wire to buy, carry, and deploy. Second, if deployed at a suitable height, a dipole can exhibit gain over a vertical. This can facilitate operation with smaller radios powered by smaller batteries.

To achieve these benefits, a dipole should be mostly horizontal and at least ¼ λ above ground. That requires two trees spaced far enough apart and two sets of arborist ropes and weights, or at least two if not three portable masts to support the center and ends of the dipole.

The dipole can be installed with a single support as an inverted-V rather than a horizontal. The support will still need to be as tall as possible for best performance. An inverted-V is a nearly omni-directional antenna. The support will have to hold the weight of the full dipole, as well as the feed line and, in some cases, a balun.

The End-Fed Half-Wave (EFHW)

If the dipole is fed at one end, the entire antenna system becomes far simpler to deploy. Half-wave wires are also resonant on all harmonics, not just the odd ones, making the EFHW a natural multiband option. The EFHW is likely the single most popular of all the simple wire antennas for portable use.

For portable operation, the feed point impedance transformer is usually mounted a few feet above ground and the antenna held up in the air at the far end. Remember that the feed point is a point of high RF voltage. Ensure that there is no one in the vicinity of the feed point when transmitting.

The radiating wire can be deployed in nearly any layout. If high and horizontal it will perform on par with a traditional dipole. If deployed vertically, it will compare well to a ¼-λ vertical and do so without a radial field. Typically, some "zigging and zagging" is necessary to get the wire in the air. Sloped runs, inverted Ls, inverted-Vs, and "that's where the branches were" paths are all acceptable, albeit with sometimes unpredictable radiation patterns.

The EFHW does not require a radial field, but a return path for the feed line current must be provided. The feed point transformer will have an output for the radiating element and a ground connection. This ground could be strapped to an actual earth ground (water pipes are a perennial favorite) or ground radials. Most commonly, portable operators simply rely on the coax feed line shield to act as the return path portion of the antenna system.

End-fed "Random" Wire

Similar to the EFHW, the "Random Wire" antenna is a popular end-fed wire for portable use. It is considered to be a "random" wire because it is not intended to be resonant on any frequency where it is to be used. The wire is installed wherever the operator can place it and connected directly to the output of an antenna tuning unit or transformer. Because the length is unknown in advance, predicting its performance is difficult. The feed point impedance of the antenna will vary over a wide range so be prepared to adjust the tuning unit.

Compact Antennas

Compact antennas need less in the way of support and are easy to deploy. Large antennas, strung through the trees, are simply not an option in many portable scenarios. On the other hand, a small tripod placed directly on the ground holding a whip antenna is much less likely to draw attention.

For portable use, the advantages of having a physically smaller antenna are obvious. It reduces the station footprint and while they may not ultimately be any lighter, smaller components are easier to pack. This makes them easier to transport in smaller cars, backpacks, or however the operator is getting to the location. Physics will not be cheated and so these physically compact antennas are a compromise. They trade performance for size and, depending on one's perspective, operational convenience as well.

Commercially produced antennas generally are more expensive than home-built versions of the same design. This is true for any antenna, but it is more pronounced for the compact portable antenna.

Loading (see the **Antennas** chapter) uses some combination of inductance and capacitance to make a radiating element electrically resonant at a frequency lower than physical dimensions of the element would indicate. The best-known example of this technique is a base-loaded vertical antenna, where a loading coil is placed at or near the bottom of the vertical radiator. This design allows for the vertical radiator to be shorter, in many cases quite a lot shorter, than a full ¼-λ.

Coil loading is also possible with horizontal antennas. Dipoles with "traps" to allow multi-band operation are shorter than their monoband versions at the same frequencies because the inductance in the traps electrically elongates the radiating element below the trap's resonant frequency. (See the **Antennas** chapter for more about traps.) Capacitance "hats" can also produce the same electrical elongation effect, and due to size constraints are the more common choice for the 160-meter band.

A very popular arrangement is to combine an adjustable loading coil with an adjustable, telescoping whip for the radiating element. (see Figure 24.37A) The coil for this arrangement is typically adjusted by means of a collar or collars which can be moved along the coil and secured with a thumbscrew at any point, thereby selecting just the right amount of inductance for the target operating frequency. The telescopic whip allows the radiating element to be adjusted so that the least amount of loading coil is needed. For higher HF bands such as 6 meters and 10 meters, the whip will likely not be fully extended, and the coil is essentially bypassed. Moving lower in frequency, the whip will need to be longer. At some point there is no more whip length available and turns of the coil start to be introduced to compensate for a radiator that is shorter than resonant. The base-loaded antenna does still require ground radials, however.

Another popular option is to combine a pair of helically-wound loaded mobile whips, making a shortened dipole. A special fixture with an SO-239 connector attaches one whip to the center conductor of the feed line and the other whip to the shield. You can see this kind of antenna in Figure 24.37B.

"Mag" (magnetic) loops are another option for portable operation. Typically 6 feet in diameter or smaller, they can be mounted on a short pipe support or tripod as shown in Figure 24.37C. The loops are very high-Q antennas which results in a very narrow bandwidth that requires re-tuning every few kHz. Loops can be home-made but be very careful to avoid lossy construction because of the extremely low radiation resistance of the antenna. Another caution is to be sure to keep the antenna away from people due to the high field strengths near the antenna. **Table 24.4** shows the minimum distance for compliance with RF exposure limits at different power levels and frequencies.

VHF/UHF Antennas

Portable operation often means that the operator is in a more remote location, which leads many to believe that VHF/UHF+ are not useful bands. This is not necessarily the case. From higher elevations, line-of-sight is a long distance and operation at the shorter wavelengths can be great fun. High gain antennas at these frequencies are much smaller than their HF counterparts, so taking them portable is practical and their benefits are more noticeable than in local repeater work.

The simplest VHF antenna is no dedicated antenna! Many HF antennas, especially wire antennas, will behave as a "long wire" once the frequency is greater than 100 MHz. A 40 meter dipole is 10 wavelengths of wire on 2 meters! Give the HF antenna you were already using a try. It might surprise you.

If the goal is an omni-directional antenna, then variations on the classic "J-pole" antenna are very popular. A J-pole is nothing more than a vertical EFHW, and so has the same gain and radiation pattern as a vertical dipole. However, unlike most end-fed antennas, the J-pole has a $\frac{1}{4}$-λ transmission line matching section built into the antenna itself.

A Yagi for 2 meters can be handheld and, if constructed so that it can be disassembled for transport, pack relatively small. Just 3 elements in a 2 meter Yagi will net the operator 6 dBi of gain, which is equivalent to doubling operating power, while at the same time providing enough directionality to reduce the effect of sources of noise to the sides. When operating on top of a summit laden with commercial communication towers, the directionality of a Yagi can be far more beneficial than its gain. The Yagi, however, is usually a monoband design.

TIPS FOR PORTABLE ANTENNAS

Remember that in a public space you are also an ambassador for the hobby. Appropriate equipment goes a long way to making a positive impression with the public and with any managers of the space you're using. Since the antenna will likely be the most visible part of the station, as a rule, a smaller footprint is a better choice. Consider placing caution tape around the antenna or support to keep people from walking into it.

Portable antennas need to be easily transportable. This generally means they need to be relatively lightweight and pack down to a manageable size. Traveling by full-size pickup truck is different from traveling by motorcycle, so each operator will need to define their own requirements for size and weight. Backpacking an antenna to a summit poses different challenges than driving to a parking lot!

Sometimes, operating portable simplifies the antenna. Since these are temporary antennas, there is no need for them to survive for several seasons and through extended bad weather. Durability for a portable antenna is more about being able to survive repeated deployments than it is surviving the time while it's up. Taking a portable antenna down for a repair is easy if the need arises.

The acceptable footprint for a portable antenna will vary by operator and by location. Operating in a vast expanse of uninhabited space may allow antennas much larger than would be practical at home. An operator working from a popular tourist attraction will have far fewer plausible options.

A club Field Day-style operation may be able to manage large antennas and even use portable and temporary towers. For personal portable setups, big or heavy antennas should be passed over in favor of smaller arrays. The few decibels of gain a multi-element, 20 meter beam may have over a wire antenna is not as significant as the mechanical considerations. Stick with arrays of reasonable size that are easily assembled and support within your abilities.

Wire antennas should be cut to size and tuned prior to their use in the field. Be careful when coiling these antennas for transport, or you may end up with a tangled mess when you need an antenna in a hurry.

Beam antennas should be assembled and tested before taking them afield. Break the beam into as few pieces as necessary for transportation and mark each joint for speed in reassembly. Hex nuts can be replaced with wing nuts to reduce the number of tools necessary.

For coaxial feed lines, use RG-58 for the low bands and RG-8X for higher-band antennas. Although these cables exhibit higher loss than standard RG-8, they are far more compact and weigh much less for a given length. Avoid the extra loss of ultra-light cable like RG-174 unless the feed line is very short or saving weight is a high priority, such as for hiking and summiting. Some ultra-light QRP radios can drive 300-ohm feed line, as well. The feed line should be attached to the antenna with a connector for speed in assembly.

24.3.4 Computers for Portable Stations

The portable station often includes a computer of some kind. Smartphones, tablets, laptops, and modules such as the Raspberry Pi present a wide range of options for automating field operation.

The first decision is whether a computer is needed at all. In the case of strictly CW or phone operation, a computer is optional. Paper logs work fine for logging CW and phone contacts and the simplicity of paper lets you leave the extra electronics (and weight) at home. All the popular portable operating programs and most contests require electronic logs, however, so you would need to transcribe the paper logs after returning home.

Many operators choose to log directly with a computer in the field which increases accuracy. For instance, the computer will automatically date and time stamp contacts to the second. Logging software can often include call sign lookup functions, which helps verify that a call sign is valid and correct. (Some contests do not allow online call sign lookup during the contest, though.)

Ask first, does the computer need to be connected to the radio? Control of the radio requires using its CAT (computer aided transceiver) protocol via an RS-232 COM port, USB interface, or CI-V single-wire serial interface for Icom radios. This collects frequency and mode data, and possibly other items, like power level. Computer interfaces can key the radio for CW or FSK. Software can play back and record audio messages as can some radios with a computer selecting messages under keyboard control. Tablet and

Table 24.4
RF Exposure and Compliance References for Small Transmitting Loops

Power (W)	*Band*	*Controlled/Uncontrolled Distance (m)*
5	40 – 10	1.2 / 1.7
10	40 – 10	1.5 / 2.1
150	40 – 10	2.4 / 4.2
1,500	80 – 10	4.9 / 6.6

Source: Kai Siwiak, KE4PT, "RF Exposure Compliance Distances for Transmitting Loops, and Transmitting Loop Current," *QST* "Technical Correspondence" May 2014, page 64.

Less Is More — Ultralight Portable Operation

Nowhere are weight and efficiency more important than on the top of a mountain and Summit On The Air (SOTA: **www.sota.org.uk**) operations illustrate that very well. There are a number of QRP 1 to 5-W "pocket" transceivers, generally operating on 40 to 20 meters, although 5- and 6-band versions are available. Larger radios such as the Elecraft KX-3 have more features, including top-class receivers. VHF/UHF handhelds are also highly portable and have the batteries (and chargers) built-in. You can find out a lot about this style of operating from KE6MP in his presentation at **www.ke6mt.us/wp-content/uploads/2018/12/KT5X-WS0TA-SOTA-UltraLyte.pdf**.

Steve Galchutt, WGØAT, and Fred Maas, KT5X, both with years of experience and hundreds of peaks activated, contribute the following valuable advice about ultralight stations. (See their **QRZ.com** web pages for more photos and links to ultralight operating resources.)

• A support mast or pole must be light and fold up quite short so it doesn't hang up on low branches while hiking. (Models are available that weigh only a few ounces, extend to nearly 20 feet, and collapse to under 20 inches.) A "tip-top" for a fishing pole can be glued on top, providing a ferrule to guide the antenna wire and strengthening the small tip section which is also telescoped and glued into the second section for extra strength.

• Antenna height is not as important on a mountain top. We have experienced good success using an antenna only a few feet off the ground when high winds require such. Lean lightweight support masts about 20 degrees in the direction of the antenna wire and orient the antenna wire down wind.

• Antenna wire needs to be *light* for lightweight supports but still strong enough to be installed and stay up. #26 or even #28 wire will easily handle 10 watts. The best is Teflon-insulated stranded wire as the insulation strengthens the wire, insulates it from branches, the wire itself is very flexible, and silver-plated strands present a low resistance.

• The EFHW installed in an inverted-L configuration offers advantages. The low end of the vertical section has almost no current, so ground losses are minimal. The last few feet of the wire can even be used as the feed line, connected directly to the radio without coax. At QRP power levels the body and radio act as a sufficient counterpoise. A simple impedance transformer eliminates the need for an adjustable tuner. A 5-band design by K1JD is described at **sites.google.com/site/k1jd5bandsota antenna/k1jd-5-band-trap-sota-antenna**.

Figure 24.C — Steve Schlang, K7TX, skied to this summit and operates a KX 2 radio with an EFHW antenna in an inverted-V configuration. (Photo courtesy Fred Maas, KT5X)

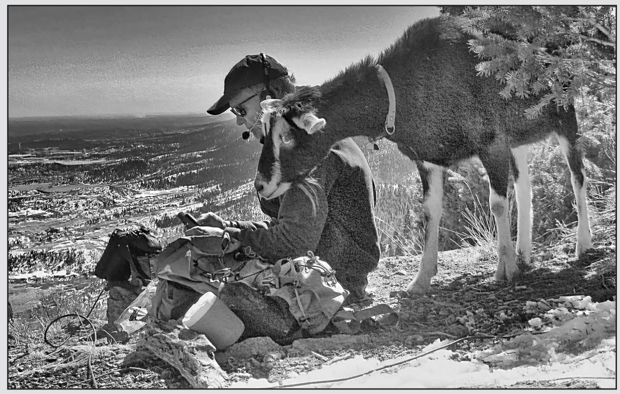


Figure 24.D — It helps to have someone willing to carry the gear and Steve Galchutt, WGØAT, enlists his pygmy goat, Peanut, who enjoys the trail as much as anyone and sometimes gives operating tips as shown here. (Photo courtesy Steve Galchutt, WGØAT)

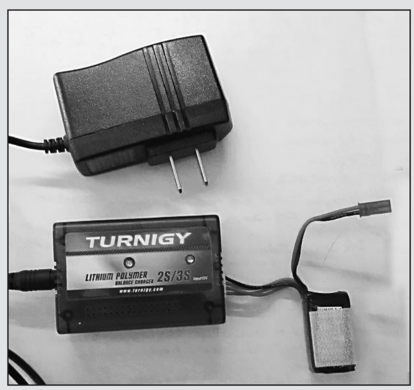


Figure 24.E — Lithium-ion batteries used to power small drones are available that only weigh a few ounces but store enough energy (up to 200 mA-hr) to power a QRP radio for an hour. (Photo courtesy Fred Maas KT5X)

smartphone devices generally do not support these external connections, leaving the operator to manually enter data into the logging program and operate radio functions. This is changing as the newest radios begin to support wireless connectivity like Bluetooth, but as a rule functionality is traded for portability when selecting a tablet or phone over a traditional computer.

Digital modes such as FT8 or RTTY make having a computer a requirement. (Some radios have built-in RTTY or PSK31/63 capabilities but generally do not make the information available to logging software.) AFSK modes also require an audio and PTT connection between the computer and radio, either as individual audio connections or via a USB audio codec. Software such as the *WSJT-X* suite that supports FT8, WSPR, and MSK144 requires a regular laptop or one of the more powerful Raspberry Pi modules (which require their own keyboard and monitor).

Having a computer in the vicinity of a radio introduces the potential for RFI due to being close to antennas and compromised station bonding. Simply moving the station and antenna farther apart is often enough. Plan for good bonding practices as described in the initial sections of this chapter. Control common-mode RF current on antenna feed lines and control cables with ferrite chokes and by minimizing cable length. In some cases, isolating connections between the radio and the computer with transformers or opto-electronics may be required. Support for Bluetooth connectivity in the newest radios provides isolation, as well. (See the **RFI and EMC** chapter for more discussion about dealing with RFI.)

RFI problems from the computing equipment are common, too. Switchmode power supplies can easily create RFI. The same solutions listed above can help. Additionally, it is often helpful to power auxiliary devices from the same battery as the radio using linear voltage regulators which do not generate RF noise. Unshielded computing devices can generate RFI directly from their circuit-boards and may need to have shielding added or be operated at a distance from the antenna.

As connectivity options continue to improve for radios, so too will the capabilities of connected computers and associated software. Options continue to expand and the trend is clearly towards more portable stations including a computer of some kind. Nevertheless, "bring along a pad of paper and a pencil or two — just in case" remains solid advice for the portable operator.

24.4 Remote Stations

The following section was updated by Ken Norris, KK9N. Although this section focuses on "remoting" HF equipment, the same considerations apply to most remotely operated stations, with the exception of repeater installations.

24.4.1 Introduction to Remote Stations

Remote stations (stations operated by remote control) have been a part of amateur radio for decades, but usually in the form of VHF/UHF repeaters. In the past, a few remote stations operating on HF have been developed in impressive locations with significantly more land, equipment and expense than for a repeater installation. Prior to the expansion of internet technologies, some of these remote pioneers utilized VHF/UHF links, dialup, or commercial microwave equipment for connectivity between the remote and home stations. There has been a significant increase in the number of remote stations over the last 10 years and the trend is accelerating rapidly.

Since this section was originally written, there have been several new developments and refinements of the technology available to access your home or remote station. As latency across the internet has been reduced, operating in fast-paced contests over very long links — even between continents — is now commonplace.

You may want to monitor your home station while you're away, avoid homeowner restrictions on outdoor antennas, or fight interference issues from electrical power lines, plasma TVs, network routers, and the like. With today's technology your home station or a remote HF station may be as simple as a 100-W HF radio and all-band dipole/vertical, to a fully automated contest station, with control and monitoring available to the operator via the internet. There is a flavor of remote station to meet almost every taste and budget.

This overview of remote station operation looks at different methods of remote operation and how they are each unique in equipment and technologies. There is no cookbook approach to creating a remote station. This discussion is intended to introduce topics to be considered in the circumstances encountered by each station builder.

Two important definitions that will be used throughout this chapter are the naming of the locations of equipment. The location for your radio, host computer, amplifier and antennas is your *station site* whether this is at your house or at a distant site. The other end of the connection is the *remote client* location. This location consists of the computer in front of you with the remote computer running client software and possibly a remote radio head (front panel) connected to the station site.

LICENSING AND REMOTE OPERATION

Before discussing the technical details, it must be emphasized that operating a remote station also carries with it an extra responsibility to be properly licensed and to identify your station correctly. Because the transmissions are made from the location of the remote station, you must follow the regulations that apply at the remote location. This is particularly important when the station is outside the jurisdiction of the regulatory authority that granted your license, such as a US ham operating a station in South America or a European ham operating a station in the US You must be properly licensed to transmit from the remote station! This may require a separate license or reciprocal operating permission from the country where the remote station is located. FCC rules require the control operator of a remotely controlled station in the US to have a US license, regardless of where the operator is located.

Don't assume that because you have a US license, you automatically have a corresponding license to operate a remote station outside the US. For instance, CEPT agreements generally do not apply to operators who are not physically present in the country of the transmitter, and you may be required to be physically present at the transmitter, as well. There may also be contest or award rules that apply to remote stations — be sure to know and follow all rules that apply.

24.4.2 Types of Remote Operation

REMOTE RECEIVERS

There are several different options for remote operation today. The most basic is the many remote receivers that are available online. These receivers are maintained by other amateurs and communication hobbyists and can be used by anyone with a computer, web browser, and the internet. Websdr and GlobalTuner are just two examples of remote monitoring sites and there are many more. (See this section's Resources list for URLs of these and other websites.) These websites give you the opportunity to be able to monitor radio activities in other countries or your own signal from another location.

A great source for listening to DX stations is on the **DXHeat.com** cluster page. If you Right click on the DX station you want to listen to, you get a popup that shows a pair of headphones, chart page, and link to the DX's QRZ page. If you select the headphones, it opens a page dedicated receiver on the wide-band WebSDR website. The wide-band SDR radio will be tuned to the DX station so you can hear them. The drawback is that this wide-band receiver is in the Netherlands. If you would like to hear what the European stations are hearing, this is a great web page.

Amateurs are also using the Raspberry Pi microcomputers, USB SDR receivers, and simple-wide-band antennas to build remote radio servers. The technologies available on these micro-computers allow remote access through a WiFi or cellular modem, connectivity by VPN (Virtual Private Network) or VNC (Virtual Network Computing) software and RDP (Remote Desktop Protocol) or use the operating system's built-in web publisher to produce the screen of the radio software. The best part is that all the components are low powered enough to be powered by a solar cell on top of a mountain or at a friend's farm.

REMOTING YOUR HOME STATION

With the availability of highspeed internet through cell phones, hotel, or office WiFi, operating your amateur radio station from the living room, back yard, while at work, on business travel, while vacationing, or just visiting the family has become an enjoyable part of the hobby. Your remote connection, referred to as "remoting," can be as simple as a computer, iPad, tablet, or cell phone monitoring the audio from your radio for the frequency you left it on, to full automated control and a remote radio control so you can catch that last needed DX country to fulfill your DXCC award. Some amateur radio operators have removed their HF equipment from their vehicles and have now installed remote cellular connections to their home stations.

DEDICATED REMOTE STATION

There are many amateur radio operators who are restricted by homeowners' association requirements or living in a temporary location, apartment, or retirement home that restricts the installation of outdoor antennas. Other operators live in areas where noise from electrical utilities and electronic devices render an HF receiver almost useless. For these reasons, setting up a station away for the restrictions and noise can be very appealing.

Some contesters have built a remote station on top of a mountain or in another country in order to be more competitive or to achieve DX while still operating from the comfort of their home. Setting up a remote station in another country does not add any more equipment than a station a few miles out of town. It does add different rules and regulations to your operating that must be followed.

Maintenance is also more difficult. If you want to find out why the amplifier is alarming when operating on 40 meters, a 6-hour drive or flight to a remote site is no trivial matter. Technology is available for remote monitoring of the remote site. As long as you have internet connectivity to the remote site, there are ways of troubleshooting your problems.

24.4.3 Remote Networking Basics

Today, the internet has become the preferred source for connectivity of your remote station. Landline telephones can still be used for remote DTMF control of your equipment or as a source for transferring the audio to and from your remote radio.

With the availability of high-speed internet at your home, at the office, or on the road from WiFi and mobile phones, reliable connectivity to your remote station has become easier. This ease of connectivity does come with the need to understand more about networking and how computers and other TCP devices communicate with each other. This section has been included to expose you to terminologies and technology that will aid in getting your internet equipment connected and operational. (See this section's Glossary in the online content for definitions of terms, abbreviations, and acronyms.)

ROUTER AND PORT FORWARDING

When you turn on your computer at home to browse the internet, it does not connect directly to the internet. As seen in **Figure 24.38** the computer first connects to a gateway most commonly known as a *router*. The router then allows the computer to connect to it and waits to see what the computer wants to do with the connection. When you open your internet browser on the computer, the router then assigns a numeric *port* within the router for the computer's IP address to route data to the IP address your Internet Service Provider (ISP) has assigned to the router.

This is basically how computers in your private home or work network communicate with the World Wide Web, public computer servers, and devices throughout the world. The router is the guardian that controls what information comes in and goes out of your private network.

Port forwarding is an option in most routers that enables you to create a permanent translation table that maps an incoming protocol port from your ISP to a specific IP address on your private network. It is a transparent process, meaning internet clients cannot see that port forwarding is being performed. This process enables you to remotely connect to TCP/IP-enabled equipment and TCP servers on a computer on your private network that are otherwise hidden from the internet by your router.

STATIC OR DDNS IP ADDRESSING

When you sign up with an internet service, the ISP provides you with a modem to connect their network with the network in your house. Normally when the modem is activated, it will request an IP from the ISP's *Dynamic Host Configuration Protocol* (DHCP) servers. Even though you can find out what the IP address is, you have no control over what IP address is assigned and how often it changes. Because it can be changed, this is a *dynamic IP address*.

For the best connection to the internet to provide access to your station remotely, a *static IP address* from your ISP is the preferred option. With a static IP address, you will be able to easily connect remotely to your remote station without the IP address changing periodically. ISPs are currently assigning more static IP addresses due to better management of active IP addresses and larger companies moving to the new IPv6 routing which has more addresses available. This means the old static IPv4 IP addresses they were using must be changed, as well.

If you are unable to get a static IP address, there are avenues for finding out what your assigned dynamic IP address is. WhatisMyIPAddress, MyIPAddress and other websites can tell you the current dynamic IP address you have been assigned from the ISP.

A better way to manage the ISP dynamic IP address is to use a service known as *Dynamic Domain Name System* (DDNS). This service will maintain an external connection to your computer through the modem/router and *firewall*, providing a named address for

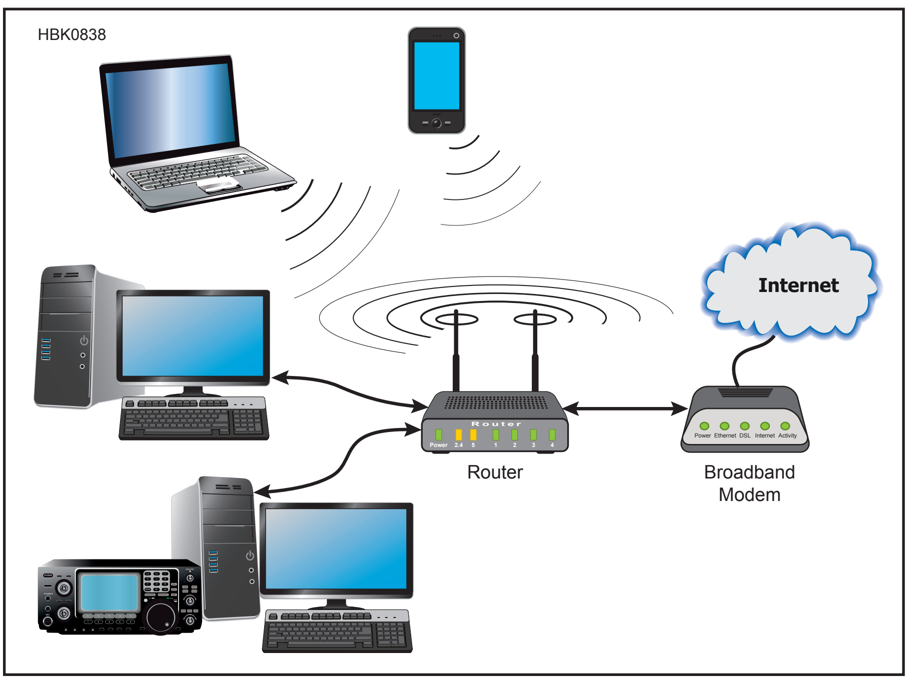


Figure 24.38 — Basic network structure and components.

you to connect to your equipment at home. This requires a small piece of software to run on your computer at home and an external DDNS service provider. Most DDNS service providers charge a fee to maintain and support this connection.

INTERNET BANDWIDTH

How much internet bandwidth do you need? How you set up your station, what devices and protocols you use, and what means you use for connecting to the internet determine if you get a reliable connection or one that freezes or delays when you are copying the call of a DX station.

If you are using a mobile connection for your roaming client station, you need *high-speed* or *high-bandwidth* service, the same as required for a streaming music service. 3G cellular service is the minimum service you can use at 144 kbits/s transfer rate. Mobile network services such as 4G, LTE, and 5G vary in most areas, but will give you network speeds and reliability closer to, if not more than, what most ISP networks can provide.

Speed is advertised by download speed (the bit rate from the ISP to your computer). *Upload speed* (from your computer to the ISP) may be only ⅓ of the download speed but is important for getting your audio and control to the transmitter. Using internet sites such as Speakeasy.net and Fast.com can give you a good indication of the download and upload speeds on your computer.

It is important to realize that sharing an internet connection can also reduce bandwidth. If others in your home are online at the same time, their activity will consume some of the bandwidth available to your network devices. A dedicated line or service upgrade to support remote station operation may be required unless you can account for all the concurrent household bandwidth requirements and determine that your service is capable of handling it all. A router with *quality of service* (QoS) prioritizing capabilities might solve or at least minimize multi-user problems on a single-line internet connection.

Rural ISPs usually consist of a wireless network over large areas. Network speeds can vary depending on the time of day or day of the week. This can be important, especially when you are trying to operate in a contest over a weekend when everyone else is at home streaming movies. If you plan to use a webcam for monitoring and security purposes, or stream a panadapter/waterfall type display, you must account for that bandwidth in your overall connectivity needs as well.

Hotels are known to vary network speeds depending on how many guests are in the hotel that night. You can check with the hotel staff to see if there is a secondary WiFi system that can give you more bandwidth.

INTERNET LATENCY

You need *low delay* (latency) to operate remotely, the same as any online gamer. For casual operating, you may be able to tolerate a latency of 250 ms or 300 ms. Serious contesters and DXers will most likely find this much delay frustrating, especially on CW. If you are a high-speed CW contest operator, very low latency is required to be competitive. Below 200 ms is adequate, below 100 ms is better. Otherwise, tuning "lags" and you will experience poor timing in the pileups. Voice and digital operating are more tolerant of delay.

You can easily evaluate basic internet latency yourself using the computer. In a *Windows 7* (PC) environment, under START | ALL PROGRAMS | ACCESSORIES you will find COMMAND PROMPT, or in a *Windows 8* and newer system, select START and type CMD. From within this DOS-like window you can run the *ping*, *tracert* and or *pathping* commands to access a particular IP address at the station site and average the response times to measure the latency. By adding the -t command to the ping command (for example, "ping 192.168.0.1 –t"), you will get continuous ping results until you use the CTRL-C keys to stop the ping process. This is critical to know in advance or to troubleshoot connectivity issues once you are operational.

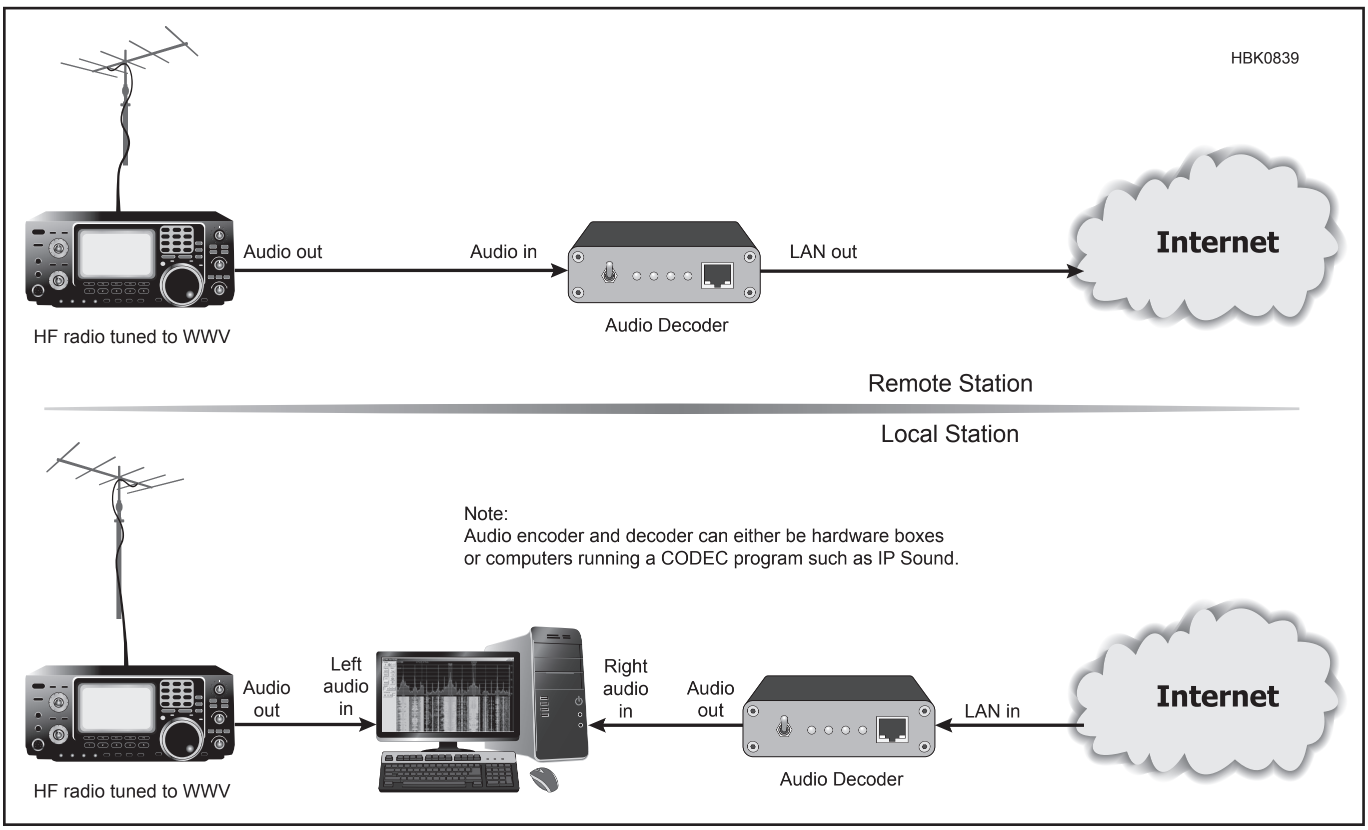


Figure 24.39 — N6RK's method for testing latency.

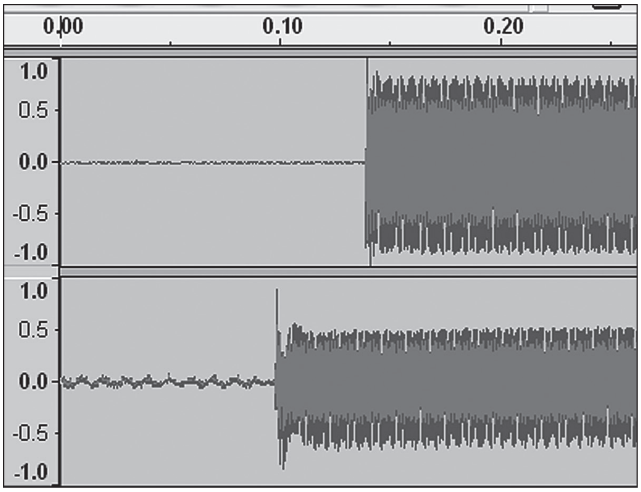


Figure 24.40 — K6VVA's latency test results.

For the purposes of conducting internet system audio latency tests, N6RK's method illustrated in **Figure 24.39** is very effective. Using a receiver at the remote site and one at the control point, the recorded latency can easily be determined. **Figure 24.40** shows a latency of 40 ms for the return audio over K6VVA's private control link using a RemoteRig audio interface that requires a network speed of about 180 kbps. The audio is crystal clear, and at 40 ms latency, little difference from having the radio control head connected directly to the radio at home is noticed at the remote site.

24.4.4 Connecting to Your Remote Station

There are many ways to connect, control, and monitor a remote station. What equipment, communications medium to connect them, and how you use your remote station is only limited by time, money, and resources available. The following methods are to be used as guidance as you plan and build your remote amateur radio station.

BASIC MONITORING

The basic remote monitoring station shown in **Figure 24.41** can consist of very few components. If you just want to set your HF radio on a specific frequency, let's say a 40 meter net, and monitor it from work during your lunch break, then all you need is an audio cable connected from the headphone/speaker jack on your radio to the microphone jack on your computer. On your computer you will need audio software to provide a connection to your mobile phone or work on a computer. Using the *Auto-answer* function on the host computer will give you unmanned audio connect. Simply connect the computer/handheld device to the audio software account on your home computer and listen in on the net.

Many remote station operators have found *Skype* to be a workable solution for remote audio routing as well as *IP-Sound*. Another way to completely avoid internet latency and bandwidth issues for audio is to use a POTS (Plain Old Telephone System) connection with a dedicated analog phone line that might also be shared with a DSL data service for control.

One of the newest technologies available to give you basic remote monitoring is the ability to use a Raspberry Pi as a TCP server for a SDR receiver. There are a few different versions of RTL-SDR TCP servers available that make it possible for programs like Airspy's *SDR#* to remotely connect to a Raspberry Pi/SDR receiver through the internet.

VNC CONNECTIONS

If you enjoy listening to your HF radio and would like to be able to tune remotely through the bands for different conversations, start with an audio cable from your radio's headphone/speaker jack to the microphone input on the computer. Your radio will need to have *computer aided transceiver* (CAT) control capabilities. Radios with CAT control will have a serial, USB, or Ethernet port available for the computer to be able to connect and send control data to the radio. Icom radios have a CI-V control port which requires a COM-to-CI-V or USB-to-CI-V interface.

You will then need radio control software installed on the computer. Several radio manufacturers have radio control software available. There are several software companies that have software to control just about any radio with CAT control. Two examples are *Ham Radio Deluxe* and *TRX-Manager*.

Once you have installed the radio control software and connected the computer to the radio, you will need remote access to the host computer. A simple scenario, shown in **Figure 24.42**, uses *Virtual Network Computing* (VNC) software, such as *Chrome Remote Desktop*, *TightVNC*, *TeamViewer* or *LogMeIn*, that allows users to take remote control of the host computer running the radio software. VNC software allows full control of the host computer, with some software including the sound interface and others requiring additional software for monitoring for the audio. Audio server software like *Skype* and *IP-Sound* can also be used. Be aware that some VNC

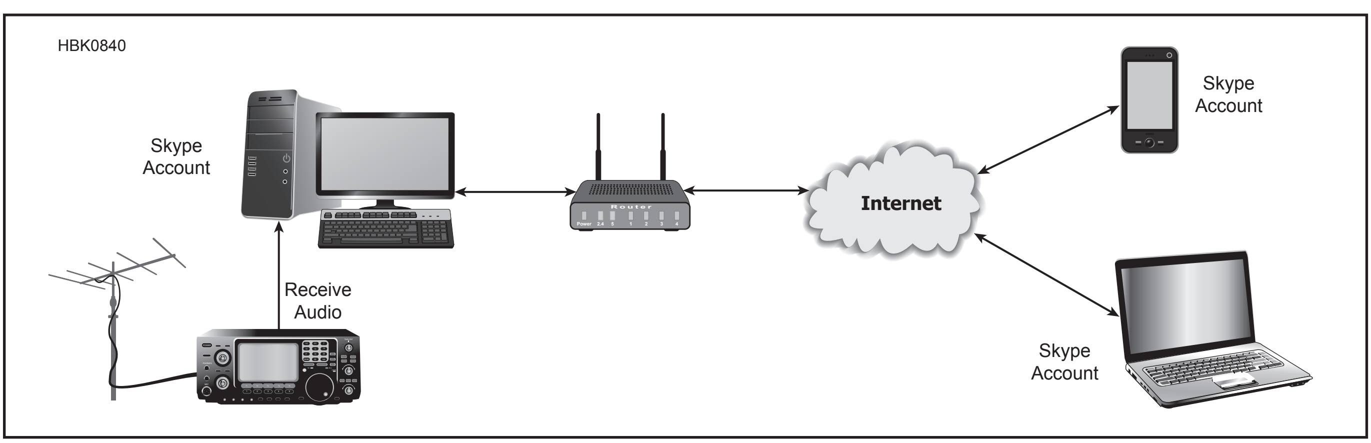


Figure 24.41 — Basic remote monitoring.

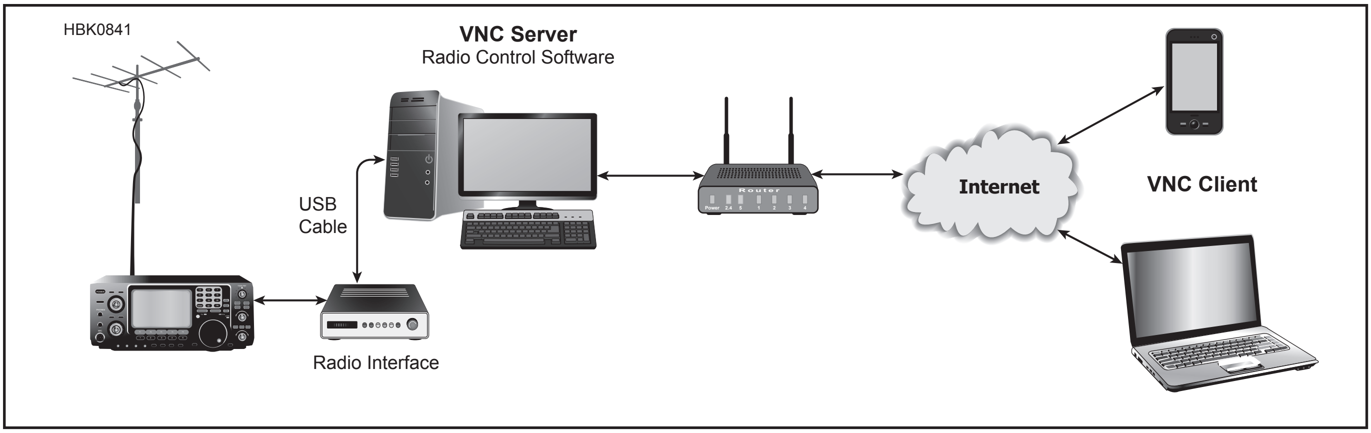


Figure 24.42 — VNC software connection.

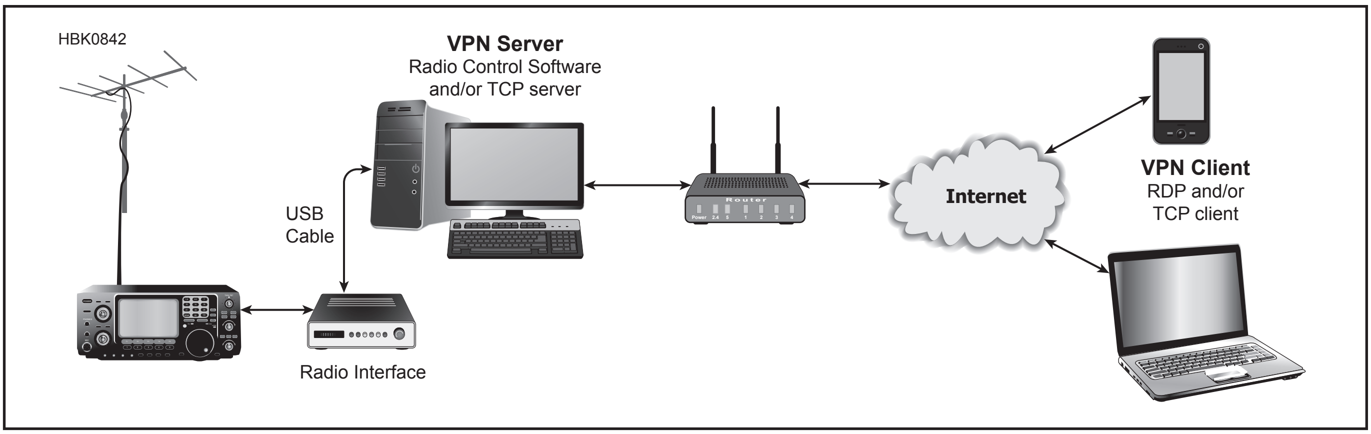


Figure 24.43 — VPN software connection.

software packages charge extra for access to the remote sound. This software does take a lot of bandwidth to pass the screens and control between the connected computers/handheld devices.

All the VNC software options mentioned here can be accessed with an iPhone, iPad, Android phone, or tablet. Once you have connected to your station with the VNC software, you will be able to change frequency and bands using the radio control software on the host computer.

VPN CONNECTIONS

A virtual private network (VPN) is like a tunnel through public internet access to connect to a private network, such as your station network. There are several VPN software packages and hardware options that enable you to create the internet connection for transporting data between the computer in front of you and the computer/devices at your home or remote station. A VPN uses encryption and other security mechanisms to ensure that only authorized users can access the network and that the data cannot be intercepted.

The VPN server at the station end can be either on the host computer or in the network router. It depends on if you need connectivity to only the host computer or the whole station network. Microsoft has included VPN servers and clients in recent versions of their operating systems and some network routers include VPN servers. Other VPN software packages include *OpenVPN* and LogMeIn *Hamachi*.

Once you have established a VPN connection to the host computer or router from your client computer, shown in **Figure 24.43**, you will be able to connect your TCP client software to the radio control TCP server software and/or accessories at your station. Another option is connecting to the radio control software on the host computer with a *Remote Desktop Protocol* (RDP) connection to view your radio control software on the screen and use *Skype*, *IP-Sound or* other audio streaming client/server software for the audio connection. This will give you a secure connection to your station.

Using a VPN connection can be combined with a remote radio head. This will give you secure access to the equipment connected to your radio and allow you to operate the radio from the remote radio head.

TCP SERVER/CLIENT SOFTWARE

TCP server/client software comprises two programs that provide a connection over the internet between your host computer and the client computer you have in front of you. Each piece of equipment can have its own TCP server/client software installed at both ends.

The TCP server software is installed on a computer that will be connected to your radio, tuner, rotator, or other station equipment, where it communicates with the station equipment by serial, Ethernet, or USB connections. Most of the TCP server software allows you to be able to control the equipment locally on this computer when you are at the station, as well as through a remote internet connection.

The TCP client software is installed on the computer that will connect to the TCP server software through your internet connection. This provides you access to the station equipment with a dedicated TCP network connection to each device you connected to a TCP server computer.

There are advantages to using dedicated TCP server/client connections to your station.

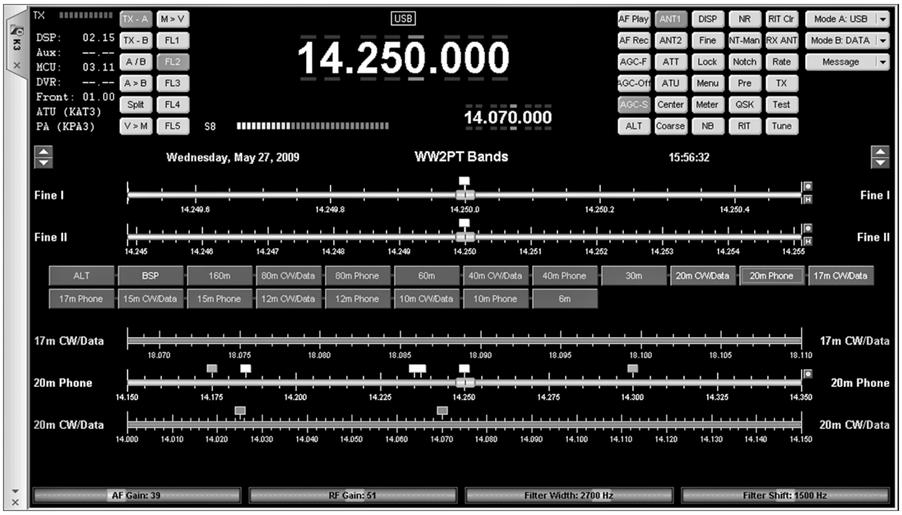


Figure 24.44 — Ham Radio Deluxe.

They use very small data packets, multiple TCP servers can be run in parallel for each device, and they can be connected only when you really need to see the data from the remote piece of equipment.

There are several radio manufacturers that have radio control software available utilizing TCP server/client technology. There are also software companies that provide software to control just about any radio with a CAT interface. Examples of this software are *Ham Radio Deluxe* (shown in **Figure 24.44**) and *TRX-Manager*.

REMOTE RADIO HEADS

Operating remotely from a computer or tablet can be fun and exciting, but it is not the same as turning a VFO or tweaking a bandpass filter knob to dig out the weak DX station. Manufacturers have developed internet-based interfaces to remotely connect a detachable radio head to the base section of the radio, hundreds of miles away.

One company to advance this idea is Microbit. Their RemoteRig standalone interfaces use separate *Session Initiation Protocol* (SIP), VoIP, and control channels to connect the two parts of the radio over Ethernet. Passing of the audio and control signals, along with CW paddle signals is transparent to the remote radio head. Elecraft makes the K3/0 remote head for the K3 transceiver that is identical to the front of the radio, giving you full functionality of your K3 station wherever you have internet access. The W4AAW multi-multi contest station uses the K3/RemoteRig combination at one of the operating positions for off-site operators during contests.

These remote radio interfaces work with several other radios. Remoting the Icom IC-706 and Kenwood TS-480 transceivers is very popular among amateurs. There are groups that have installed the base part of the Icom IC-706 in different locations and have the ability to connect to any one of them from the radio head. They have the capability to change the profile in the RemoteRig at the radio head for it to connect to the different remote site base units.

The FlexRadio Maestro (as seen in **Figure 24.45**) gives you an all-in-one Plug and Play control console for the Flex-6000 series radios. This unit has a built-in local area network (LAN) connection, as well as an integrated Wi-Fi client module for local wireless network connectivity. The LCD touch screen allows for pan, zoom, monitoring, and menu operation. The back of the unit provides connections for CW paddle, PTT, microphone, headphone, and other accessory connections to give you full access of the remote radio. An optional battery can make this remote unit a fully wireless option.

HAM RADIO ONLINE

If you are unable to invest in the equipment to operate remotely and really want to experience the rush of operating a contest or DX from a station with large antennas and lots of power, there are options available online.

One such service is RemoteHams. They offer the opportunity to use their RCForb client software on a PC computer or Android device to remotely connect to and operate stations around the world that are part of their community.

RemoteHamRadio currently offers you a chance to operate up to 25 dedicated world-class amateur radio stations across North America using an Elecraft K3/0, FlexRadio Maestro, or from your home computer/smart device using the RHR WebDX online or a custom desktop application. (See **Figure 24.46**.)

Using these systems, you have access to a community of stations through the internet, offering an experience not available through more modest stations.

24.4.5 Station Automation

Automation is key to having a fully functional remote station. The ability to control your rotator, antennas, and amplifier from your computer has been around for some time. Connecting a local host computer to the equipment and remotely monitor the host computer works, but now several manufacturers have added remote TCP server/client software to control your station from off-site. The following section describes software and hardware to enable automation and remote control of your station.

SWITCHING ANTENNAS

You can simplify your remote station by using one antenna for all the bands. Using a multiband dipole or vertical antenna will eliminate the need for antenna switching. Using the SteppIR BigIR vertical antenna with its controller, for example, gives you a

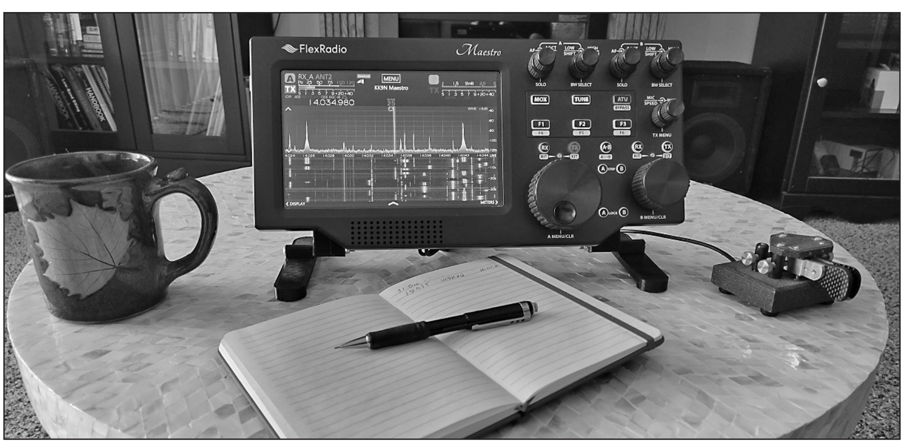


Figure 24.45 — Wireless FlexRadio Maestro.

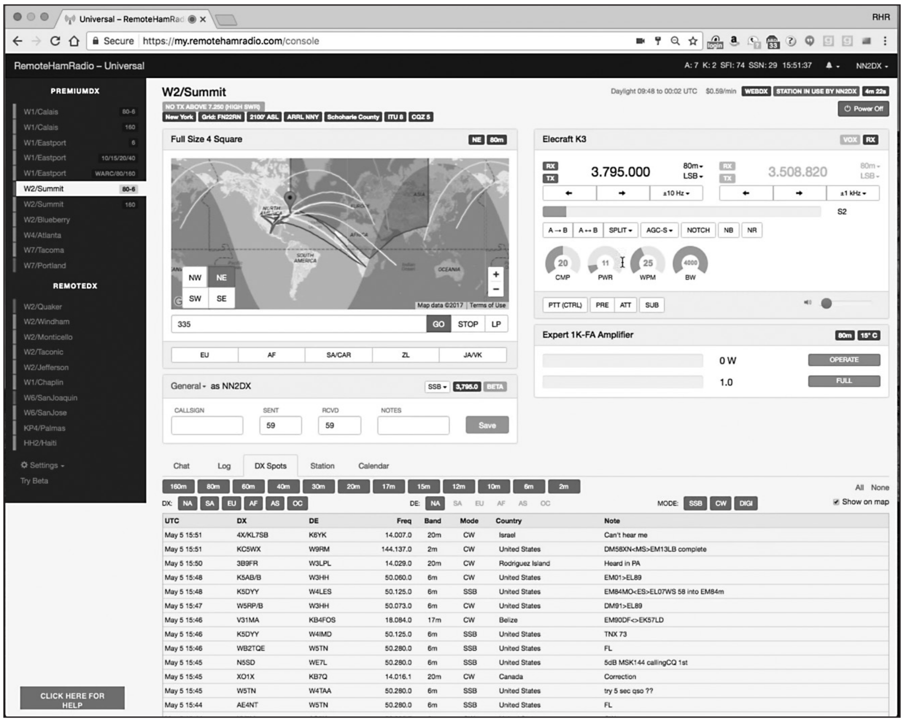


Figure 24.46 — RemoteHamRadio WebDX.

versatile antenna that follows the frequency from your radio.

To automate your antenna system, one of the first pieces of hardware you will need is a band decoder. A band decoder detects what band your radio is on and passes this information to the antenna switching network. The band decoders can detect the band either by a binary coded decimal (BCD) output from the radio, through a CI-V interface on an Icom radio, or by reading the frequency data from the radio. Band decoding can be accomplished with standalone units, such as the Array Solutions BandMaster or Elecraft KRC2, or a decoder built into an antenna switching controller, as with the Ameritron RCS-12, EA4TX RemoteBox, or Hamation integrated controllers.

An alternative to using a band decoder takes advantage of station control or logging software with the capability to send band data to antenna switching units via Ethernet or serial connections. The Green Heron Engineering antenna switches can be controlled by local software, as well as through TCP server/client software. Snaptekk offers a 4-port antenna switch with WiFi and a TCP server built in.

Additional advantages of Hamation antenna switches and EA4TX RemoteBox is the availability of USB connections to the host computer and TCP server/client software. With this software you can reconfigure your automatic antenna selection remotely or manually control what antenna you want to use.

The Antenna Genius from 4O3A Signature is the next generation of automatic antenna switches that eliminates the need for a band decoder or computer. The firmware in this line of antenna switches support connection and monitoring of band/antenna data through BCD, PIN to port, or advanced API software. The API software allows deep integration into supported amateur radios such as the Flex-6000 series.

ROTATORS

Automating your rotator system usually starts with installing an interface in the rotator control box to give your computer control of the rotator. Electronic Rotator Control (ERC) interface kits from Vibroplex or EA4TX give you the capability of connecting to your computer via USB or serial connections.

Most logging and contesting software, either directly or indirectly, gives you control of your rotator as you enter a call sign into the call field of your logging software. *PSTRotator* control software (see **Figure 24.47**) can interface with several logging software packages. It also has built-in TCP server/client software to tie it into your logging software on your remote client computer for automated rotator control from an offsite operating location.

RF AMPLIFIERS

Several modern amplifiers have the capability of full automation by detecting and following the frequency of the radio's output signal. Add this to the automatic antenna switching and tuners found in some of today's high-end amplifiers, and automation of your station has become much easier.

Most modern RF amplifiers can read the CAT data straight from the transceiver, set the band on the amp, a preset memory location on the tuner, and the appropriate Transmit antenna. Combine this with a remote head radio connection and you have no need for a VPN/RDP or VNC connection to your station for manual control, providing you with a clean, low bandwidth connection for your remote radio head.

A good example of remote monitoring and

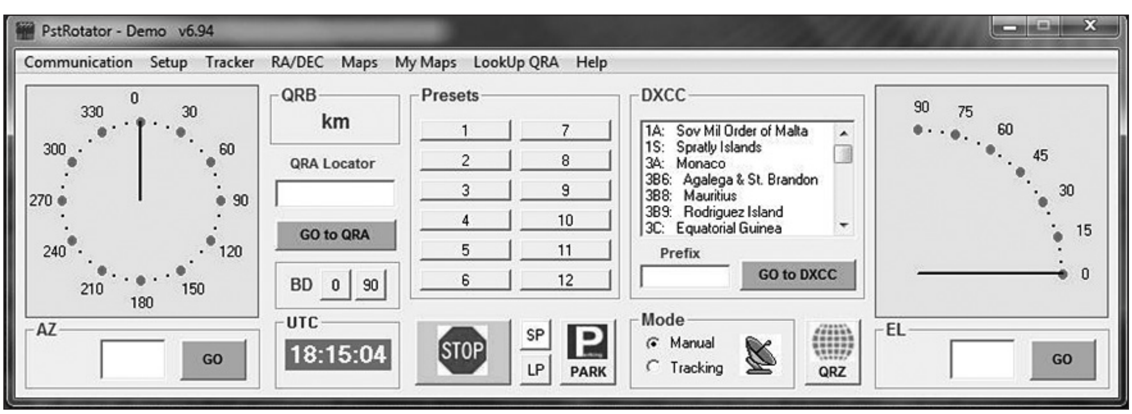


Figure 24.47 — PSTRotator software.

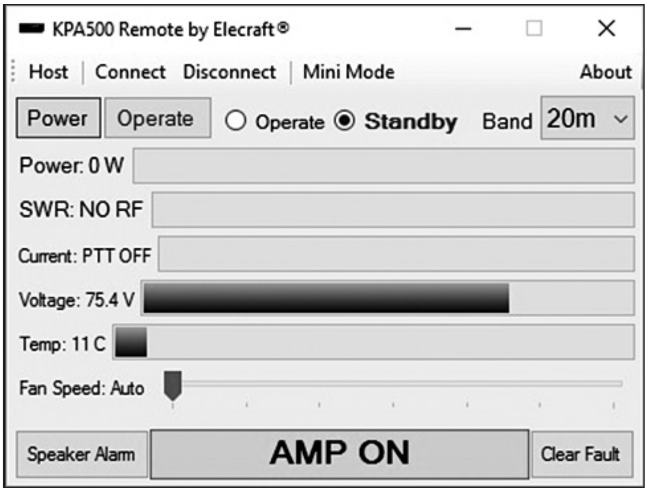


Figure 24.48 — Elecraft KPA500 TCP server/client.

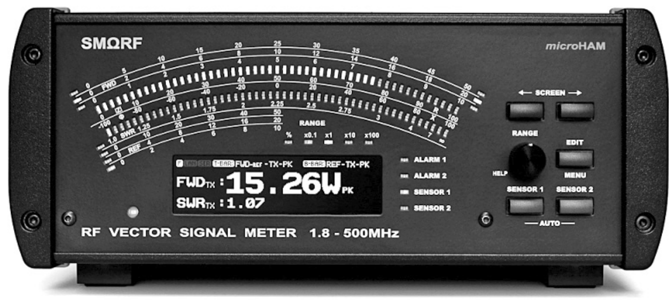


Figure 24.49 — MicroHAM SMΩRF power meter.

control is the Elecraft KPA500 amplifier and KAT500 tuner. Both have Aux connections to the radio for frequency tracking and serial connections for the host computer for control and monitoring. This allows for custom TCP server software to be run on a host computer that can be mirrored on a remote client computer as seen in **Figure 24.48**. For amplifiers with serial or USB connections and no TCP server software, they can also be connected to your host computer, then a remote VPN/RDP session or VNC connection will give you remote access to configure and monitor the amplifier.

Several of today's RF amplifiers are being produced with an Ethernet port incorporated into their design. This Ethernet port provides a built-in TCP server so any computer with the manufacturers TCP client software can connect directly to the amplifier for control and monitoring of the unit.

STATION MONITORING

It's important to know that a remote station is operating correctly when in a contest or trying to snag that rare DX station. There are a few manufacturers of power and SWR meters that include serial ports and software to monitor the meter on the host computer. The TelePost LP-100A power meter includes an RS-232 serial port and LP-500/700 models have USB for connection to the host computer. This software can be monitored via a VPN or VNC connection. TCP server/client software from Wizkers will allow remote access to the LP-100A through your host computer.

Several other RF power meters have built-in Ethernet connections and TCP server/client software for direct connection to the meter from a remote site without going through a host computer. The SMΩRF meter from MicroHam shown in **Figure 24.49** is one such example that gives the operator a full range of information about how the station is operating and evaluates the antenna system in the event of a problem.

POWER AND RELAY CONTROL

There are many ways to remotely turn devices on and off in your station. If you want to turn your radio, amplifier, and computer on and off, or switch between antennas, there is equipment available to do this.

Using your phone line to control devices is as simple as using the DTMF keypad on a phone. Several manufactures produce equipment to connect to the phone line with on-board relays that are turned on and off by DTMF tones. You can buy units with 1 to 8 relays from Velleman and Viking Electronics.

Using the internet to control relays is also possible. Digital Loggers and Belken Ethernet-enabled power strips that can be turned on and off by an app on your Android or iPhone. **Figure 24.50** shows how G4IRN uses a pair of Wi-Fi units to turn his amplifier and 12 V power supply on and off. This works great for turning on a power supply or switching between two antennas. For a lower cost option, Velleman makes a relay kit that connects to your host computer by USB and provides software that runs on the computer with an app to control the relays from your phone.

RADIO INTERFACES

Connecting the radio to the computer can be as simple as running serial cables and audio cables from the radio to the computer, but serial connections can be difficult to configure, and the audio connections can allow noise to get into the receive and transmit audio. It is recommended that an interface between the radio and the computer be installed. Several manufacturers make interfaces for most radio models that have CAT control in them, such as the ones offered from MicroHam, Tigertronics, and West Mountain Radio. Using interfaces simplifies connections and configurations. They also provide higher quality analog-to-digital audio converters than what most computers come with.

Several newer radios have the interface built in. A USB cable is all that's required for audio and CAT between the radio and the computer.

SERIAL PORT SERVERS

Serial port servers, such as the Moxa *Nport* or *Digi Connect* series, are interfaces that connect a RS-232/422/485 device to an Ethernet port. These port servers can act as a gateway between two protocols or pass encapsulated serial traffic between a serial device and a remote computer over Ethernet networks. Unless your software on the client computer is designed to communicate with the serial device over Ethernet, redirect software such as the *Digi RealPort* is required to manage the encapsulated serial traffic. Serial port servers are used when you do not want to use a computer at the station to connect the serial port on a piece of remote station equipment.

RASPBERRY PI

The Raspberry Pi is a tiny and affordable computer that has taken on a powerful role in the amateur radio world. This small computer is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation in association with Broadcom. Taking advantage of the Linux operating system, this computer utilizes the Node-Red programming environment for communicating between a wide range of devices through RS-232, USB, or TCP/IP using direct communication or APIs. This data can be displayed and controlled with user defined interface screens as part of the Node-Red Dashboard as in **Figure 24.51**.

Almost any piece of amateur radio

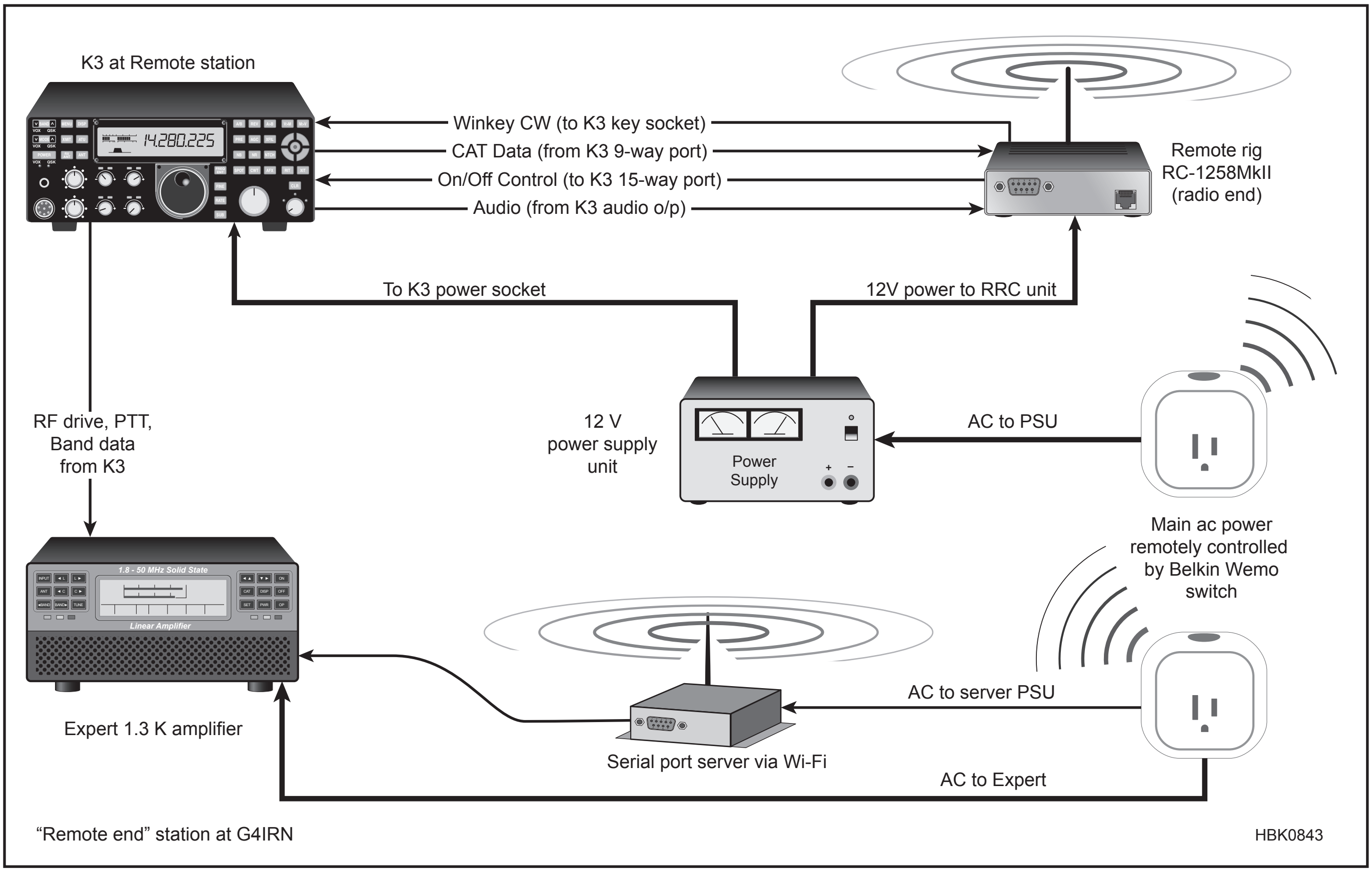


Figure 24.50 — Belken WiFi switches.

equipment that has an external communications port can be part of the Node-Red program. The following is a general list of modern devices that can currently be monitored and/or controlled by Node-Red:

- Amateur radio transceivers
- Tuners
- Amplifiers
- SteppIR Antennas
- Rotors (Using PstRotator software)
- Antenna Switches
- Preamps
- Watt meters
- USB Relays for external control
- Ethernet based power switches
- Weather Stations

The Node-Red Dashboard is a browser-based GUI interface that can be viewed at the operator's home station or as a window into the remote station through the internet. This Dashboard can turn your station on or off, show you how much power your radio is putting out, the VSWR of your antenna, which antenna is connected, what direction the antenna is pointed, current weather conditions, DX spots, and a host of other information. The Dashboards can display basic information as for a contester just wanting to know the antenna switched and when the VSWR goes high, to the casual operator monitoring everything at his station and getting an audio alert when they tune the radio outside the operating frequency of their license. And it's as simple as adding a Port Forwarding rule to your router and a Static IP (or DDNS service if no Static IP is available) to get remote access to the Node-Red Dashboard.

There is a large group of amateurs that have been building the individual "flows" for different pieces of equipment. If you have equipment that you would like to monitor or control through one piece of software, Node-Red is the best answer today.

If you are interested in learning more about Raspberry Pi and Node-Red, the first place to start would be to read the September 2021 *QST* article on page 30 "Node-Red for Ham Radio" by David De Coons, WO2X, and Michael Walker, VA3MW. This article explains Node-Red and its uses in amateur radio. Another great source is to join the online user group. The group's home page is at **groups.io/g/nodered-hamradio**. The amateurs that monitor the on-line groups can answer questions and direct you to the sources for your situation. The user group also maintains a database of custom "flows" for different pieces of equipment and functions helpful to the amateur radio operator, written by amateur radio operators.

Youtube is also full of helpful content on using Node-Red in amateur radio. Kyle Krieg, AAØZ, Dave De Coons, WO2X, and Michael Walker, VA3MW have all produced wonderful YouTube videos on installation and programming Node-Red applications for amateur radio.

ETHERNET IN THE STATION

Several of today's amateur radio manufacturers have embraced Ethernet communications in the equipment they produce. This allows for TCP or UDP communications between the radio, amplifier, tuner, antenna switch, filter controller, and other station accessories through a local Ethernet network. They have also produced custom API software for computers to interact with this equipment. This eliminates the need for all the 1-to-1 serial connections and radio interfaces previously used, reducing cabling and configuration headaches.

But using Ethernet communications brings its own set of problems. Without proper shielding, RF can get onto the CATx Ethernet cable and interfere with communications between devices. Using shielded CATx cable (grounded only at one end) or properly installing toroid coils can prevent RF from getting into your equipment. (See the **RFI and EMC** chapter.)

Figure 24.51 — Node-Red Dashboard.

Figure 24.52 — Stream Deck.

Another problem with Ethernet networks is excessive network traffic. Sharing your radio equipment with other devices in the home can cause interference and delays in communications between your radio equipment. One way to resolve this issue is to use an isolated Ethernet network dedicated to your radio equipment, and a separate network for Internet connectivity for your main computer and the remainder of the house. Adding a USB-to-Ethernet adapter to your main computer can link the second network to the Internet and keep the two networks isolated, reducing traffic on the radio network.

If you still want access to your radio from outside you house and also isolate your radio network from other parts of the house, a good router can be installed and programmed for 1 WAN to your ISP, and 2 individual LAN (House LAN and Station LAN) networks, each with different IP schemes. This will give both local LAN's access to the Internet but keep both networks from interfering with each other.

REMOTE CW

One problem CW operators will run into while operating remote is their dots and dashes not getting to the radio and transmitted as intended. Internet delays and breakup of CW data will distort the CW data causing undecodable transmissions. The most efficient way to send CW to a remote transmitter is by using *Winkeyer* software. Most logging software support redirecting CW characters to the local *Winkeyer* client application that sends it to the remote radio or interface to be converted from characters to dots and dashes for the transmitter to send.

Another problem CW operators run into is getting the transmitter sidetone back to the operator's location when the remote radio is generating the sidetone. One answer is to add a computer at the radio to input the sidetone audio and stream it back to the operator. FlexRadio users can use the Maestro to send the CW data to the remote radio and provide a local sidetone.

A third option is to use a local K1EL Winkeyer, like the WKUSB, and setting up K1EL *Com Port Scanner* software from K1EL Systems. This software will create virtual Winkeyer channels. One for the remote radio and a second one to the local K1EL Winkeyer. This will give you a local sidetone for the CW characters you are sending to the remote radio.

STREAM DECK

The Elgato Stream Deck is another power tool for local and remote operation of the radio station. The desktop device comes in several different models ranging from 6 – 32 buttons. Each button can be programmed for an operation that lets you open apps on your computer, adjust audio, mute your mic, turn on lights and so much more locally. A good resource for amateur radio use of the Stream Deck is Github *Hamdeck* and *Ham Radio Workbench*.

If you are a FlexRadio 6000 Series user, the Stream Deck can be programmed to monitor and control the remote radio (see **Figure 24.52**). See the FlexRadio Peripherals and Station Integration for details on setting up the Stream Deck. Other manufacturers will be supported soon as operators learn how to configure their radios and publish the plug-ins for the Stream Deck.

24.4.6 Remote Site Requirements

PURCHASE VS RENT OR LEASE

Although having direct control over every aspect of what you want to do is most desirable, you may want to consider a rental or lease with a cooperative landowner. In either case, having a detailed agreement or contract prepared by a competent attorney is a must. Be sure to include every contingency you can think of, and especially what happens if the landowner decides to sell. Leasing or renting with an option to purchase allows you to fully evaluate the site before making a long-term commitment to it.

RELIABLE ACCESS BY ROAD

If your remote site is not on developed property, will you be able to get there safely, rain or shine? What happens if any problems develop that require immediate attention at the remote site? Pavement or a good all-weather, well-maintained gravel road should be available. Having more than one means of getting in or out should emergencies arise while you are at the site is also an important consideration. These concerns must be addressed before agreeing to purchase, rent, or lease a remote site.

GEOLOGICAL AND OTHER HAZARDS

Evaluate the geological factors involved. In a hilltop or mountaintop site, is there evidence of soil movement that could affect access or damage your equipment shelter or tower installations? Does the property sit near an earthquake fault? Is there a significant risk of fire during fire season? Is the site exposed to high wind or storms? In flat-land sites, is there a risk of flooding or drainage problems? Remember, you won't be there to rescue your equipment! In consideration of both your initial construction activities and ongoing maintenance tasks, are there any wildlife hazards from animals or insects? What about allergies or reactions to plants such as poison ivy or poison oak? Diligently investigate all aspects of a potential remote site *before* you end up with bad surprises down the line. For a reasonable fee, there are companies from which you can secure a Geological and Property Hazards report to aid in your assessment.

RAW SITE PREPARATION

It you are fortunate enough to locate suitable property, be sure to evaluate the site preparation needs. How much time and money will be necessary to develop the remote site to meet your specific needs? Is there brush and vegetation to dispense with? Will trees need to be cut down? Will bulldozers, excavators, and trenchers need access to the site? Concrete trucks? Service vehicles? Diligent evaluation of all costs involved will reduce unnecessary stress.

SITES WITH EXISTING FACILITIES

Finding a site with a self-supporting tower or two in place that can accommodate your needs, along with a building large enough for your equipment and operational needs can be like finding a pot of remote gold. However, unless you are experienced with towers and construction, hire professionals to evaluate everything. If you are considering co-locating at a remote site with existing antennas and equipment in use, consider hiring a professional to help you evaluate the likelihood of problems. Birdies and intermodulation could end up being a source of potential conflict and stress if problems can't be resolved.

TERRAIN CONSIDERATIONS

Evaluate the terrain on the bands you wish to operate. For HF, Dean Straw, N6BV, has developed a very useful program called *HFTA — High Frequency Terrain Assessment*. (See the *ARRL Antenna Book*.) Use *HFTA* to assist you in placement of your antennas. Don't expect excellent ground/soil conductivity if your remote site is on top of a rocky mountaintop.

If you plan to use vertical antennas, make sure there is sufficient room on the property to place the radials, whether on a mountaintop or flat area. Placing verticals near water, especially saltwater, is the most desirable way to achieve the low takeoff angles for long-haul DX. Remember that exposure to salt air or spray will create significant maintenance issues.

NOISE LEVELS

Since one of the reasons for building a dedicated remote station away from your home is to lower noise levels, you'll want to carefully evaluate existing and potential noise sources. Start by visiting the site with a receiver in several different types of weather and listening on all the bands you intend to use with a full-size dipole antenna. If noise levels are low, this is no guarantee that problems won't crop up in different seasons or from hardware failures. You should avoid nearby substations or high-voltage and power distribution lines. If you will be sharing a site with other users, coordinate with them to test intermodulation and adjacent channel interference before you go into full operation.

ELECTRICAL POWER

Having electrical power already available at your remote site can certainly save a lot of money. The most ideal situation is to have underground power to the remote site. Be sure to evaluate the full costs of installing ac power if it is not already present at the site or on the property. Truly remote sites may require wind, solar, or generator power systems like that shown in **Figure 24.53**.

If your remote site will require solar/wind/battery power, it is critical that you properly assess sunlight path and duration, wind patterns, and provide sufficient battery storage to meet your intended operating needs during lengthy periods of inclement weather. The article "Designing Solar Power System for FM Translators" is a valuable resource for planning of remote HF station off-grid power. (See the Resources section below.) You must thoroughly account for the power requirements of each and every piece of equipment.

There are various estimates for the duty cycle of transceivers. A conservative duty cycle of 50% for CW/SSB is recommended for power capacity evaluation. (RTTY/digital/AM/FM duty cycles will likely be higher.) Internet switches, routers, rotators, computers, and anything electrical will also consume

Figure 24.53 — Solar panels can be used to charge a bank of batteries to supply power. Effective off-grid power requires an accurate and conservative estimate of power needs and available energy sources. [Rick Hilding, K6VVA, photo]

power. A supplementary diesel or propane remote-start generator to a basic off-grid system may be an appropriate option, particularly if you plan on using an amplifier. If your remote site is in a rugged terrain rural area, make sure a diesel or propane service provider vehicle can get to the location *before* you make final plans! It may be possible to use smaller propane tanks you can haul in a truck, but any manifold-type system necessitates insuring that the proper BTU requirements can be met based upon the propane generator manufacturer's ratings. Installing a solar and wind remote battery monitor system is advisable.

When you have made an accurate assessment of your complete system needs, add a generous additional contingency factor. It is also advisable to get quotes on your proposed system from at least two different "green power" equipment suppliers, and to make sure they fully understand your requirements and intended use *before* you purchase anything.

INTERNET ACCESS

If you are planning to operate your remote station via the internet, be sure that broadband service such as cellular, rural wireless, DSL or cable TV can reach your site by asking the local service provider to do a site evaluation. Satellite internet downlink speed may be fast, but uplink speed is often quite a bit slower. Be sure the minimum link speed is adequate in both directions.

If your control point is close enough to the remote site, another option is to implement your own private wireless "bridge" system. Even if multiple "hops" are involved, with the right equipment you can potentially have better results than using even broadband internet. Hamnet technologies (see the **Digital Modes and Protocols** chapter) may be an option to connect a remote station that's not too far away.

INSURANCE AND SECURITY

You've heard the expression "Stuff Happens." Unless you have blanket coverage in an existing homeowner's insurance policy that includes your remote site equipment, look into the ARRL "All-Risk" Ham Radio Equipment Insurance Plan. If you will be hiring others to do work at your remote site, be sure that liability coverage issues are addressed. The same applies to any guests or visitors such as fellow hams. Have a competent attorney draw up a "Liability Release" agreement with strong "Hold Harmless" language.

If your remote site is yours alone and not a co-habitation arrangement with other services, be sure and evaluate all security needs (a necessity even if co-located). You might need one or more security gates, webcam surveillance and auto-remote notification of security breaches.

PERSONAL SAFETY

Regardless of your age, it is prudent to have someone with you at the site. You could severely cut yourself or fall and break a leg. If there are wildlife hazards in the area, take appropriate steps to protect yourself.

Carry a first aid kit and have one readily available at your remote site. Keep some emergency supplies such as various sealed food items in a varmint-proof container and a case of bottled water in the event you find yourself stranded.

If your remote site is within the coverage area of a local repeater, take along a handheld radio (with batteries charged) as part of your SOP (Standard Operating Procedure). This is especially important for rural and remote operating sites.

24.4.7 Station in Your Hand

Operating or just monitoring band conditions from your mobile phone or tablet is almost as easy as from your computer. With today's smartphone technologies, Skype, VPN, RDP, and VNC connections to your station are quite possible.

There are several apps available or being developed for connections directly to your radio or radio interface. *RRC-Nano* is an app for Android devices from RemoteRig which makes it possible to remote your station. It uses the RemoteRig interface at the station site to provide remote access to the radio through your phone.

Available for the Flex-6000 series users with IOS devices is *SmartSDR* app for the iPhone or iPad. A small fee on the Apple Store gets you a third party IOS application (see **Figure 24.54**), that allows you full access to your remote FlexRadio Systems 6000-series radios.

24.4.8 Future of Remote Operation

With the increasing interest and equipment available for remote operation today, manufacturers of amateur radio products are moving forward with upgrades to existing and new equipment to take advantage of the Internet and expanding broadband coverage. Future radios will be easier to interface to other equipment in the station using APIs and will provide access from anywhere in the world. Several manufactures are developing new APIs and software for TCP Server/Client connections to their equipment.

With all the talent and resources in the amateur radio world, the Raspberry Pi and Stream Deck will continue to advance into more powerful station tools.

24.4.9 Special Events and Demonstrations

Remote stations come in very handy during special events. If you are putting on a demonstration of amateur radio, setting up an effective antenna may not always be viable, and you may not be able to communicate very well. Local noise levels or RFI problems may present significant challenges.

Setting up a remote link to your home or dedicated remote station will give you a definite advantage and make the experience more enjoyable for the audience. For example, a remote client station was used at a Boy Scout Jamboree-On-The-Air event. Young scouts were given the chance to communicate with other scouts around the world with the help of a capable station without the usual compromises associated with portable

Figure 24.54 — Flex IOS app

stations. This makes for a more effective demonstration of what amateur radio can do.

24.4.10 Remote Station Resources

For other great resources on how to set up a remote station, see the following videos, articles, or books:

Aaker, M., K6UFO, "Remote Operating for Amateur Radio: Ten Things to Know" see **www.k6ufo.com/attachments/Remote_Op_Ten_Things.pdf**

Aaker, M., K6UFO, "Remote Access — Six Ways to Implement" see **www.k6ufo.com/attachments/K6UFO_Visalia_2016.pdf**

Aaker, M., K6UFO, "Remote RTTY Contesting" **www.k6ufo.com/attachments/K6UFO_Dayton_RTTY.pdf**

ARRL Website Radio and Technology Topics, Link and Remote Control, **www.arrl.org/link-remote-control**

Craft, B., Evans, J., and Cook, M., *Raspberry Pi Projects for Dummies* (Wiley, 2015).

De Coons, D., WO2X, Basics of Node Red for Ham Radio **www.youtube.com/watch?v=nqJPPHG4aBw**

Ford, S., WB8IMY, *Remote Operating for Amateur Radio* (ARRL, 2010).

Hilding, R., K6VVA, "How Not to Build a Remote Station — Part 1," *National Contest Journal*, Jan./Feb. 2010, pp. 8 – 10.

Hilding, R., K6VVA, "How Not to Build a Remote Station — Part 2," *National Contest Journal*, Mar./Apr. 2010, pp. 19 – 23.

James, E., KA8JMW and Pendley, M., K5ATM, "Raspberry Pi: A Low Cost Platform for Amateur Radio Projects," **https://www.nm5hd.com/documents/PRESENTATIONS/RaspberryPi.pdf**

Krieg, K., AA0Z, - Getting started on a Remote HF station: **www.youtube.com/watch?v=0UJs5C1Yqzo**

Krieg, K., AAØZ, - Intro to Node Red for Ham Radio **www.youtube.com/watch?v=1WsEBCixuGc&t=2099s**

Sepmeier, Bill, "Designing Solar Power System for FM Translators" *Radio Guide*, Sep. 2008, pp. 6, 8.

Walker, M., VA3MW, Setting up my First HF Remote Station: **www.youtube.com/watch?v=C7d5C7nc5R0**

Yerger, Alfred T., WA2EHI, "Remote Control Your Rig via the Internet," see **www.arrl.org/files/file/Technology/LinkRemoteControl/RemoteControl.pdf**

Web URLs for Companies and Websites in this Section

4O3A Signature — **4o3a.com**
ACOM — **acom-bg.com**
Airspy — **airspy.com**
Ameritron — **ameritron.com**
Array Solutions — **arraysolutions.com**
Belken — **belkin.com/us**
Chrome Remote Desktop — **remotedesktop.google.com/**
Digi — **digi.com**
Digital Loggers — **digital-loggers.com**
EA4TX — **ea4tx.com/en**
Elecraft — **elecraft.com**
FlexRadio — **flexradio.com**
Hamdeck — **github.com/ftl/hamdeck**
Ham Radio Deluxe — **ham-radio-deluxe.com**
Ham Radio Workbench — **hamradioworkbench.com**
Hamation — **hamation.com**
HAMNET — **broadband-hamnet.org**
Icom — **icomamerica.com/en**
IP Sound — **iw5edi.com/software/ip-sound**
Kenwood — **kenwood.com/usa/com/amateur**
LogMeIn — **secure.logmein.com/home/en**
LogMeIn Hamachi — **vpn.net**
MicroHAM — **microham-usa.com**
Moxa — **moxa.com**
MyIPAddress — **myipaddress.com/show-my-ip-address**
OpenVPN — **openvpn.net**
PSTRotator — **qsl.net/yo3dmu/index_Page346.htm**
Raspberry Pi — **raspberrypi.org**
RealVNC — **realvnc.com/index.html**
RemoteHamRadio — **remotehamradio.com**
RemoteHams — **remotehams.com**
Skype — **skype.com**
Snaptekk — **snaptekk.com**
SPE Expert — **linear-amplifier.com**
SteppIR — **steppir.com**
Teamviewer — **teamviewer.com/en**
TelePost (N8LP) — **telepostinc.com/n8lp.html**
Tigertronics — **tigertronics.com**
TightVNC — **tightvnc.com**
TRX Manager — **trx-manager.com/demoe.htm**
Velleman — **velleman.eu**
Vibroplex — **vibroplex.com**
Viking Electronics — **VikingElectronics.com**
Websdr — **Websdr.org**
West Mountain Radio — **westmountainradio.com**
WhatisMyIPAddress — **whatismyipaddress.com**
Wizkers — **wizkers.io**