Bonus Chapter 1

The Technical Basics

In This Chapter

- Operating a receiver
- Operating a transmitter
- Operating hand-helds and mobiles
- Building antennas and feedlines
- Digital interfacing
- Working the satellites
- Learning about ionospheric propagation

So here you are, wondering what all those controls *really* do. What is a/an [insert your favorite mystifying term here]? This chapter will help you understand some of the technical details behind the front panel, making you a better operator.

Before plunging in, here are a few reminders:

- Read the operating manuals.
- Follow the manufacturer's recommendations.
- Don't be afraid to ask for help.

Remember that your equipment may not have all of the features I discuss in this chapter; or it may call them by other, proprietary names. If you understand the function, you'll likely be able to figure out what the function or control is called on your gear. In this chapter, I avoid proprietary names, but when I do use them, I identify them as such. I am also going to assume that you can set your radio to any desired frequency, select the desired mode (SSB/CW/FM/and so on), and can find any of the controls and navigate the configuration menus.

In Appendix B, there are a number of references to useful resources. As a beginner, you should visit or read these "early and often." Ham radio is a lifetime learning experience and no ham knows everything.

Operating a Receiver

The receiver is without a doubt the most important part of any station. You can't even begin a contact without being able to hear the other station. To keep the other station tuned in and to reject noise and interference, the receiver has more controls than any other piece of gear and you'll want to know how to use them all. My description of the controls is generic. Your operating manual will describe the function of each control in your particular radio.

The function of a receiver is to zero in on one tiny, nearly infinitesimal portion of the radio spectrum, exclude all other signals except for the desired one, and maintain an even level of output for a wide range of input signal strengths. The better it does those three things, the better a receiver it is. Let's start with the first of those three functions — the one you will use more than any other — tuning.

Tuning

The large tuning knob or knobs on radios designed for primary use on single sideband (SSB) and Morse code (CW) transmissions is simple and intuitive to use. There are a number of adjustments you can make to the way it works.

- **Tuning Rate and Up/Down:** Changing the *tuning rate* varies the rate at which the frequency changes with each turn of the tuning knob. For CW, you might want the radio to tune slowly — just 1 or 2 kHz per revolution. On SSB, that rate makes tuning from signal to signal too slow, so you might want 5 or even 10 kHz per turn of the knob. *Step size* is the smallest amount of frequency change you can make and changing it may have a similar effect to changing the tuning rate. Front panel *Up/Down* buttons generally have a much larger step to allow you to move quickly within a band. Your tuning knob may also sense the speed at which you are turning it and increase or decrease the tuning rate accordingly.
- **Fast/Jog/Band/Lock:** To really change frequency in a hurry, the radio may have a *Fast* function. This greatly increases the tuning rate when active (and may have other effects). *Jog* acts like a joystick to slew frequency up and down very quickly. *Band* moves you from one ham band to another. *Lock* freezes all frequency adjustments until pressed again. (This can be very disconcerting if you don't notice it or forget that it's on — suddenly your radio won't tune!)
- **Display Frequency:** On SSB or FM, the display frequency is the carrier frequency of your signal, something to keep in mind when operating near a band edge. Properly adjusted SSB signals are about 3 kHz wide. If you are on USB, stay 3 kHz below the band edge, and stay 3 kHz above

the band edge on LSB. On CW (or RTTY or PKT), the display frequency is usually the frequency at which a signal will produce the desired tone, not the actual signal transmission frequency. This is discussed more in the section on filtering, below.

- **Pitch:** Not to be confused with *sidetone* (the audio tone you hear when sending CW), the pitch control allows you to configure the filters so that their peak response will be at the audio frequency you prefer for copying CW. Pitch doesn't affect your transmit frequency.
- **Scanning:** VFO scanning sweeps the receiver frequency across the band between a start and stop frequency. Memory scanning steps through a set of channels and stops if a signal that opens the squelch is found.

VFO and memory control

The tuning knob controls a VFO (Variable Frequency Oscillator) that determines a radio's frequency. A radio only has one VFO circuit, but the radio's microprocessor can control it in a way that makes it look like there are two: *VFO A* and *VFO B.* There are lots of uses for two VFOs — saving a net or schedule frequency, keeping watch on a frequency for a DX station, and so on.

Switching between VFO A and B is controlled by buttons labeled something like “A_B” and “A-_B.” The first means “change VFO B to match VFO A.” The second means “exchange VFO A with VFO B.” The transfer may also include mode and filter selection.

TIP

If there are two DX stations you're trying to work, use the A and B VFOs to “bounce” between the pileups. Tune to station #1, save VFO A to VFO B, tune to station #2, then press “A-_B” to change between pileups instantly. You have to remember who you're calling on your own, though.

VFO A and B are really just special cases of a radio's *memory channels.* The memories store a radio's frequency, mode, and other control parameters. Because most hams have “favorite” frequencies, operate on nets, hang around calling frequencies, or have regular schedules, it's nice to be able to recall them quickly. Memories are treated as numbered *channels.* Contents are viewed by changing from VFO to MEM operation, then selecting a memory. The settings can then be transferred to one of the VFOs for operating. Information is stored in memories by setting the radio's frequency, mode, and so on in VFO operation and then *writing* the settings into a memory channel.

Along with VFO A and VFO B and the memory channels, many rigs also have a *scratchpad memory.* This memory takes fewer steps to write and recall so that it can be used quickly. Another type of memory is called *bandstacking registers.* These store VFO settings from a single band. The contents are recalled by repeatedly pressing the keypad button for that band. For example, if I have a pair of registers on each band, I might elect to use one for CW operation and the other for SSB, or for SSB and FM.

Tuning technique

For SSB, tune until the operator's voice sounds most natural with an even distribution of bass and treble. This insures that you would sound natural, as well. On FM, the voice should be clear and without distortion. A discriminator output may be available to show you when you are centered on the carrier frequency. For RTTY and other digital signals, you will likely tune using a visual indicator from your processing equipment or software.

Receiver Incremental Tuning (RIT) is a "fine-tune" adjustment that allows you to vary your receive frequency *without* changing transmit frequency. You'll use this in round table and net QSOs to accommodate slight frequency offset or drift between stations. If you leave it on, you'll be off frequency for subsequent contacts — oops!

You will quickly acquire a personal style of handling the tuning knob and approaching a signal. Here are some good skills to learn to make tuning efficient:

- Change frequency in about the same steps as the signal widths on the mode you're using — 3 kHz on SSB, 500 Hz on CW, 20 kHz on FM, and so on. This allows you to move to an adjacent signal quickly.
- Estimate how far off frequency you are for a voice signal and tune close to the correct frequency in one knob twist.
- Tune through a band of CW signals, placing each one right at your chosen pitch frequency.
- Recognize the sounds of the various data signals and what they sound like when properly tuned in. This will speed up the process of getting your system locked on to a signal.

Filtering

To reject undesired signals, receivers use band-pass filters (BPFs). A very "wide" BPF at the signal frequency, called a *preselector,* passes signals from an entire ham band and rejects or *attenuates* signals at other frequencies, called *out-of-band* signals. The receiver then begins converting the RF signal to audio or data.

Each conversion is done by a *mixer* that changes the signal frequency to an *Intermediate Frequency* (IF). There may be more than one such conversion. At each of the IFs, an additional BPF is applied to the signal, becoming progressively narrower at each step.

The sequence of filters is shown in Figure B1-1. The preselector is shown passing *in-band* signals. A *roofing filter* rejects all but nearby signals. It gets that name because it acts like a "roof" over other, narrower filters. In subsequent stages, narrower signal filters attempt to isolate just the desired signal. Think of the filters as a narrowing sequence of windows through which your receiver looks at the radio spectrum.

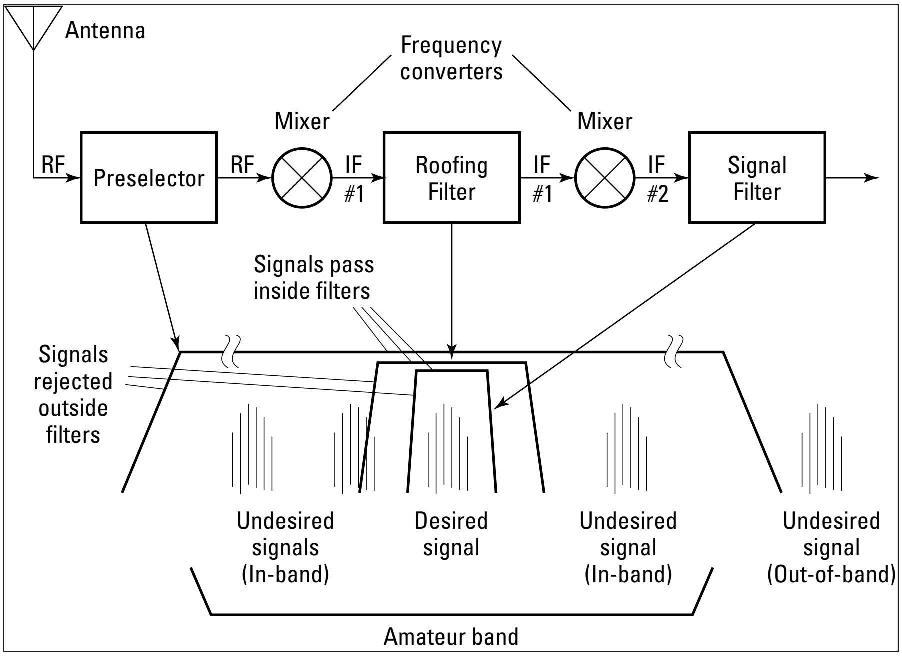

Figure B1-1: Preselectors, roofing filters, and signal filters all reject undesired signals.

Chapter 12 refers to *fixed-bandwidth* crystal filters. Digital Signal Processing (DSP) filters are now standard in most radios and are much more flexible with nearly equivalent performance. Signal filters for SSB have a 1.8 to 3 kHz bandwidth. For CW and digital data, filter bandwidths are from 250 Hz to 1 kHz. FM requires a 15 kHz filter. Install the greatest amount of filtering your budget allows, because this is an important receiver function.

Selecting a filter

When you select an operating mode, the radio will also select an assumed choice of filter — usually the widest filter you have installed for that mode. (If you don't have a narrow CW filter installed, the radio will use the SSB filter.)

While tuning and for casual contacts, to avoid missing signals use the widest filter settings that give you an acceptable amount of noise or interference. I like a wider filter for the cleaner sound and to hear a little bit of "what's going on around me." If the band is crowded or noisy, select a narrower filter or reduce filter bandwidth. It's important to have the CW or data signals tuned in properly so that as you "tighten up" the filters, you don't have to adjust the main VFO. Using the wider filters will also develop your ability to copy "by ear."

With fixed-bandwidth filters, your choice of bandwidth is limited to whatever filters are installed in the radio. Some radios can vary the net bandwidth by shifting IF frequencies or using DSP. Practice adjusting this control to get used to the different sound qualities at different filter bandwidths.

Shifting away from and notching out interference

Another popular filtering feature is known as *IF Shift* and proprietary names such as "Passband Tuning (PBT)." This allows you to offset the frequencies of the various IF stages so that the filters pass higher or lower frequencies than normal. This is useful if a nearby QSO is a little too close for comfortable listening. You can shift your receiver's filters just a bit higher or lower in frequency and reduce the amount of interference. This removes some of the incoming signal's high or low frequencies, but may result in a dramatic improvement in intelligibility.

You can also remove a small portion of the received audio by using the *notch filter.* This is intended to reject single interfering tones, such as a tuner-upper or broadcast carrier. The notch frequency can be varied throughout the audio range and gives speech a somewhat hollow sound. If the receiver output "sounds funny," check to see if your notch filter is on.

Hearing well by using gain control

The receiver will do its best to output a clean, clear signal, but it has to cope with an extremely wide range of signal strengths and noises, roughly a factor of 10 billion (100 dB) to 1, give or take a couple orders of magnitude. It's amazing that receivers do as well as they do. You can give your receiver a helping hand by learning how to make the best use of all of its controls.

When a receiver isn't able to properly handle the signals coming into the antenna jack, the circuits become overloaded and distortion occurs. If more than one strong signal is present, they can mix together and cause *intermodulation products* or *intermod.* Both intermod and distortion create interfering signals *in the receiver*. The most common stages to be overloaded are the *front-end* stages closest to the antenna. *Front-end overload* results in the severe interference.

TIP

To tell if your receiver is being overloaded, turn on the attenuator. If the noise or interference disappears or is reduced by *more* than the amount of attenuation (figure about 6 dB per S-unit), then your receiver is being overloaded. Leave the attenuator on, turn down the RF Gain, or otherwise reduce the level of signals coming in through the antenna.

Automatic Gain Control (AGC) keeps the output of the receiver steady by continually adjusting the gain of the various IF and RF amplifiers. Louder signals cause AGC to turn the gain down and *vice versa.* The AGC circuit needs to respond at different speeds to CW, data, or voice signals — FAST (for data and CW) and SLOW (for voice) to give the signal an even output level. Setting AGC to AUTO sets the response speed based on the selected mode and OFF disables it entirely (you'll have to operate the RF Gain control manually).

The AGC circuit uses the audio output to make a decision on what overall gain should be. If a loud and undesired signal is close by, it can fool AGC into reducing gain unnecessarily. To the listener, it sounds like the desired signal has done a deep fade. This is called *AGC pumping* and causes severe distortion that can sound like interference from a nearby station.

You can give your receiver the best chance to output a clean signal by setting your gain controls as follows:

- **Preamplifier:** Turn this OFF unless really needed. Although the *preamp* makes weak signals stronger, it will make it easier for a strong signal to cause overload. Proprietary features such as "Advanced Intercept Point (AIP)" or "Intercept Point Optimization (IPO)" are really preamp controls — when you turn them ON, they reduce receiver gain to reduce overload.
- **Attenuator:** Reduces the incoming signals at the antenna terminal. Don't be shy about adding some attenuation to help the receiver cope with strong signals.
- **RF Gain:** Controls the gain of the IF stages. When you turn this control down, you'll notice your receiver's S-meter going up. That's because the S-meter is really measuring how much the AGC circuit is reducing gain. A strong signal requires a lot of gain reduction to maintain a constant output level, so the meter shows a large deflection. When RF Gain is turned down, it's the same as if the AGC circuit is responding to a large signal. Reducing RF Gain will often make the band sound "cleaner" because noise isn't being amplified as much. Adjust RF Gain frequently!
- **Noise Blanker (NB):** Turn this OFF unless really needed. Noise blankers look for the short, sharp pulses characteristic of ignition or line noise. When one is detected, they turn off the receiver for the duration of the pulse. When strong signals are present, they often fool the noise blanker into turning off the receiver. The resulting distortion is similar to AGC pumping and can be quite disruptive. Use sparingly.

- **DSP Noise Reduction (NR):** This works on the output audio signal instead of the RF and IF signals as for Noise Blanker. The DSP circuit analyzes the signals to decide what is noise and removes it. The results can be pretty amazing with a lot of band noise just disappearing. The DSP sometimes creates *artifacts* in the resulting audio that may be objectionable.

Practice is the key! If you wait until you have interference to start learning how to use the gain controls, you'll be clumsy and your contact will likely be disrupted. Learn the various symptoms of receiver ailments and what controls cure the problem.

These controls and settings don't form a group, so I just cover them one at a time:

- **Receive Antenna:** Some radios have the ability to let the receiver listen to a different antenna than the transmitter uses. Why? This is popular on the lower HF bands where an efficient transmit antenna may pick up too much noise. If the regular receiver input signal is also available (usually called "RX Out"), then the signal can be filtered or processed before it gets to the receiver. Remember that if you set the receiver to use the receive antenna and nothing is connected, the receiver will sound dead.
- **Squelch:** A very odd word for a perfectly understandable function. Squelch mutes the audio output unless the signal exceeds a level set by the squelch control. This keeps you from having to listen to noise until a signal appears. Remember that if you accidentally turn up the squelch level, no audio will be heard and the receiver will sound dead.

Operating a Transmitter

Now that we have those complicated receivers behind us, it's time to turn our attention to the outgoing part of the radio, the transmitter. Start simple by setting the radio to CW mode.

CW operation

Transceivers have a ¼-inch phone jack input labeled "Key" on the front or rear (or both) panels. Look at your operating manual for the correct plug style (mono or stereo) and wiring.

Some radios include a CW keyer that is turned on and off by a front panel button or a configuration menu selection. Keys, keyers, and paddles all plug into the same jack, so you'll have to read the manual to find out what the proper wiring is for each. Keys and keyers both have the same plug wiring.

If using an external keyer causes the radio to send garbled code, then the rig's internal keyer is active. Turn the keyer function OFF so that the radio thinks it's being keyed by a straight key.

If the rig keys as soon as you plug in your key or keyer, regardless of whether the keyer is turned on or not, then you probably don't have the right type of plug on the key cable or it's miswired. Most radios use a stereo phone jack to accept a key or a paddle, so a mono plug shorts the middle contact to ground.

Semi- or Full-Break In (QSK) switches between transmit and receive so rapidly that you can hear other signals between your own dits and dahs. QSK helps you coordinate with another operator or use a busy frequency. If you have VOX turned on, QSK is defeated and the radio remains in transmit while you are sending.

The control for output power is labeled "RF PWR" or "CAR" (for "Carrier"). If your radio has an internal antenna tuner, the minimum power will be set to a few watts so that the tuner control circuitry has enough power to work.

Controlling speech audio

Setting up a transmitter for clean speech operation is more complicated than CW. The most important adjustments are for microphone gain (usually labeled "MIC GAIN") and *speech processing,* which is called "Compression" or "Processing." Your operating manual will have a specific procedure for adjusting both of these controls. It's an important responsibility to have a properly adjusted signal to preserve your own intelligibility and to prevent interference to others.

Microphone gain controls the amplification of the weak microphone signal. Set too low and your output power will be low. Set too high and your audio will be distorted. Use your radio's *Automatic Level Control (ALC)* indicator to set the microphone gain as described in the operating manual. By itself, ALC does not guarantee a clean signal.

If you have a *station monitor* (available as an accessory from most radio manufacturers), it's easy to set your microphone gain. With the speech processor OFF, turn up the microphone gain until the maximum output on voice peaks stops increasing, then back off one-tenth of a turn or so.

The next step is to adjust the speech processor. Speech processing increases your average signal power, but at the expense of distorting your audio by amplifying the low level portions more than the high level portions. This is called *compression.* You don't need it at all if your signal is getting through well. With a modest amount of compression, you will be a little "louder" to the other station. With too much compression, you sound like a bad public address system. Follow the operating manual's instructions for setting the level of processing. I find that more than 10 dB of compression in the processor hurts more than it helps.

If your over-the-air audio is distorted on voice peaks, some of your RF output signal may be getting picked up byf the microphone cable. Identify RF feedback by slowly reducing power or using a dummy load for transmitting while having a nearby ham listen or using a separate receiver to listen to your own signal. If the distortion disappears, then it's RF feedback, almost always caused by a broken microphone cable connection or poor radio grounding.

If your radio has a *monitor* feature, you can listen to your transmit audio as you speak. This helps you adjust your audio, but isn't a substitute for an off-the-air report on your signal. You should use the monitor only when using headphones, otherwise you will have audio feedback between the microphone and speaker.

As with CW, output power is set by the "RF PWR" or "CAR" (for "Carrier") control. If you use AM, the amount of carrier your signal contains is set by this control. For SSB, it controls the *Peak Envelope Power (PEP),* and for FM it controls the overall transmitter output power.

Setting the VOX system

Operate for a long session using only *Push-to-Talk (PTT)* with a hand mic and your aching thumb and elbow will illustrate the need to use *Voice-Operated-Transmit* or *VOX.* VOX uses the audio from your microphone to switch the radio to transmit. Properly adjusted, it supports a very natural, flowing conversation. There are three main VOX controls:

- **VOX Gain:** Sets how much audio from the microphone it takes to activate or *trip* the VOX. High VOX Gain means that it only takes a whisper (or your breathing) to trip. This is irritating to listeners and causes unintentional transmissions. VOX Gain should be set to the minimum level required for your ordinary speech to trip the VOX. Microphone gain affects VOX sensitivity, but not *vice versa.*
- **VOX Delay:** Once the VOX circuit is tripped, VOX Delay controls how long it takes to return to receive if you're not speaking. The delay should be just long enough to hold the radio in transmit between words and phrases. Set too short and you will rapidly switch between transmit and receive, chopping up your speech and wearing out the switching components.

- **Anti-VOX:** If you use a speaker or like your headphone audio loud, that can also cause the VOX to trip. Anti-VOX takes a little bit of the received audio and subtracts it from the microphone signal. This prevents the received audio from causing a transmission. Turning up Anti-VOX too far can make operation of the VOX system sluggish or drop out inappropriately.

What is *MOX?* MOX stands for Manually Operated Transmit and allows the operator to switch between receive and transmit manually, if necessary.

Microphone technique

Learning how to use a microphone will pay huge dividends on the air. Start by using a good quality microphone. Don't waste the capabilities of an expensive radio with a cheap, garage sale microphone. Chapter 13 shows several popular styles, and a new radio will include a decent hand-mic.

Learn how to set the transmit speech controls so that your voice sounds its best on the air at a natural speaking level. Find a nearby friend who knows your voice, then meet on a band that's closed for the evening or a spot that's not busy and practice getting all of the controls set properly. With your friend listening, learn how to set the processor so that you don't generate interference or *splatter* on nearby frequencies. Memorize the ALC and compression levels for proper operation.

Speaking over a microphone is different than speaking in person. Hams new to SSB or FM have a tendency to slur and hurry their words and phrases, making them very difficult to understand. Practice speaking very clearly, using phonetics, taking deep breaths, and modulating your voice more than you would if you were face-to-face with the other person. They can't see your face, so the visual cues of conversation aren't there. All of the information has to come from your voice alone, just like a radio announcer.

TIP

Repeating this excellent advice from Chapter 11: YOU DON'T NEED TO SHOUT INTO THE MICROPHONE! Shouting doesn't make you any louder at the other end! By adjusting your microphone gain and speech processor, you can create a very understandable signal at normal voice levels! Your contacts and family will thank you for doing so. Save the shouting for celebrating your latest DX contact!

TIP

The microphone should not touch your lips or be directly in front of your mouth. The sudden gusts of air as you form letters like "P" and "B" (they're called *plosives*) sound like annoying pops and thumps. A desk mic should be a few inches from your mouth. Boom mics should be to the side of or below your mouth. Speak *across* a hand mic to minimize the effects of the air gusts. Check on the air to see what works best for you and your microphone.

VFO control and operating split

The same VFO and memory functions work on transmit, so only Transmit Incremental Tuning (XIT) is new. Like RIT, this is a "fine-tune" adjustment that lets you listen to one frequency and move your transmitter around. I find this most useful when calling a DX station a little off frequency in a pileup. The same caution as for RIT applies, as well — if you forget that it's on, you'll be off frequency for subsequent contacts.

Operating *split* properly is an important skill in a variety of settings. When operating split, the receive frequency is set by one VFO and the transmit frequency by the other. Split is usually used in HF DX operation (see Chapter 11) within a single band and on VHF/UHF satellite operation between bands.

Learn how to do this properly to avoid causing unintentional interference and transmit in the right spot. Here is an example procedure for HF split operation:

1. **Tune VFO A to the transmit frequency of the station you're listening to.**
2. **Press "A_B" to store that frequency into VFO B.**
3. **Tune VFO A to the frequency where the station is listening.**
4. **Press "A-_B" to switch VFOs and listen to the station on VFO B.**
5. **Set the transmitter to use VFO A — consult your operating manual for the exact steps to do this.** It might be a "SPLIT" button on the front panel or a VFO A/VFO B control switch.
6. **With power turned all the way down, press PTT or key the transmitter.** Your display should change to the transmit frequency. Turn power back up.

This seems complicated, but with a few repetitions, you'll become quite used to it. The procedure for cross-band split is similar, but depends on how your radio is designed, so consult the manual for the exact instructions.

Tuners

Adjusting an antenna tuner can seem confusing at first, but there is a method to the madness. The tuner's operating manual may provide some guidelines, but assuming that you have one of the popular "T-circuit" units (see Figure

B1-2) with two capacitors and one inductor, following these steps will allow you to find a match most of the time:

1. **Be sure the tuner is well grounded and that all connections to antennas and the radio are secure.**

   If your tuner has an antenna switch, double-check to be sure the right antenna is selected.

2. **Set the capacitors and inductors to their maximum values (the actual inductance and capacitance).**

   This configures the tuner to have the least effect — a good place to start.

3. **Reduce power output from the radio to a few watts of CW (use the minimum power necessary to tune) and send a brief call sign to identify yourself.**

   Watching the SWR meter on the radio or tuner, make short transmissions of a few seconds while you make adjustments.

4. **Adjust the inductor for the minimum SWR, then the input capacitor (closest to the transmitter) for minimum SWR.**

   Repeat until SWR reaches 1:1 or a satisfactory value. If there is no clear minimum, reset the input or output capacitor to half value and try again.

5. **Adjust the output capacitor for minimum SWR.**

   Readjust both the input capacitor and the inductor for minimum SWR. Repeat until SWR reaches 1:1 or a satisfactory value.

6. **When you are done tuning, identify yourself on the air once again.**

Make a table of your tuner setting for your favorite bands and antennas to minimize on-the-air tuning.

TROUBLESHOOTING

If you can't achieve a match with any combination of settings, the impedance at the tuner's output is probably beyond the ability of the tuner to match to 50 ohms. You could also have a bad feedline or connection. Try the antenna on a different frequency or try the tuner on a "known good" antenna to be sure it is working okay.

There are also tuning aids such as the Vectronics VEC-512 (`www.vectronics.com`) that use the receiver to detect noise as the antenna is tuned. This allows you to avoid transmitting while tuning up.

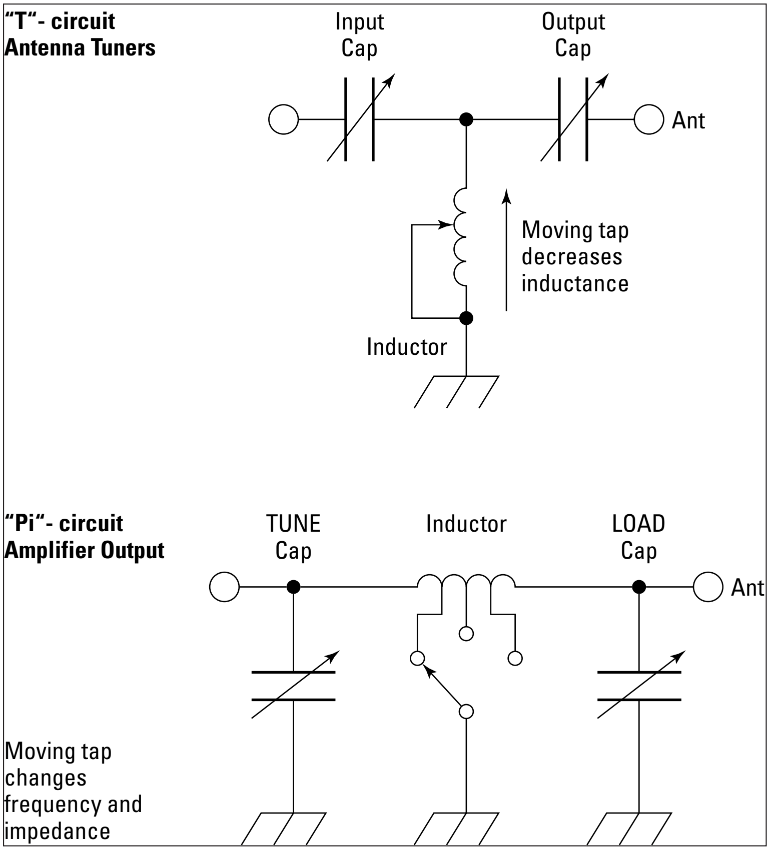

Figure B1-2: "T" and "Pi" impedance matching circuits found in tuners and amplifiers.

Amplifiers

Adjusting a high power tube amplifier is similar to adjusting an antenna tuner. Your amplifier's manual will tell you how to adjust your particular model as well as specify limits for input or *drive* power. Here is the general procedure (follow the same recommendations as with a tuner for short transmissions and recording common control settings):

1. **Reduce transmitter power to 10 or 20 watts.**

   Set the amplifier's bandswitch to the desired band and the bias switch to the CW or CW/TUNE position. Set the LOAD control to its minimum value.

2. **Apply drive to the amplifier.**

   While watching the plate current, adjust the TUNE control for a "dip" in plate current.

3. **Adjust the LOAD control so that output power or plate current approaches the desired level.**

   Readjust the TUNE control to dip the plate current. If necessary, increase drive and readjust LOAD and TUNE.

An amplifier's output adjustment circuit is very much like an antenna tuner in that it matches the impedance of the tube or tubes to the 50-ohm load. It is usually configured as a "Pi" circuit as shown in Figure B1-2. The TUNE control adjusts the output circuit for resonance, causing the dip in plate current. The BAND switch varies the inductance which works with the TUNE capacitor to set the resonant frequency and with the LOAD capacitor to adjust the output impedance.

Amplifiers generate a lot of RF power, which can be dangerous if not treated with respect. Understand the RF safety rules in your license manual. Be sure your feedlines and antennas are sufficiently rated to handle the amplifier's output. The tubes or transistors in your amplifier are expensive; follow the manufacturer's guidelines *exactly* and do not exceed the operating limits for input or output power.

RF safety

As you'll recall from your licensing study, you'll need to perform an RF safety evaluation once you decide on power levels and antenna placement. If you plan on using an indoor antenna, the evaluation will be more important because of its proximity to people. Plan ahead so that your station meets all safety concerns from the moment it's finished.

Operating Hand-helds and Mobiles

All of the things you've learned about operating a receiver and transmitter apply whether you're operating from home or on the road. Along with the operating guidelines in Chapter 10, there are some additional technical tips and tricks that help make mobile and portable operation more efficient.

Do you think driving while talking on a mobile phone is unsafe? Try watching someone try to drive while configuring a radio to use a new repeater channel! This is not a smart thing to do in motion, even with the radio display up on the dashboard. Talking in heavy traffic is also unsafe. Pull over and get the job done or stand by until traffic clears up.

Programming memories and cloning

You'll quickly find a number of useful frequencies to store in your radio. You'll also find that just loading the information into the next available memory channel results in a disorganized list that's inconvenient to use. Group similar information into consecutive channels. Reserve one block for 2-meter repeaters, another for 70-cm, some for the land-mobile or aviation channels, several for broadcast stations, and so forth, depending on your radio's capability. That way, if you forget the exact channel number, you'll know what group it's in and can find it quickly.

Programming the memories from the radio's front panel can also get old. Many radios have the ability to download memory information from a PC program. This is quite convenient and can make setting up a whole band full of frequencies a breeze. *Cloning* refers to duplicating the configuration of an entire radio in another radio. This can be done by using a PC program to program each radio individually. Some radios also have a standalone cloning function that uses a special cable to connect two radios together.

Selecting and charging batteries

There are three types of batteries used with hand-held and portable radios: disposable alkaline, rechargeable Nickel-Cadmium (Ni-Cad), and Lithium-Ion (Li-Ion), referring to the electro-chemistry inside the battery. Of the three, disposable alkaline and Li-Ion chemistry offer the greatest *energy density,* which is measured in Watts/kg. Higher energy density is good because it means longer operating times from a given size battery.

Battery packs hold pre-assembled groups of cells inside a single case. The batteries charge and discharge as a unit. The pack's energy storage capacity gradually dwindles as the batteries age. When it is no longer able to hold an adequate charge, it must be replaced or rebuilt. Always have a spare battery pack.

A small battery pack charger is a standard accessory for hand-held and portable radios. Most are wall-transformers that take several hours to recharge even small packs. A more convenient solution is the *drop-in charger* that holds the entire radio while charging the battery. Drop-in chargers also act as a base for the radio during stationary use. Unfortunately, radios and packs are not standardized, so one manufacturer's charger won't charge other packs.

To use disposable batteries or individual rechargeable cells, you need the empty battery pack that can be easily disassembled to load them. An advantage of using the individual rechargeable cells is that they can be charged by any manufacturer's charger. The advantage quickly becomes apparent when you have several radios from different manufacturers.

Battery capacity

If you are going to use batteries for hand-helds or portable radios (as opposed to solar power or a generator), learn how to calculate total energy usage in terms of *ampere-hours* (A-h). This is a rating of how long the battery can supply a given amount of current while maintaining its rated voltage. A battery with an 8 A-h *capacity* can theoretically supply 1 ampere for 8 hours or 8 amps for 1 hour. Realistically, *derate* a battery to 80% of its rated capacity. Figure out how long you expect to operate from a fully-charged battery and add up the total current usage from all equipment. Multiply those two figures together (current and time) to get your required battery capacity.

Simple chargers just dump charge into a battery until its *terminal voltage* (voltage across the + and - terminals) comes up to a nominal rated value. At that point, the charger can't force any more change into the battery. *Quick chargers* apply a lot of charge to the battery in a hurry (which makes it heat up) until the battery reaches rated voltage. After that, it switches to *trickle charge,* just supplying enough current to keep the battery charged. (This is also called *float charging.*) Quick chargers can recharge even a large battery pack in an hour.

If you use large batteries, such as gel-cells or deep-cycle automotive batteries, a charger designed specifically for those batteries must be used. Automotive battery chargers are generally not suitable for long-term use; they are just for getting enough charge into the battery to start a car and will damage the battery if left connected. Many hardware and RV stores sell inexpensive trickle chargers just for these batteries.

External power

Most hand-held radios can be run from external DC power. To operate from a car, they must accept the automotive range of 9–16 VDC. Car-power adapters are available that plug into a cigarette lighter plug. Some hand-helds cannot transmit while external power is attached.

Mobile radios take a lot more current than hand-held radios — up to 25 amps for 100-watt output models. Supplying this amount of power to the radio will require at least some under-the-dash work to find an adequately rated DC circuit. You may have to run the radio power cables into the engine compartment and directly to the battery. Using a lighter plug is generally not an option for the larger mobile rigs.

WARNING!

BE CAREFUL! Automotive batteries can supply a lot of current and a short-circuit can have disastrous consequences. *Never* work on an automotive electrical system with the battery connected. Mobile stereo shops can often consult on or perform the installation professionally. When using external power of any sort, be sure the power cable has a fuse in the positive lead. Some cords also have a fuse in the negative lead to protect against short-circuits to that lead.

Mechanical safety

If you have a radio in your car, make sure it is secure. Even a small hand-held can be hazardous in a crash. Don't place unsecured rigs on the dashboard or seat. Install a microphone clip — grabbing for a microphone or sliding radio has caused more than one accident!

Building Antennas and Feedlines

This section will not be a discussion on the theory of how antennas and transmission lines work — that's quite beyond the scope of this book. I will cover some of the technical aspects of building and installing antenna systems. For detailed information on antenna design, *The ARRL Antenna Book* is the acknowledged ham radio antenna reference. The ARRL also offers online antenna theory and modeling classes.

Building wire antennas

The first thing to cover with wire antennas is, strangely enough, wire! There are lots of different types of wire and some are more suitable than others for making antennas. Avoid using aluminum or galvanized wire because of stretching, difficulty of making reliable connections, and resistive losses.

- **Soft-drawn solid copper:** Used for electrical wiring in the home in sizes of 10 to 16 AWG. Soft-drawn wire will stretch several percent under tension, affecting antenna tuning. Solid wire will also break if nicked, kinked, or flexed repeatedly.
- **Stranded copper:** Also used for home electrical wiring with the same concerns about stretching. More flexible than solid wire and resists breaking better.
- **Hard-drawn copper:** Stronger than soft-drawn, but has the same tendency to break at nicks and if repeatedly flexed.
- **Copperweld:** Solid or solid steel wire for strength with a copper cladding for good conductivity. Excellent for antennas in 10–18 AWG. Can be difficult to work with due to springiness, but the stranded versions are easier to work with.

For general antenna work, the inexpensive THHN insulated wire sold in home improvement stores is fine. If you are planning on putting up large or heavy antennas or live in a windy area, then the Copperweld is a better choice. Many types of wire specifically for antennas are available from vendors such as The Wireman (`www.thewireman.com`) or the Radio Works (`www.radioworks.com`).

The wires are attached to insulators: Two common types are shown in Figure B1-3. The *stress* or *egg* insulator is used between wires and supporting ropes or cables. The wire and rope encircle each other, but are kept apart by the insulating material. The center or *dog bone* insulator is used to separate sections of wire. The corrugations increase the distance over which any current would have to flow and prevent water buildup that would short the wires together. Insulators are typically made from glass, ceramic, or plastic. Homebrew insulators made from polycarbonate plastic or UV-resistant PVC will also work for small antennas.

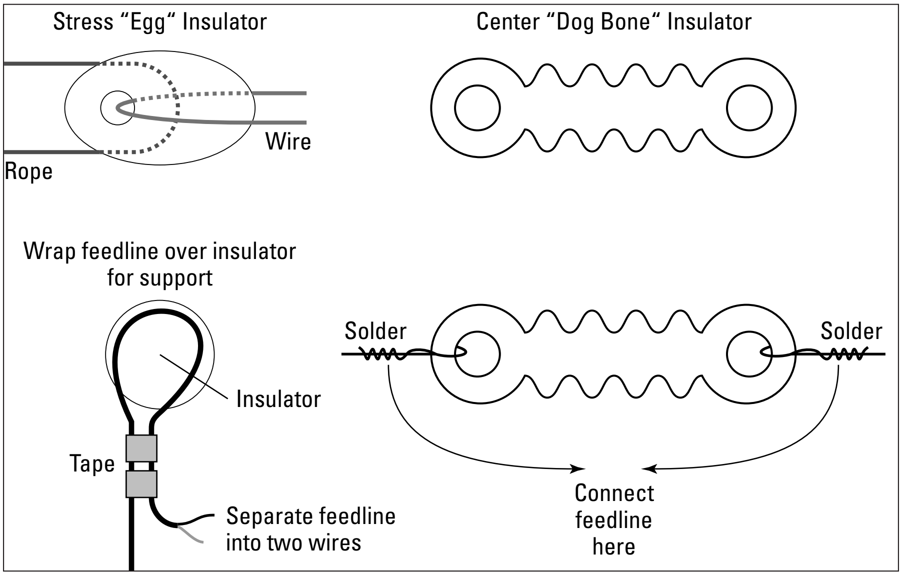

Figure B1-3: Common methods of attaching wires, feedlines, and insulators.

Soldering the wires of the antenna requires a soldering iron or gun with at least 100 watts of power, but 250 watts is preferable. Smaller irons and guns can't heat the wire enough and your solder joint will fail. Pencil butane torches work well, but a propane torch is too big. Practice on a few test joints before doing the antenna connections. The wire must be hot enough to let the solder flow all the way through the joint, but not so hot that plastic insulators are melted through. Once the joint is done, a spray of plastic coating is a good idea.

Attaching the feedline can be done many ways as long as it is supported adequately. Remember that the feedline will hang from the insulator, flexing in the wind. The figure shows one of many ways of taking the stress off the electrical connections. If you prefer to terminate the feedline in a connector, the Budwig 809 center insulator has a built-in coaxial connector. It's also important to keep water out of coaxial cable. Once the connections are complete, coat the exposed braid and center conductor with a sealant such as "Liquid Electrical Tape" (available at hardware store electrical departments).

Useful knots to learn are the Sheetbend, Bowline, Two Half-Hitches, Fisherman's knot, Square Knot, and the Clove Hitch. Log on to `www.scouter.com`, select Scout Skills, and enter **knots** into the search window to find good knot references. The Two Half-Hitches knot is useful for attaching ropes to insulators and branches. The Clove Hitch attaches ropes to supports and posts. Ropes should be UV-resistant to prevent gradual deterioration and sudden failure.

While the time-honored technique of supporting wire antennas is to throw a rope through the branches of a tree, this often leads to the antenna falling in the wind or after the tree gradually abrades the rope. What works better is to install a pulley in the tree (either on a rope or attached directly to the tree) and run the support line through the pulley. This allows the support line to move in the wind. A counterweight will provide tension, while allowing movement.

WARNING!

I hate to keep nagging you about safety, but be *sure* that your wires won't go anywhere near a power line, including underneath them. When you are throwing lines into trees, be sure you know where that line can go on its journey.

Manufactured beams and vertical antennas

Along with the ubiquitous wires, hams have a wide assortment of antennas to buy from dozens of manufacturers. These are usually made of aluminum tubing, held together with U-bolts, rivets, and clamps. Quad antennas are the exception, being made from wire loops supported on fiberglass arms or *spreaders.* Let's start with a piece of oft-neglected advice:

- Follow the manufacturer's instructions. Many antenna problems are really caused by failures to follow directions. Unless you are very experienced, do just what the manufacturer says. If the instructions don't make sense, ask a friend to have a look or call the customer service department. It's a lot easier to get it right before it goes up in the air!

Here are two valuable tips for assembling antennas made from aluminum tubing, whether they are multi-band HF verticals, beams, or simple monopoles.

- **Preventing oxidation:** Joints in aluminum antennas develop a crust of oxide and minerals over time that cements the joints together and breaks the electrical connection. The time to prevent oxidation is at assembly by coating the inner and outer surfaces of the joint with an anti-oxidation compound such as Noalox or Penetrox. You don't need much, about the volume of a pea for 6 inches of overlap for 1-inch diameter tubing. Use the compound on all tubing joints, strap contacts (such as on feed point assemblies), and where feedline connections are made.
- **Securing Joints:** Antennas that use steel hose clamps or other screw-type clamps can have problems with the clamps loosening over time due to thermal cycling. Aluminum and steel expand at different rates, so a clamp must be put under enough tension to keep the joint tight regardless of temperature. Assemble the antenna, tightening the clamps with a ratchet. Let the antenna sit outside for a couple of days, then go back over the antenna and tighten every clamp. You'll probably find one or two that need tightening.

For all types of antennas, avoid inexpensive plated fasteners like the plague. They will rust quickly and are often impossible to disassemble. Use stainless steel fasteners. Large load-bearing, stainless steel bolts and nuts can *gall,* developing surface defects that cause the threaded surfaces to jam. A small amount of anti-seize compound on the threads is cheap insurance against a frozen bolt. Use lockwashers or Nylok nuts to hold screws tight.

Raising and supporting antennas

With the antenna assembled, now comes the fun part — getting it up in the air. First, stop and do . . . yes, another safety check. As you hoist, push, or pull your antenna up into the air, it will be doing its best to get back to the ground. Masts and poles can tip over in any direction. Stay clear of power lines by a radius of at least 50 percent of the total structure height. If you are getting help from friends, have a group meeting before starting to make sure everybody knows just what the plan is and their part. Everyone should know who is directing the action and what commands and signals they'll use. Make a dry run first, if possible.

Enlist the help of someone experienced in raising antennas, particularly if this is an HF beam of any size. Let that person show you the ins and outs of using ropes, tackle, and safety equipment. Practice until you are comfortable with the terms and how to use all of the equipment.

Figure B1-4 shows a very simplified diagram of how to raise large antennas to the top of a tower or pole. If you can, use a mast at least one foot higher than where you want to mount the antenna. Use the mast as a *gin pole* for the antenna, holding its weight with a block and tackle and a rope held at the ground level. The climber at the top can then work without having to support the weight of the antenna, too. Lift the antenna using a sling instead of tying the rope to the boom-to-mast plate. This lets the climber attach the boom-to-mast U-bolts immediately without any other rigging.

Use a *snatch block* at the base of the tower to keep the rope crew away from the base of the tower. They can see the climber and stay clear of any dropped object. It also keeps all of the pulling force in line with the tower and not to one side. The *tag line* under the antenna is to control and steer the antenna as it goes up. If there are guy lines to avoid, having one or more tag lines allows the ground crew to steer the antenna around them.

This only scratches the surface of safe rigging techniques. Don't attempt a large project without adequate help and preparation. "Book learning" is not enough to protect you, your helpers, and your equipment. Be safe!

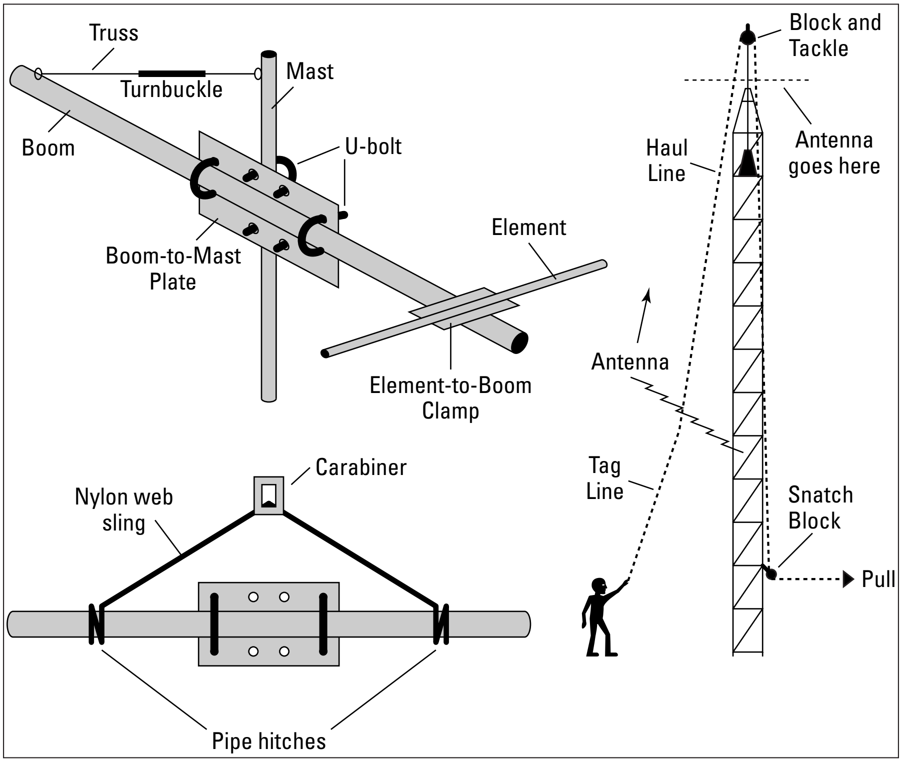

Figure B1-4: Basic elements of Yagi-style beams and how to raise them.

Testing and adjusting antennas

Wire antennas are adjusted by trimming the length of the elements. Yagi type antennas often use a feed point impedance matching network because their unmatched impedance is quite a bit below 50 ohms. There are two primary types of feed point networks, as shown in Figure B1-5: the *gamma* and *beta* (or *hairpin*) *match*.

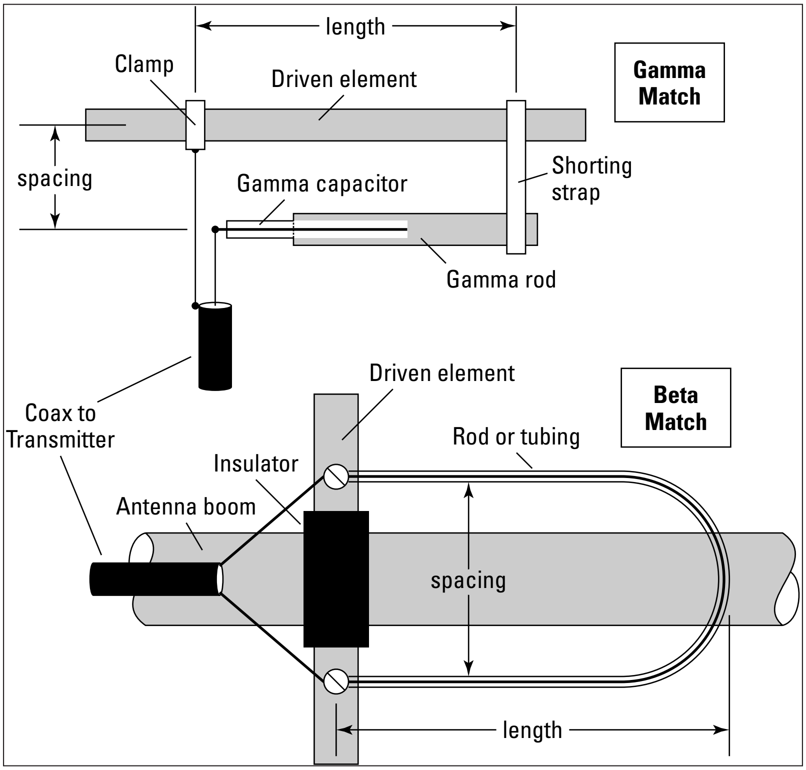

Figure B1-5: The gamma and beta match adjust the Yagi impedance to 50 ohms.

The assembly manual of the antennas will give detailed instructions on how to adjust either network. On manufactured antennas, a gamma match should only require adjustment of the shorting strap position (don't forget the oxidation compound) and possibly the length of the gamma rod. Spacing should not have to be changed. For beta matches, the length of the loop or hairpin may need to be adjusted, but not the spacing.

For a manufactured antenna, the network dimensions after adjustment should be fairly close to those in the manual. If they differ by more than 10 percent, if the minimum SWR can't be lowered below 1.5:1, or if the adjustments don't behave as represented in the manual, something is wrong. Stop and check the assembly and all element lengths. If all seems to be assembled properly, take careful notes about what happens as you adjust the antenna, then contact the manufacturer.

An *SWR sweep* checks the antenna over the bands for which it is designed. You can do this with your transmitter and SWR meter, at the risk of causing interference. A *noise bridge* can be used with a receiver to measure impedance at different frequencies, but the sequence of measurements is a little cumbersome. I heartily recommend the use of an *SWR Analyzer,* shown in Figure B1-6.

The analyzer makes it easy to measure SWR at numerous points across a band while putting out only a very low-level signal. The SWR is read directly on a numeric display along with the test frequency. A meter also shows the SWR, making it easy to find the point of minimum SWR. Using an SWR analyzer makes short work of adjusting an antenna's feed network or element length for minimum SWR at the desired frequency.

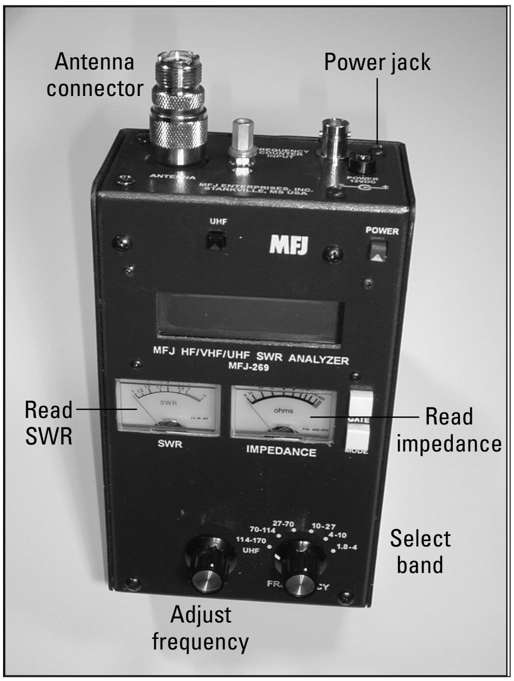

Figure B1-6: An SWR analyzer measures SWR, frequency, impedance, and other parameters.

If at all possible, test and adjust the antenna at the installed height. Ground and nearby objects can affect the antenna, making SWR measurements inaccurate. If you adjust the antenna under those conditions, it will act differently once in place, sometimes quite differently. If you can't adjust the antenna in place, hang it pointing straight up (HF) or point it into the sky (VHF/UHF) with the reflector (the longest or largest element) parallel to and 6 to 10 feet off the ground.

Placing ground in the least sensitive part of the antenna's pattern minimizes its effect and the adjustment should be close to actual performance once in the air. The antenna's resonant point will likely rise a small amount — less than 100 kHz at HF and barely noticeable at higher frequencies — when raised.

Radials for ground-plane verticals

The ground-plane antenna relies on an electrically-reflective surface to "make up the other half" of its ¼-wavelength radiator. If you happen to live on a metal ship or in a building with a metal roof to mount the antenna on, you're lucky! Most of us have to make do with dirt and wires, though, which aren't nearly so conductive.

The more conductive you can make the ground under your antenna, the smaller the amount of power that will be lost and the stronger your signal will be. The usual and most practical technique is to use wires stretched out *radially* from the base of the antenna. Needless to say, you can't just leave them scattered about your yard, so what do you do? How many do you need?

You'll hear scary numbers of radials, like "120," but don't think that you must have that many or the vertical won't work. You can get pretty close to top performance with 16 to 32 wires. The usual length is ¼-wavelength at the lowest frequency of operation. Radials are *not* tuned. That length is just the point of diminishing returns: longer than that and additional benefits are small. Make the radial wires as long as is convenient. If you can only lay down short wires, then use as many as you can.

Do you have to dig up the whole back yard? Not at all. If you have a lawn or field, Mother Nature will work for you. Mow the grass as short as you can where you will lay down the wires. Attach the radial wire to the ground connection at the antenna and stretch it out on the ground to full length. Hold the wire down with jumbo bobby pins or 6-inch pieces of stiff wire bent double every few feet. Then wait. In a few days, the wires will be disappearing below the grass and after a few weeks, the natural thatching and aerating processes will pull the wire down to the roots of the grass and the wires will be invisible and un-mowable.

To connect the radials at the base of the antenna, use a ring of heavy copper wire as a *bus* for soldering all the radial wires together. A single piece of strap or flashing can connect the ring to the antenna feed point ground. Another popular method is to use a metal plate with a lot of screw terminals.

Working with feedlines and connectors

The different types of feedlines and connectors were covered in Chapter 12 and I assume that you've made your purchase. Now it's time to install some connectors (if you're using coaxial cable) and put that feedline to work! Putting connectors on coax has a reputation for being difficult, but that's not true . . . if you have the proper tools and use them properly.

Let's start with the PL-259 (the plug that goes on the end of the cable). Installing the PL-259 connectors properly will prevent frustrating and hard-to-isolate failures, so it's to your benefit to learn how to do it correctly.

The tools you will need are:

- A *sharp* utility knife and small, *sharp* wire cutters.
- A coax stripping tool. RG-8 and RG-213 size strippers are available from The RF Connection at `www.therfc.com/index.htm`. RadioShack carries a smaller model for RG-59 and RG-59 as part number 278-248.
- A 100 to 250-watt soldering gun or iron and damp cellulose sponge (not plastic).
- Rosin-core solder.
- Locking pliers.
- A small vise (a machinist's vise will do).

While there are as many ways to install PL-259s as there are hams, we'll defer to the manufacturer's instructions. Amphenol (a large connector manufacturer) publishes instructions on their Web site for installing all of their RF connectors. The PL-259 instructions with drawings can be found for RG-8 and RG-213 cables at `www.amphenolrf.com`. Select UHF, then Straight Cable Plugs, find the 83-1SP, and select Assembly Instructions. *The ARRL Handbook* also has a set of instructions. Figure B1-7 shows a typical workbench setup for "doing" connectors. Make sure you have adequate lighting. To make these instructions work for you:

- Practice on a piece of scrap cable.
- Put the outer connector shell (called the *backshell* or *coupler*) on *first* and be *sure* it's pointed the right way, with the knurled end towards the connector body. Double-check before doing any soldering. (We've all put them on backwards or forgotten — you'll join the club eventually.)
- When trimming the jacket, disturb the braid as little as possible and try to avoid nicking the individual strands. Be sure the coax stripper blade depth is set properly.

- When trimming the center insulator, don’t nick the center conductor. Cut close to the conductor, then twist off the insulation.
- Make sure the plug body is clean of any grease or oil. A touch-up with a steel or brass bristle brush will clean off any oxidation. A severely grimy connector shouldn’t be used at all.
- After you’re done trimming, slide the plug body on and off to be sure all of the center conductor strands go into the center pin and that none are flared outward to short against the body. This is a good time to double-check that backshell.
- When screwing the plug body onto the cable jacket, a tiny dab of oil or silicon grease on the jacket will make the job easier. Clamp the locking pliers on the knurled portion of the plug body and turn the body in an even motion as it seats on the jacket. Don’t use pliers on the jacket — if you can’t hold the cable by hand, something is blocking the connector.
- Use a small vise to hold the cable as you work on it. Only tighten enough to secure the cable; don’t bite into the jacket. You’ll need to twist the cable by 180 degrees in each direction as you solder.
- Make sure your soldering iron is hot and the tip is clean. Hold the iron against the body hole and melt a little solder on the tip to aid in transferring the heat to connector. Be patient! Wait for the solder to start to flow onto the connector body and into the hole. This will take at least 15 seconds for most irons. The solder shouldn’t “bead up” in the hole.
- When you’ve done one hole, loosen the vise and twist the cable to the next hole. Don’t wait between holes; keep the connector hot.
- When all four holes are soldered, use the damp sponge to soak up some of the heat from the connector. Don’t soak the connector with water, just hold the sponge against the plug body.
- To complete the job, reorient the cable in the vise so that the connector angles slightly down and then solder the center pin. Fill the hole with solder to prevent water from entering.
- When the connector has cooled, wipe off any flux residue and use the utility knife to trim any excess solder from the center pin. Check for short circuits with an ohmmeter.

TIP

To crimp or not to crimp? Crimp-on PL-259 connectors are certainly a lot easier to put on, but there’s a catch. They should *never* be exposed to the weather, nor should they be used where vibration or mechanical stress (bending or pulling) will be present. The crimp between the shield and connector body will deteriorate over time, creating a lossy, intermittent connection. Sealing the connector with tape will help, but you are much better off limiting the crimp connectors to indoor use.

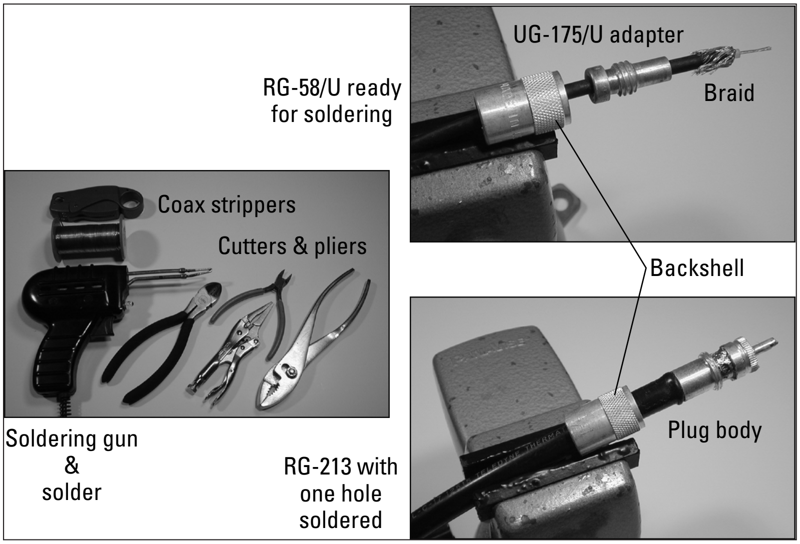

Figure B1-7: Typical setup and tools for installing RF connectors.

For smaller cables, such as RG-58 or RG-59, you'll need an adapter (the UG-175 and UG-176, respectively, Amphenol part numbers 83-185 and 83-168) to hold the braid against the inside of the plug body. The adapters screw into the plug body — give it a try first:

- Slide the adapter onto the cable.
- Remove ¾ inch of jacket and loosen the braid slightly.
- Slide the adapter forward until the front end is aligned with the end of the jacket.
- Fan the braid back and over the adapter like a turtleneck sweater.
- Use a small hose clamp to press the braid against the adapter while you use the sharp knife or cutters to trim the braid just above the adapter's threaded section.
- Remove ⅝ inch of the center insulator, keeping the center conductor strands together. Twisting them together slightly and tinning the end keeps a strand from getting loose inside the connector.
- Press the plug body down over the adapter and braid, screwing it down onto the adapter. Use an ohmmeter to check for shorts between the center pin and body.
- Now you can solder the connector for the thicker cable.

N-connectors are often used at VHF and UHF and are designed to be waterproof. There is little soldering to do, because these connectors use a clamping system to capture the cable braid. The center pin is placed on the center conductor and soldered with a small iron. The hole is very small, so using a magnifier may be a good idea. The installation instructions are found by following the Type N link at www.amphenolrf.com, then selecting Straight Cable Plugs. Choose a connector for the type of cable you are using and select Assembly Instructions.

Because the N-connectors do not solder the braid to the body of the connector, they can be reused. The gaskets should be replaced if the connector has been installed for any length of time. The center pin can also be reused, removing the solder inside by heating followed by a sharp shake against a wastebasket or workbench. Be careful when flinging molten solder around — wear eye protection.

Baluns

Balun (pronounced “B_L-_n”) is an abbreviation of “balanced-to-unbalanced transformer.” Baluns are found at antenna feed points and at coaxial-to-open wire junctions. There are two types of baluns: *choke baluns* and impedance transformer baluns.

The function of a choke balun is to prevent RF current from flowing on the outside of a coaxial cable. It does not perform any impedance transformation. At the end of a feedline, the RF energy inside a coaxial cable will flow both into the load and back along the outer surface of the braid. RF current may also flow on the outside of the line due to picking up energy from an antenna. This is undesirable because the current should flow in the load, such as an antenna. By preventing the undesired current flow, the *unbalanced* energy in the coaxial line (where the outside of the shield is grounded) is made to drive a *balanced* load (where equal currents flow in and out of each terminal).

Choke baluns make the outside of the cable shield look like a high impedance to RF current. Make a choke balun by coiling the feedline in a single layer to make the outer shield into an inductor. (The inner conducting surfaces are unaffected.) Table B-1 shows the coil diameter and number of turns that are required at the various frequencies. Another type of choke balun is made by placing a number of *ferrite beads* over the end of the cable. *Bead baluns* can be homemade or purchased commercially.

Table B-1 Coil and Bead Choke Baluns

	Frequency Range	*Number of Turns or Beads*	*Type of Bead Material*
Coil	3.5–14 MHz	8 turns, 7” diameter	—-
Coil	14–30 MHz	6 turns, 4” diameter	—-
Bead	HF and VHF	12 beads	Amidon FB-77-1024

Impedance transformer baluns are used to change the impedance of a feedline to a value that matches a load or that of another feedline. Impedance transformers are specified by the ratio of transformation: 4:1, 6:1, 9:1, and so on. Those that use ferrite cores can only be used over a specific frequency range. They also connect unbalanced coaxial feedlines to a balanced load, but do not prevent RF current from flowing on the outside of the coaxial cable if the line picks up energy from an antenna.

Digital Interfacing

The major hurdle to using the digital modes is getting all the signals to and from the radio. Because most radios are designed to transmit voice and CW, not data, you'll need to make use of whatever inputs and outputs the radio provides. Luckily, the process is straightforward and more radios are being designed with dedicated interfaces for data.

Connecting to a radio

Let's review the radio inputs and outputs first. Figure B1-8 shows the general connections between radio, controller, and the computer.

- **Microphone Audio & Microphone Ground:** Usually connected to the microphone, but used as an audio input on the data modes. This is a *low-level* input and needs to be protected against interference from the transmitter output. Signals connected to this input should use shielded cable with the shield connected to the microphone ground (not the control ground) to prevent ground loops. An ohmmeter test between microphone and control ground pins may show a connection, but the grounds are routed differently within the radio and should not be connected together externally. Symptoms of problems with this signal are hum or distortion on your output audio.
- **Push-to-Talk (PTT):** Short this pin to the control ground to key the transmitter, just as if you had pushed the microphone PTT switch. The connection can be made with a transistor or relay. Whatever does the switching should pull the voltage below 0.7V to insure reliable keying. Open the circuit to turn off the transmitter.
- **Receive Audio:** Some radios make this signal available on the microphone connector. Otherwise, use the External Speaker output on the radio's rear panel. This should also be a shielded cable to prevent RF interference from the transmitter. Whatever the source of audio, it should have an adjustable level, usually the front-panel AF or Audio Gain.

- **Squelch (SQL):** This output signals that the channel is busy. The normal convention is that a +12V signal indicates the squelch is open. Packet TNCs wait for an inactive channel before transmitting.
- **Control Ground:** A common ground shared by several low-speed switch and control lines such as PTT and SQL. Do not use this ground for audio shields unless specifically instructed to do so.

Your radio may also provide special audio input and output lines for high-speed data. Read the manual carefully for instructions about connecting these lines to an external data controller or computer sound card, particularly how to shield the cables and where to ground them.

For audio connections, you can use a regular shielded audio cable such as RadioShack 278-512 or a miniature coax like RG-174. If you use cable with a shield and a *twisted pair* of conductors, use the wire pair for the audio and audio ground, connecting the shield to the control ground or connector shell.

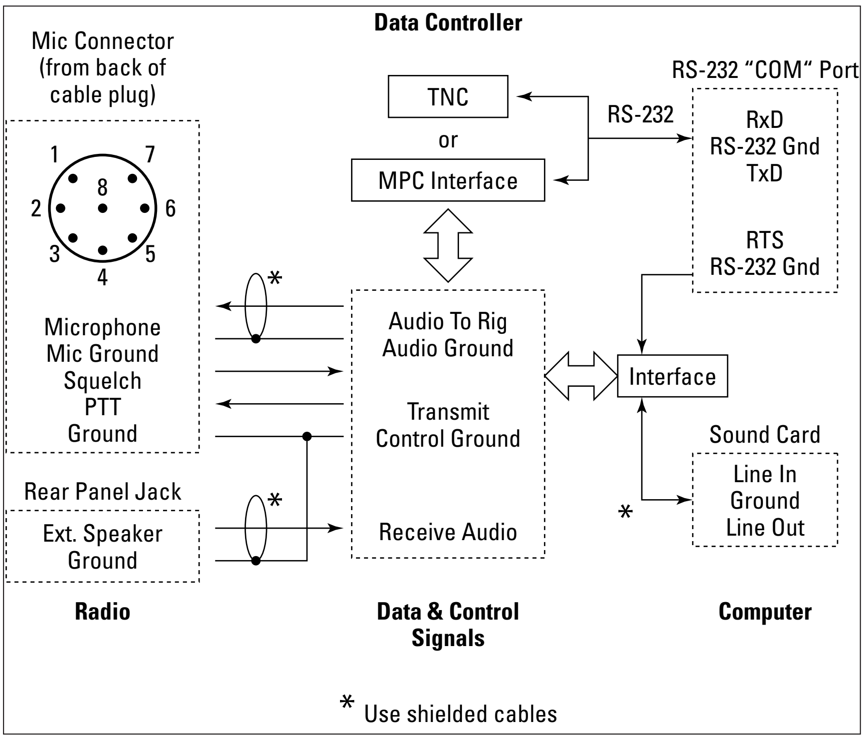

Figure B1-8: The signals and shielding conventions for data controllers, radios, and computers.

Using an external data controller

Packet operation requires a Terminal Node Controller (TNC) between the computer and radio. Another popular piece of equipment is the Multi-Protocol Controller (MPC), used primarily on HF. Both of these connect to a PC serial or "COM" port using RS-232 signals. To connect these to a radio requires a special cable carrying the signals described in Figure B1-8.

There is no standard connector on an external controller, so you'll have to make up your own cable. The controller manufacturer may provide an *unterminated* cable that plugs into the controller, but relies on you to make connections to the radio. Follow the rules for shields and grounding discussed in the previous section.

When you are making data and audio cables, that's a good time to slip a ferrite bead or two over the cable. The beads can then be held in place against the connector with a cable tie. This is a lot easier than having to wind the cable on a larger (and more expensive) core when interference occurs.

The controller is a central point for a lot of wires and cables: power, digital data, control lines, and low-level audio. It's an easy target for RF pickup, so grounding is doubly important. Be sure to tie the case of your controller to the shack RF ground system and keep cables as short as is practical.

Interfacing directly to a computer

More and more software is available that uses the computer sound card to encode and decode data signals without an external controller. Computers and radio have entirely different notions about grounding, particularly in the RF-laden environment of ham radio. The solution is to use an interface circuit that isolates the grounds of the two systems, but allows audio and control signals to pass.

Both MFJ Enterprises (`www.mfjenterprises.com`) and West Mountain Radio (`www.westmountainradio.com`) make popular sound card/radio interface units. You will also find interface kits and wiring instructions on the fine Web site of Ernie Mills WM2U (`www.qsl.net/wm2u`). The PSK31 page found there is an excellent tutorial on connecting a computer to a radio.

The key to all of these interfaces is the use of *transformer coupling.* Small audio transformers pass the data signals in each direction, but there is no direct contact. This breaks any ground loops between the computer and radio, keeping noise and hum from the AC power lines from contaminating the low-level audio signals. Control lines are less touchy about noise but are often isolated with *optoisolators.*

Optoisolators or optocouplers are a package containing a light-emitting diode and a light-sensitive transistor. When the input circuit drives current through the LED, turning it on, it also turns on the output transistor. This makes optoisolators ideal for transferring control signals between systems without making direct contact between them. For additional information about these devices, download the documents “General Description” and “Application Examples” from the Vishay Electronics Web site (`www.vishay.com/optocouplers/related#appnot`).

Adjusting the data signal

The data controller or sound card software must have a proper signal to work with or you won’t be able to send or receive data effectively. By understanding the basics of the signals, you’ll have much better on-the-air results. First, read the background information in Chapter 12 on the data mode you are using, including the reference materials. You need to know what kind of a signal you’re tuning in!

Second, there are three adjustments you need to master:

- **Tuning:** The adjustment of receiver frequency so that the data signal tones are of the proper frequency (on SSB-based modes) or that the signal’s carrier frequency is centered in the receiver’s passband (for FM modes). VHF packet channels are centered on known frequencies, so setting your radio’s frequency to the desired channel is generally sufficient. For other modes, tuning guidance is provided by displays on the controller or in the PC software. Tuning displays generally have marks or guides that correspond to the desired signal frequencies or amplitudes. When your receiver is on the right frequency, the display will show the signal concentrated on those marks. Each controller and program are somewhat different, so consult the manual or Help files for a specific description. Once you get the signal tuned in, listen to it by ear to get a feel for what properly tuned signals of each type sound like.
- **Outgoing audio level:** The level of the audio signal input to the microphone connector as modified by the Mic Gain control. Just like for voice operation, the radio’s operating manual should have a procedure to follow to insure that you don’t set the level too high, which causes distortion and interference. The speech processor should be OFF for data. If you set the level too low, then your signal will be weak, but otherwise okay. There are two adjustment points: one in the controller, the interface, or the sound card software, with the other being the radio’s Mic Gain control. If there are no instructions, a good starting point is to set the controller or software gain to 50% of maximum and then adjust the Mic Gain.

- **Incoming audio level:** The level of the audio signal supplied by the receiver. The single control that affects output level is AF Gain. The controller or program instructions should guide you on the best way to set this signal level. If you don't have instructions, find a signal on the air that is fairly free of noise or fading. Increase the level until you can get a clear tuning indication on your controller or software. When the tuning is set properly, reduce the level until you are no longer able to receive the data reliably. Now increase the level until data is copied reliably and note the characteristics of the tuning display or listen to the signal by ear.

TIP

Specifying the frequency of a digital signal on SSB equipment has the same problem as SSB voice. Do you specify the frequency of the carrier or of one of the data tones or of the center frequency of the transmitted signal? The usual convention, as with voice, is to specify the carrier frequency. If I say to a friend, I'll meet you on RTTY at 14.085 MHz, what I'm really saying is that I'll set my displayed frequency (i.e. the carrier) to 14.085 MHz LSB, but the actual tones of 2125 Hz and 2295 Hz tones will actually cause RF signals at 14.085 MHz to 2125 or 2295 Hz = 14.082875 and 14.082715 MHz. It's easier to use the displayed carrier frequency. Be sure to ask!

Working the Satellites

Communicating through the amateur satellites is not that much different from using a repeater or chasing a DX station that is operating split. There is one additional element to consider: The station you're trying to communicate with is moving in the sky. That means you have to know when and where the satellite will be visible to you. You will also have to be able to compensate for the *Doppler shift* resulting from its motion. Here's an example showing how to make a satellite voice QSO.

An FM repeater satellite is the easiest and can be accessed with a dual-band VHF/UHF hand-held or mobile radio. Let's say you want to try the Saudisat 1-C, also known as SO-50. It is a cross-band repeater that you access on 145.850 MHz (67.0 Hz CTCSS tone) and transmits on 436.795 MHz. You may be able to work the satellite with a rubber duck antenna, but a dual-band mobile whip will work much better.

- Log on to the AMSAT Web site (`www.amsat.org`) and obtain the orbital elements as discussed in Chapter 12. Enter them into your satellite tracking software and determine when the satellite will be visible. (Make sure the satellite is operational, as well.)
- Program three memory channels of your radio to use when the satellite is approaching, when it is closest to you at mid-pass, and when it is receding. Table B-2 shows the appropriate frequencies. As it approaches, the

Doppler shift will cause you to hear the satellite at a *higher* frequency and the satellite will hear you at a higher frequency. The converse is true when the satellite is moving away. Note that the transmitter and receiver Doppler shifts are in opposite directions, this is because the Doppler shift only applies to the *receiving* station. The satellite will experience a Doppler shift on your signal, too, so you must compensate by moving your transmitter in the opposite direction. Note also that Doppler shift is frequency-sensitive and so is greater at higher frequencies (although it's the same *percentage* of the frequency).

Table B-2 SO-50 Operating Channels

	Receive Frequency (MHz)	*Transmit Frequency (MHz)*	*Rx Offset/Tx Offset (kHz)*
Approaching Channel	436.800	145.748	+5/-2
Mid-pass Channel	436.795	145.850	0/0
Receding Channel	436.790	145.852	-5/+2

- Select the approaching channel and at the appropriate hour listen for the satellite's signal with the receiver squelch open. When it comes in range, you'll hear the noise level begin to drop. Alternate between the approaching and mid-pass channels to see which gives the best reception.
- Listen to the signal as the satellite passes overhead and moves away, switching to the receding channel as necessary until the signal fades. Practice receiving on a few more passes and see if you hear others using the satellite. You'll quickly learn how contacts are made.
- Satellite passes are short, so keep transmissions to a minimum. Try a short transmission, such as "This is NØAX calling." You might get an answer! Only one person can use the satellite at any time, so keep the contact short — the longest passes are only 10 to 15 minutes!

Satellite transponders

The SSB/CW transponders are frequency converters that receive signals over a range of input frequencies and translate them to a range of output frequencies. For example, one of AO-40's transponders has an input or *uplink* range of 435.550 to 435.800 MHz and an output or *downlink* of 24048.025 to 24048.275 MHz. Notice that the uplink and downlink bands have the same width (250 kHz) so that if I transmit 10 kHz from an uplink band edge, I will be 10 kHz from the downlink band edge. Each uplink/downlink pair is called a *mode* that is identified with letters corresponding to the ham bands used. For example, Mode U/S means the satellite is receiving on 435 MHz (U) and transmitting on 2.4 GHz (S).

Working the International Space Station (ISS)

The ISS has a VHF voice and data ham radio station aboard and nearly all of the astronauts that call it home are hams! You can talk to them or send and receive messages. While their schedule is very busy, they enjoy using ham radio to keep in touch and break up the routine in space. You can connect to the packet station aboard the ISS and receive a nice certificate as a result!

You'll need a 2-meter FM radio with 10 to 25 watts of output. An omnidirectional antenna will work and a small beam is even better. You also need a packet radio TNC such as a Kantronics KPC-3 or the equivalent. You'll need a computer running a terminal program, such as Hyperterm or Procomm, configured to log all of the data going to and from the TNC. With your transceiver set to the ISS frequencies (145.990 MHz uplink and 145.800 MHz downlink), wait for a long pass visible at your location. Your TNC will begin to decode messages if anyone else is logged on to the ISS system. When you see the all-clear message, try to connect by typing "C RS0ISS-1." If you're successful, you'll get a CONNECT message back! If not, keep trying on good passes and sooner or later, you'll make it through!

The complete procedure, including how to set up your TNC, is posted on the *Ham Radio For Dummies* Web site.

The downlink band of an *inverting transponder* is inverted from the uplink, meaning that signals at the high end of the uplink are found at the lower end of the downlink. You'll need to know that before trying to communicate through the satellites. The information is available on the AMSAT Web site.

To work the satellite transponders, you'll need a radio that can operate *cross-band split.* Because the uplink and downlink are on different bands, the radio will have to jump from one band to another when you key the transmitter. The radio will also have to operate *full duplex,* that is, receive and transmit on those two bands simultaneously. You'll need to hear your own signal on the satellite's downlink in order to be able to find stations calling you and to compensate for Doppler shift as the satellite moves.

To do this, you can use two separate radios or purchase one of the "satellite rigs" that are made just for this purpose, such as the Kenwood TS-2000, Yaesu FT-847, or Icom IC-910H. Using separate radios requires that you perform tuning operations manually. Either way, it will take some practice and I recommend that you listen to the satellite downlinks to become comfortable with tuning and the characteristics of the signals before transmitting.

You don't have to have a big array of antennas, steerable in both azimuth and elevation to work the satellites, either. Many stations use nothing more than omnidirectional verticals, although that limits the amount of time they can access the "bird." A simple *turnstile over reflector* antenna can be home-brewed for a few dollars and a pair mounted on an inexpensive TV antenna rotator for 360-degree coverage. Start by listening for satellites on your existing antennas to determine if you need a more capable antenna.

There is a lot of terminology associated with satellites — more than I can cover here. If you plan on making the satellites a regular part of your operation, I recommend that you study the references on the AMSAT Web site, in Chapter 11, and Appendix B. You've experienced the basics of satellite operation and now will be able understand the discussions as you construct a more capable satellite ground station.

Learning about Ionospheric Propagation

Chapters 8 and 9 introduce the day/night characteristics of the HF bands and the basic types of propagation you'll encounter on the VHF and UHF bands. Once you start operating regularly, you'll want to know more about how propagation works and how it can be predicted. Propagation of radio waves is sufficiently complex that you can spend a lifetime studying it, but you only need to commit a few hours of reading time to learn the basics.

Start by reading the chapter on Radio Wave Propagation in *The ARRL Antenna Book.* (It may be available at your library.) This valuable reference covers all of the common propagation types, their causes, and their effects. It also includes a discussion of how predictions are made for what HF bands are open and when. (Other references are listed in Appendix B.) What I present here are the fundamental concepts involved.

Reflection and absorption

Propagation on the HF bands is a continual balancing act between the ability of the ionosphere to reflect and to absorb radio waves. The ionosphere can be thought of as having three layers in order of increasing height: D, E, and F (which also splits into the F1 and F2 layers). All are in sufficiently thin air that solar ultraviolet (UV) radiation can partially *ionize* the molecules by knocking electrons free. The ionized layers affect radio waves as you learned during your licensing studies, bending and absorbing them.

Reflection by bending is primarily performed by the F layers. As frequency increases, ability to bend signals decreases, resulting in a maximum frequency at which a signal can be returned to Earth. This is the *Maximum Useable Frequency* or *MUF.* The stronger the solar radiation, the more the ionosphere can bend a signal and the higher the MUF. This is why the higher HF bands on 14 MHz and higher come to life with the sunrise and close again after dark.

There is one other variable that affects MUF and that is *angle of incidence.* Just as even rough surfaces can reflect light well at low angles, the ionosphere's layers reflect signals better at low angles. At high angles, such as straight up, the F layers may pass a signal right through to outer space, where a signal grazing them at a few degrees may reflect cleanly. This results in the *skip zone* surrounding your station on the higher HF bands; few local signals are heard, but DX signals may be strong. The local signals aren't reflected by the ionosphere at the high angle required to come back down to your antenna.

There is one problem with higher levels of solar radiation: The lower layers become lossier to signals travelling through them, particularly at low frequencies. At some point, enough signal is lost so that there is a *Minimum Useable Frequency,* as well. For example, during the day the D layer effectively absorbs energy on the 7 MHz band and below, making long-distance contacts impossible. As the sun sets, reducing its illumination of the ionosphere, these bands come alive with long-distance contacts.

Predicting propagation

Given the dependence of absorption and reflection on frequency, angle, and solar radiation levels, this can make for a complex situation. That's where propagation prediction tables and programs come in. These programs take solar radiation, time, date, and the Earth's *geomagnetic field* into account, calculating the expected signal levels between any two points on Earth at any HF frequency. You or your computer can supply the time and date. The geomagnetic field has been mapped by scientists over the years so that for most conditions, the strength of the ionosphere over any point on Earth is known. That leaves the solar radiation levels.

Solar and geomagnetic indices

Solar radiation data and the conditions of the ionosphere (disturbed or stable) are measured continually here on Earth and by satellites in orbit. The data is made available to Web sites and is broadcast by WWV (`www.boulder.nist.gov/timefreq/stations/wwv.html`) at 18 minutes past the hour (and at 45 minutes past the hour on WWVH). There are three key indices that are used by propagation prediction: solar flux, the A index, and the K index. WWV announcements also include the current and predicted state of the geomagnetic field.

The solar flux is a measure of how much energy is entering the Earth's atmosphere. As mentioned earlier, more radiation means higher MUFs and that makes the HF DXers and VHF Sporadic-E operators happy. The flux ranges from a low of 65 during sunspot cycle minimums to approximately 300 during solar outbursts.

The A and K indices measure how active the geomagnetic field is. More activity disturbs the ability of the ionospheric layers to reflect signals and causes more absorption. The higher the values for these indices, the worse the conditions on HF will be, in general. If the K index is reported as 0, 1, or 2, conditions are generally good. Values of 3 or 4 are somewhat disturbed, and a value of 5 or more indicates a storm (9 is the maximum). The A index varies over a wider range and reacts more quickly than the K index, so look for changes in the A index to indicate future conditions.

Propagation prediction programs use this information (usually just the K index) to calculate the strength of a signal travelling between two points. The ionosphere's reflective and absorptive characteristics are taken into account, as well. The result is a prediction of what the MUF will be for that particular path and the expected signal levels or *signal-to-noise ratio.* Here are three of the popular programs:

- **W6ELProp by W6EL:** A freeware Windows program (`www.qsl.net/w6elprop`)
- **Wincap Wizard 3 by Kangaroo Tabor Software:** (`www.taborsoft.com/wwizard3`)
- **VOACAP:** Developed for Voice of America and available to the public from several sources (try ON4BAA's excellent propagation Web site at `www.stroobandt.com/propagation/index.html`)

Solar storms

Sometimes the sun's quiet radiance changes to a violent outburst from sunspots, the more active regions on the sun. These can have dramatic effects on the ionosphere and propagation, so hams pay pretty close attention to them. Here are some of the more common terms you'll hear:

- **Blackout or Sudden Ionospheric Disturbance (SID):** A sudden pulse of X-rays from the sun can cause all ionospheric layers to become highly lossy to radio signals. If you are on the air during an SID, signal strength starts dropping and a hissing noise rises to eventually cover all but the strongest signals. The bands generally recover from an SID in a few hours.
- **Coronal Mass Ejection (CME):** Not to be confused with what happens after drinking too much Mexican beer, a CME occurs when a large amount of material, highly ionized gas and charged particles, is repelled from the sun's surface. The material impacts the Earth's geomagnetic field 30 to 36 hours after it is detected and may cause geomagnetic storms.
- **Geomagnetic Storm:** A significant worldwide disturbance of the Earth's geomagnetic field. This also stirs up the ionosphere's layers and makes them less reflective and more lossy.

- **Solar Flare:** A large radiation pulse from the sun that occurs when some of the stored magnetic energy in the sun's outer layers is released. The largest and most disruptive are the X-class flares, followed by M-class, and then C-class, which are essentially normal behavior.
- **Solar Wind:** The stream of charged particles (mostly protons) that flows steadily outward from the sun. Higher velocity or density can disturb the ionosphere and cause a geomagnetic storm.

Near real-time information about solar activity is available from numerous Web sites. Two of my favorites are Spaceweather (`www.spaceweather.com`) and, by Tomas NW7US, `www.hfradio.org/propagation.html`. You will not only get activity updates, but images from the solar observatory satellites, pictures of auroral activity, and other interesting data. It's safe to say that you'll want to bookmark one of these or a similar site to keep an eye on Ol' Sol.