

# ARRL Amateur Radio Education & Technology Program

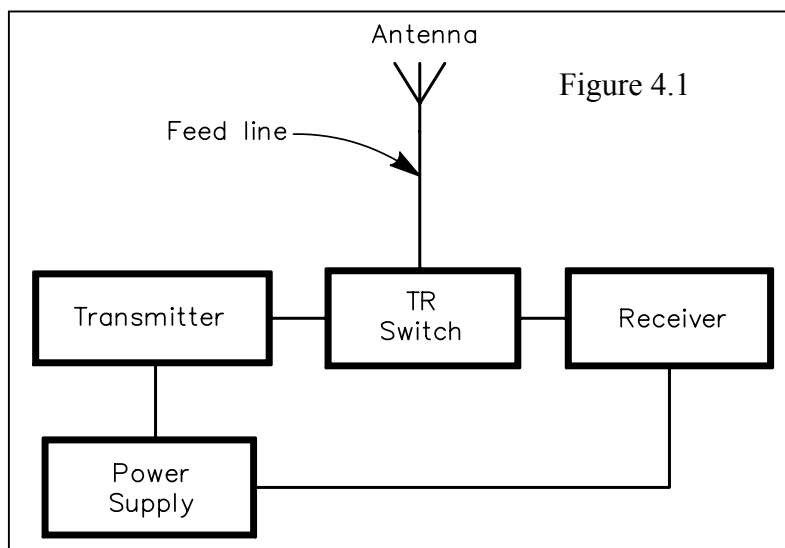
## Unit 4 Transmitting and Receiving Devices

### INTRODUCTION

In this unit you will be introduced to some of the basic equipment that goes into an Amateur Radio station. This will include: transmitters, receivers, filters, antenna switches and other equipment. You will learn how to connect the equipment to make a fully functional ham radio station.

You will learn some new terms that may be confusing at first. Don't worry if you don't understand everything at first, these terms will be reinforced later in other units.

One of the new terms you will be introduced to is *block diagrams*. In a block diagram, each part of a station is shown as a box. The diagram shows how all the boxes connect to each other. Once you start working with block diagrams you will catch on quickly.



To get started, look at **Figure 4.1**. This is a block diagram of a simple Amateur Radio station. Let's discuss the blocks one at a time.

### Section 4.1 TRANSMITTERS

The heart of a radio station is the transmitter. It is a device that will transmit radio signals out over the air. These signals are often called RF, for *radio-frequency* signals. A TV station or your favorite radio broadcast station both need powerful transmitters to get their signals out to the public but amateur radio operators use much less power to communicate with each other. A transmitter transmits an electrical signal that can be picked up by a receiver, such as a household radio. *Because students of all ages can earn their own amateur radio licenses, we will talk about amateur transmitters. All transmitters operate in basically the same manner, whether broadcast or amateur.*

A transmitter puts out a signal called the *radio-frequency carrier* or *RF carrier*. An RF carrier can be switched on or off with a Morse code key to make dots and dashes. These dots and dashes turn messages into coded forms that radio operators can understand. RF carriers can also be altered to carry actual voice messages by a special circuit in the transmitter called a modulator.

A transmitter and a receiver can be combined into one unit called a *transceiver*. Some circuits in the transceiver do double duty, sometimes helping with transmitting and other times helping with receiving. Other circuits are for transmitting or receiving only. Combining the two types of radios into one package simplifies design, saves space, and reduces cost as well. In our discussion, we will talk about transmitting and receiving as separate topics even though transceivers can perform both functions.

In a home amateur radio station, a transmit/receive switch allows one antenna to be used by both the transmitter and the receiver. See the TR switch in **Figure 4.1**. In a modern transceiver, the switching function is accomplished automatically. In simpler or older radios with separate transmitters and receivers, the operator may have to switch between transmit and receive by hand.

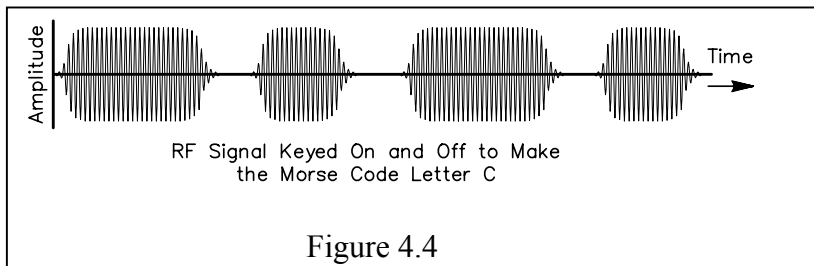
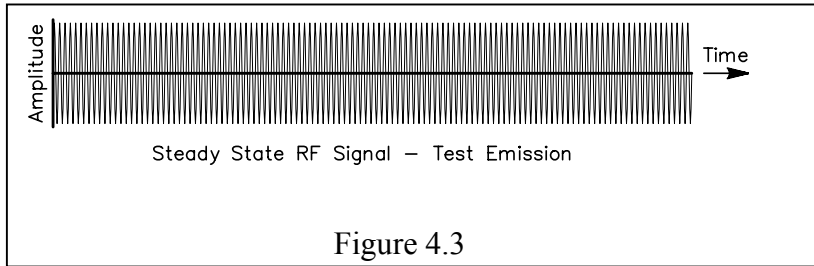
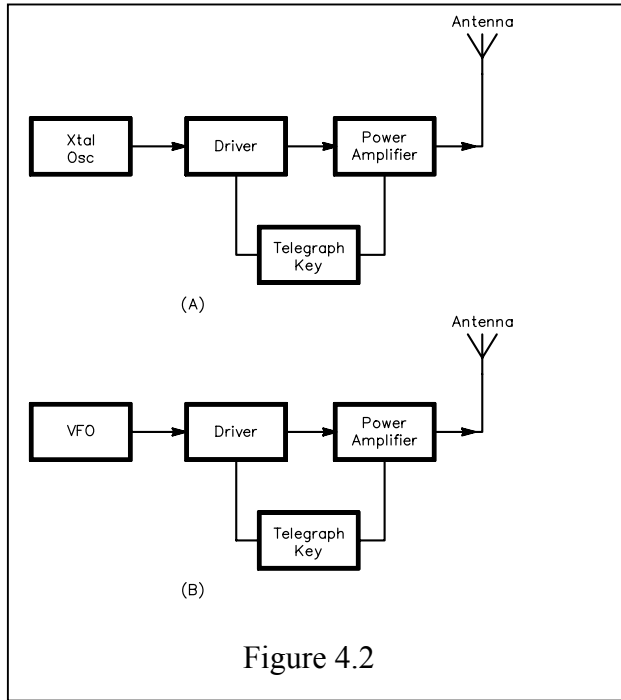


### Morse Code (CW) Transmitters

What is a transmitter made of? Inside a transmitter there are various parts or components that work together to produce RF signals. **Figure 4.2A** shows a block diagram of a simple amateur transmitter. It produces CW (continuous wave) signals when a special switch called a key is closed. The signal is produced by a *crystal oscillator* made from quartz. The quartz keeps the signal on frequency. Two other stages include a driver and a power amplifier. In order to send information, you have to modulate the RF carrier. This means you have to do something to it or change it somehow. If you just hold the key down, you will send out an unmodulated carrier, See **Figure 4.3**, but if you move the key down or up you will be able to turn the signal on or off to make dots and dashes. See **Figure 4.4**. This is how you can send Morse code to someone else, by modulating the carrier signal on and off.

With a crystal oscillator, you can send messages on only one frequency (just like your favorite radio station...it's always on the same place on the radio dial.) With a variable-frequency-oscillator or VFO (*Figure 4.2B*) you can change the transmitter frequency whenever you want, such as when a certain frequency is already being used by someone else.

Even though *Figure 4.2* doesn't show it, the transmitter also needs a power supply of some sort. The diagram leaves this off to make it simpler to understand.



## Phone

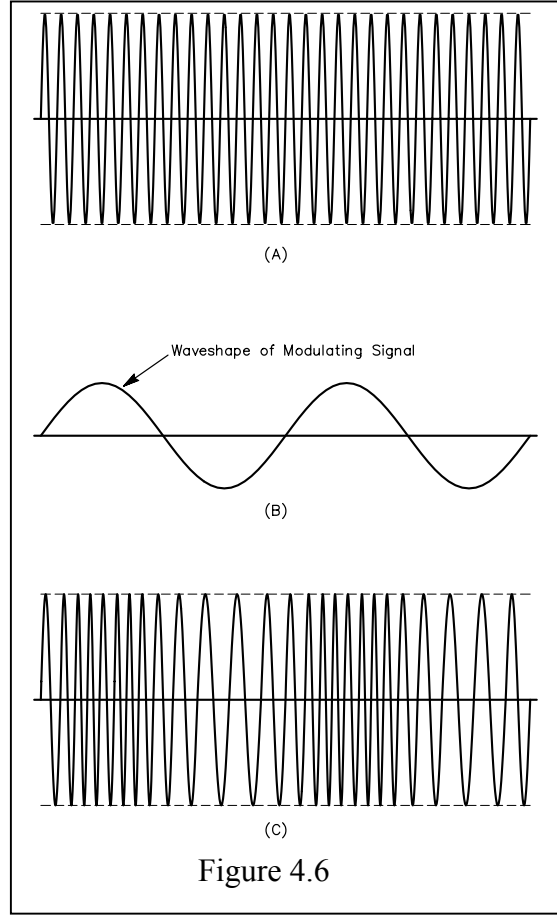
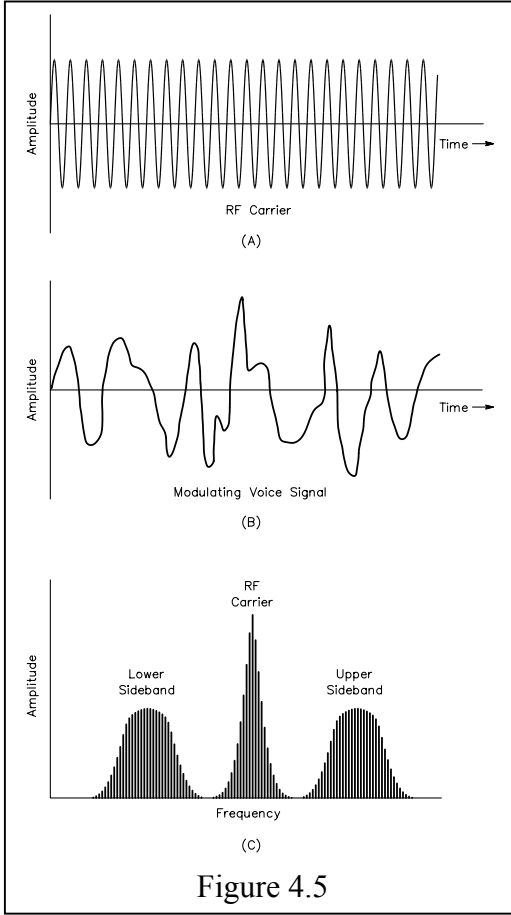
Any *voice* mode used for communication is known as a *phone emission* under the FCC Rules. AM, SSB and FM voice are all *phone emission types*. We are familiar with AM from our commercial radio stations.

## Single-Sideband

What is single-sideband (SSB)? Now we will get a little technical but don't worry about it. If you concentrate, you will be able to understand the process. Begin with a steady radio frequency (RF) signal such as you would get by pressing the key of a CW transmitter and just holding it down. This signal is called the *RF carrier*. See **Figure 4.5**. Then combine this signal with a voice signal from a microphone. This is called modulation. The resulting signal has two sidebands, one higher in frequency than the carrier frequency and one lower in frequency than the carrier frequency. They are called upper sideband and the lower sideband. For a single-sideband voice signal, the carrier and one of the sidebands is removed, and only one sideband is transmitted. The RF carrier is the signal that we modulated to produce a radiotelephone signals. SSB is the most common voice mode on the HF ands.

## FM Transmitters

As mentioned, information is sent over a radio wave by somehow changing the characteristics of the signal or carrier. This is called *modulation*. FM radio systems have a special method of modulating the carrier. In FM the carrier is modulated by changes in voltage. These voltage changes represent information to be sent. Microphones, video cameras, and computer modems can all send information over radio waves. The carrier frequency can go up or down depending on how the modulating voltage rises and falls. FM modulation produces an excellent quality audio signal that is especially good for mobile or portable communication. See **Figure 4.6**.



## RECEIVERS

A transmitter sends out information. The RF signal it produces goes to a transmitting antenna. The antenna radiates the signal into the air. Some distance away, the signal is picked up by a receiving antenna. A current is created in the receiving antenna that travels down into a receiver. Here the RF energy is converted into something you can understand such as an *audio signal*. You hear the audio through a loudspeaker or a set of headphones.

Just about everybody is familiar with receivers. Receivers take signals out of the air and convert them into signals that we can see or hear. Your clock radio is a receiver and so is your television set. If you look around the room you're in right now, you'll probably see at least one receiver. A receiver is also a very important part of an Amateur Radio station.

A good receiver can detect weak radio signals. It separates them from other kinds of signals and interference. The ability to detect weak signals is called *sensitivity*. The ability to separate radio signals from other kinds of signals is called *selectivity*. A good receiver also stays on frequency without drifting. This is called *stability*. In general, a good receiver must be sensitive, selective, and stable.

Like transmitters, receivers can be simple or complex. You can build a simple receiver that will work surprisingly well. The ARRL *Handbook for Radio Amateurs* has receiver plans, including sources for parts and circuit boards. A crystal set is an easy-to-build AM broadcast receiver. You can find information on building a crystal set at internet web sites such as [www.midnightscience.com/project.html](http://www.midnightscience.com/project.html). Many companies supply relatively inexpensive radio kits, such as those produced by MFJ, Vectronics, Tentec ([www.tentec.com/tkit.htm](http://www.tentec.com/tkit.htm)), and others.

## TRANSCEIVERS

In most modern Amateur Radio stations, the transmitter and receiver are combined into one box. We call this combination a *transceiver*. It's really more than just a transmitter and receiver in one box, though. Some of the circuits in a transceiver are used for both transmitting and receiving. Why a transceiver? Transceivers generally take up less space than a separate transmitter and receiver.

Many modern radios need 12 V dc to operate. This makes them ideal for use in a car as part of a mobile radio station. If you have one of these new modern radios, you will need a separate *power supply* to operate it in your house. The power supply (usually) converts the 120 V ac from your wall socket into 12 V dc to power the radio.

A 100-watt transceiver may draw 20 amperes of current when it is transmitting. A heavy-duty power supply is often required to provide the current needed to operate the radio while transmitting. Some radios have built-in power supplies while others are designed only for 12 V operation, and therefore need an "external" power supply.

## FILTERS

We use many kinds of filters in our daily lives. We have filters for our coffee, filters for water, filters for air conditioners and even in our televisions. You are familiar with most of these filters but you may not have known about the filter in your television set. Let's look at the filters used in radios and why they are necessary.

Sometimes, wireless communication causes interference in home entertainment systems. This can be a problem for some ham radio operators as well. When you transmit a radio signal, the signal carries along with it some extra information called *harmonics*. Remember that a radio

signal is transmitted on a particular frequency. Harmonics are signals that occur on different frequencies that are exact multiples of the transmitted signal's original frequency. For example, if you have a frequency that you're transmitting on, multiply it times 2 and you now have a harmonic frequency. If these extra harmonic signals are strong enough, they can interfere with broadcast signals. For this reason, modern amateur radio transceivers have *filters* built in that *attenuate* (reduce) unwanted harmonics. Modern amateur radio transceivers seldom create harmonic-related interference.

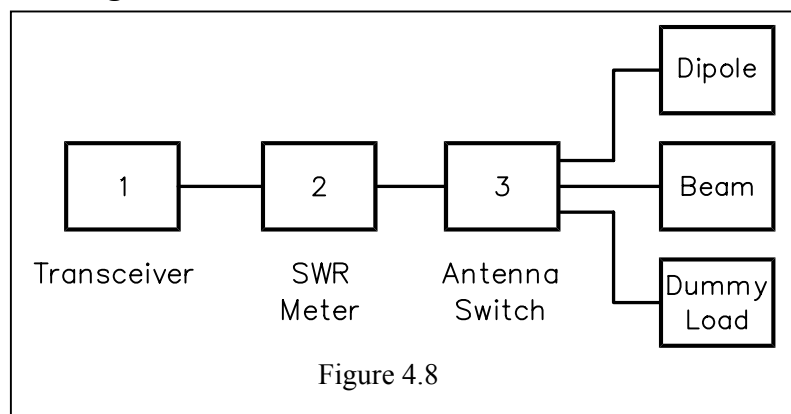
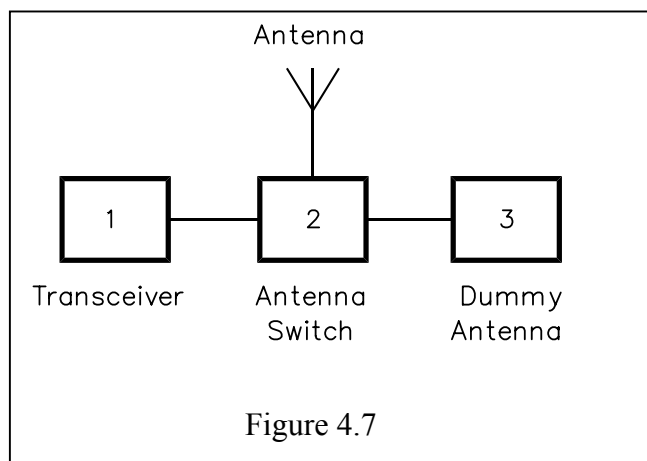
How do filters work? Filters are like gatekeepers. They allow certain frequencies to travel through a circuit but they block others. In an amateur radio transceiver, the desired frequency is allowed to pass but unwanted harmonic frequencies are stopped by the filter. Filter circuits are found in all modern communication devices and allow various kinds of equipment to operate on different frequencies without interfering with each other.

## STATION ACCESSORIES

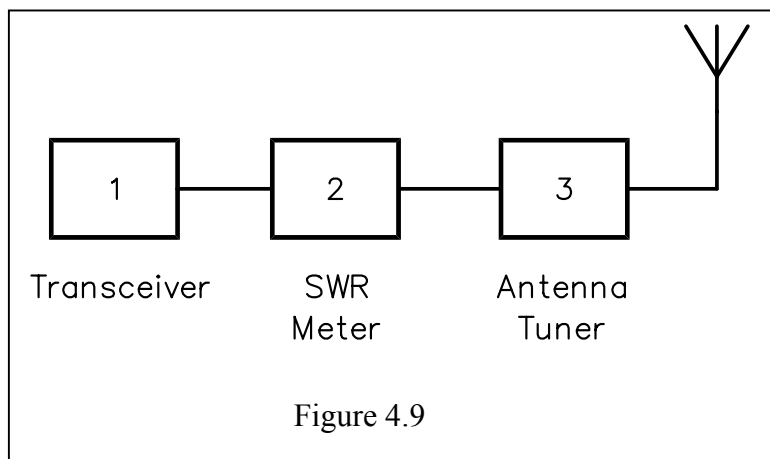
So far, we have been talking about a very basic station layout. We showed you how transmitters and receivers are connected to antennas to either send or receive radio signals in a simple home station that you could build yourself. To communicate effectively, you also will need a few accessories. Let's look at what you need.

### Antenna Switch

Different types of antennas are useful under different operating conditions. An amateur radio operator may have more than one antenna and may want to switch from one antenna to another. Each antenna has its own feed line to connect to the radio. You could disconnect the feed line from one antenna and then connect another. This is time-consuming and very inconvenient. A device called an *antenna switch* will allow you to change from one antenna to another by the simple flick of a mechanical switch. See **Figure 4.7**.



All the feed lines from the different antennas connect to the switch inside the station where the operator can easily flip the switch. An antenna switch can also be used to switch between a regular antenna and a special kind of antenna called a dummy antenna or dummy load, used for tuning and testing. See **Figure 4.8**.



### Standing Wave Ratio Meter (SWR)

Some stations have an SWR meter, which measures something called *standing-wave ratio* (SWR.) This indicates how well your antenna is working and whether or not you may have a problem with it. Antenna problems can damage radio equipment so it's important to know how well the antenna is working.

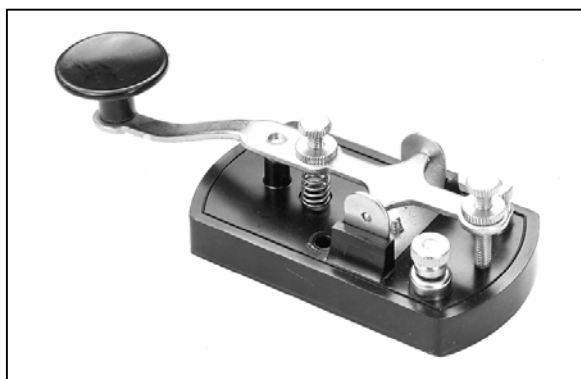
### Antenna Tuner

Another useful accessory in a ham radio station is an antenna tuner, also known as an *impedance-matching network*. (Impedance is similar to resistance.) It allows you to use one antenna on several different bands. Because it matches the impedance of the antenna system to the impedance of a transmitter, it is sometimes called a *Transmatch*.

An SWR meter is used along with an antenna tuner to show the operator if the antenna system is working properly. See **Figure 4.9**.

### Morse Code Key/Keyer

Morse code is transmitted by switching the output (outgoing signal) of a transmitter on and off. This can be controlled completely by hand using an old time code device called a straight key. The operator manually works the contacts of the key up and down to produce code. The spacing between dots and dashes as well as the speed at which the code is sent require a lot of practice. Over the years, electronic keyers have been developed to make sending code easier. The keyer sends perfectly timed code characters, which are easier to understand. See



### Microphone

A microphone is used to transmit voice. It converts sound waves into electrical signals that can be used by a transmitter. Like a code key, the microphone connects directly to the transmitter.



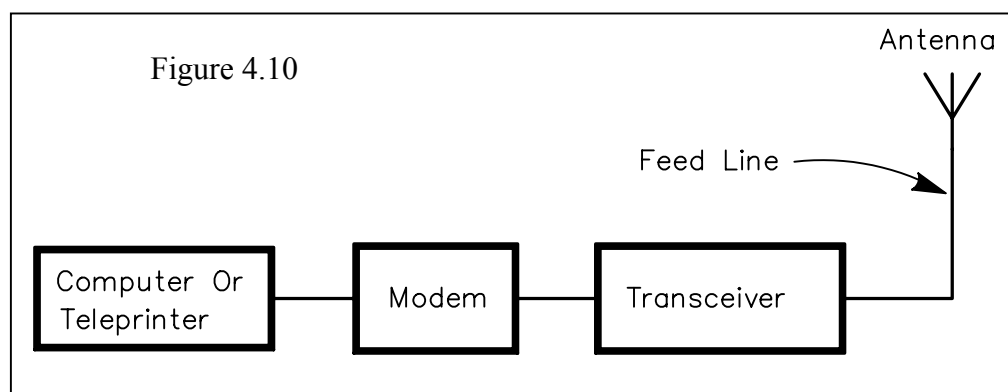
## RADIO TELETYPE and DATA COMMUNICATION

So far we've been discussing Amateur Radio transmissions that you can listen to, but some transmissions are designed to be received and printed automatically. These are sometimes called *digital transmissions*. Radioteletype (RTTY) and data communications are examples of this form of communication. Information is sent from one computer to another in a way similar to the Internet. In Amateur Radio data communications, however, you use amateur radios to send the information instead of telephone lines. You type information into your computer and then your transmitter sends it out over the air. Another amateur radio station receives the information, processes it and prints it out on a computer screen or printer. This is popular with many hams. Here we will talk about how to set up a station for digital communication.

### Radioteletype

*Radioteletype* (RTTY) communication goes all the way back to World War II when the U.S. military connected teletype machines to radios to send important messages over the air. Mechanical teletype machines were originally invented to send printed messages over a telephone line. In places where there were no telephone lines, the military began using radios to send the information. Hams began using this technology after the war but now have replaced the old teletype machines with computers, although some hams still use the old machines for fun.

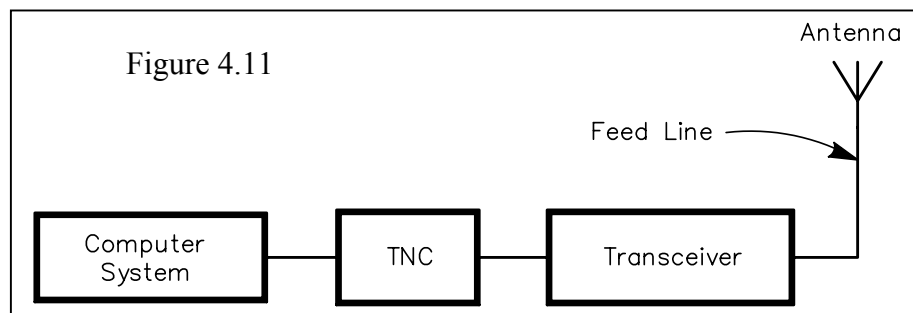
These days we use a device called a *modem* for Amateur Radio digital communications. Modem is short for *modulator-demodulator*. A modem takes digital information from a computer and modulates a transmitter with it. The transmitter sends the information over the air so that another radio station can receive it. The receiving station also has a modem that demodulates the radio signal so the information can be sent to a computer on that end. The computer processes and displays the signal. As mentioned earlier, some hams use an old time teleprinter instead of a computer. A



complete radioteletype station must have a computer or teleprinter, a modem, and a transceiver. See **Figure 4.10** to see how these components are connected to each other.

## Packet Radio

*Packet radio* uses a device called a *terminal node controller* (TNC) as an interface between a computer and a transceiver. (An interface is something that joins two other things together.) The TNC acts something like a modem but takes the data from a computer and breaks it up into little pieces called *packets*. Like a modem, the TNC goes between a computer and a radio, as shown in **Figure 4.11**.



By breaking up the information into packets, one channel (frequency) can handle the information from several different users at the same time. Besides containing the information from your computer, the packets also carry addressing, error-checking and control information. This is a very efficient method of sending wireless data.

Now you know a little about how radios work, let's look at how antennas work!

## HOW ANTENNAS WORK

We know that a transmitter generates radio-frequency energy. We convert this electrical energy into radio waves with an *antenna*. An antenna may be just a piece of wire or other conductor designed to radiate the energy. The antenna converts current into an electromagnetic field (radio waves). The radio waves spread out or *propagate* from the antenna. It's like dropping a marble into a pail of water or a pond. The waves expand out in all directions. Waves from an antenna radiate in all directions, though, not just in a flat plane.

It also works the other way. When a radio wave crosses an antenna, it generates a voltage in the antenna. That voltage isn't very strong, but it's enough to create a small current. That current travels through the *transmission line* to the receiver. The receiver detects the radio signal. In short, the antenna converts electrical energy to radio waves and radio waves to electrical energy. This process makes two-way radio communication possible with just one antenna.

Some antennas work better than others. Antenna design and construction have kept radio amateurs busy since the days of Marconi. In your class you will probably experiment with different types of antennas. You can have fun building and testing your own antennas.

## Wavelength

How long should an antenna be? Antennas have to match the operating frequency used for transmitting and receiving. The length of an antenna depends on the *wavelength* of the

operating frequency. The wavelength of a signal is related to its frequency. We can use mathematical formulas to determine wavelengths for different frequencies.

The symbol for wavelength is the Greek letter lambda ( $\lambda$ ). To determine the wavelength of a given frequency, we use the following equation:  $\lambda$  (in feet) =  $984/f$  (in MHz). The letter "f" stands for frequency. Here's an example. Suppose we want to determine the wavelength of a frequency of 52.15 MHz. Substituting in the formula we get:  $\lambda = 984/52.15 = 18.9$  ft.

Whenever we talk about an antenna, we refer to its design frequency. This means the antenna is *designed* to work on a certain amateur band. Most popular ham antennas are less than one wavelength long for whatever band they are designed to operate on. For example, a very popular antenna that is easy to build and use is the  $1/2\text{-}\lambda$  *dipole antenna*. We can use a variation of the equation we gave above to calculate the length of a  $1/2\text{-}\lambda$  dipole antenna:

$$\lambda \text{ (in feet)} = 468/f(\text{MHz})^1$$

Antennas operate most efficiently at what is called their *resonant frequency*. The resonant frequency is the frequency that matches the length of the antenna. You can change an antenna's resonant frequency by changing its length. If you lengthen it, the frequency goes down. If you shorten it, the frequency goes up.

## Feed Lines

To get the RF energy from the transmitter to the antenna you use transmission line. A transmission line is usually made from coaxial cable and is connected between the transmitter and the antenna. Transmission line is also known as *feed line*.

## Characteristic Impedance

One electrical property of a feed line is *characteristic impedance*. Impedance is like resistance (see the section on antenna tuners) and is influenced by the space between line conductors and the insulation in the feed line. An SWR meter (described earlier) helps us to determine the amount of impedance in our antenna system, which includes the feed line as well. If the impedances of the transmitter and antenna system don't match, some of the transmitter's power bounces back to the transmitter, lowering the overall power output. If the mismatch is bad enough, the transmitter can be damaged. The SWR meter helps us to keep the SWR as low as possible by telling us if there's a problem. See **Figure 4.12**.

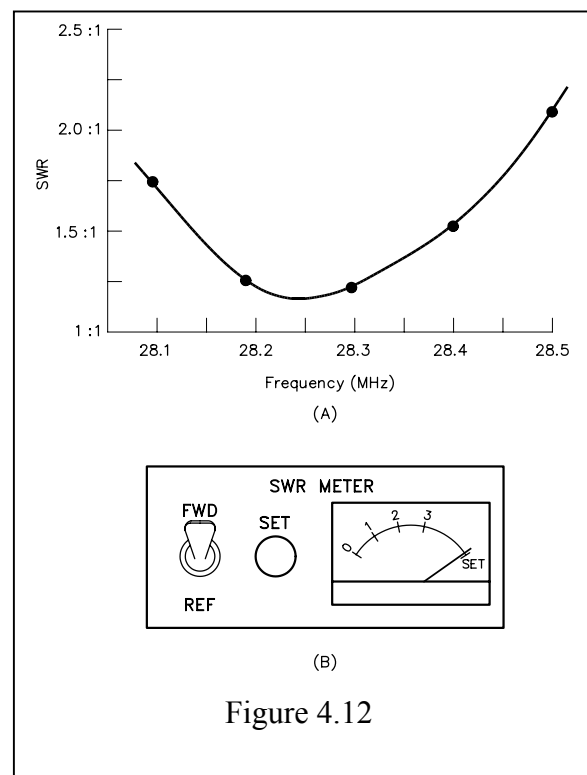


Figure 4.12

<sup>1</sup> Since this is a  $1/2\text{-}\lambda$  dipole, why don't we use the formula  $492/f(\text{MHz})$ ? 492 is one half of 984 in the first equation, so what gives? A dipole antenna has an insulator in the middle and some supporting lines on both ends of it. This increases the electrical length of the dipole so we have to physically shorten it a little to make it work right.

## TYPES OF ANTENNAS

### Half-Wavelength Dipole

Probably the most common amateur antenna is a wire cut to  $\frac{1}{2} \lambda$  at the operating frequency. The feed line attaches across the insulator at the center of the wire. This is the *half-wave dipole*. (Di means two, so a dipole has two equal parts). Each side of the dipole is  $\frac{1}{4} \lambda$  long. **Figure 4.15** shows construction of a simple dipole antenna.

We use equations like the one given in the section on wavelength ( $L$  (feet) =  $468/f$  (MHz)) to help us know how long to make the elements of an antenna. Usually we have to tinker around with the length of a wire or other element to get the best impedance match. Here is where the SWR meter can help us to match the antenna to our transmitter.

*(See Activity Sheet #4.2 – Antenna Construction)*

### The Quarter-Wavelength Vertical Antenna

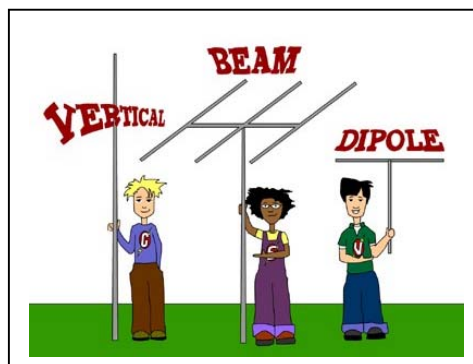
The quarter-wavelength vertical antenna is popular with hams because it is effective and easy to build. It requires a single vertical element plus some horizontal ground radials, usually made from wire or metal rods. Vertical antennas radiate equally well in all directions.

**Figure 4.16** shows a simple vertical antenna you can make. For this equation use the equation: Length (in feet) =  $234/f$  (in MHz).

### Beam Antennas

Beam antennas are directional. That means they concentrate their energy in one direction. The most common directional antenna is the Yagi antenna. Yagi antennas have two important advantages over dipole and vertical antennas. First, by concentrating most of its transmitted signal in one direction, the antenna provides *gain* or *directivity* in the direction it is pointed. Gain makes your signal sound stronger to others. Second, the antenna reduces the strength of signals coming from other directions.

A Yagi antenna has several elements attached to a central boom. The elements are parallel to each other and are placed in a straight line along the boom. The feed line connects to only one element, called the driven element.



## ANTENNA LOCATION AND SAFETY

A final word about antennas. *Never* put your antenna or feed line under, or over the top of electrical power lines. *Never* place a vertical antenna where it could fall against the electrical power lines. *Avoid* running your antenna parallel to power lines that come close to your station. Should any part of your antenna come in contact with the power line, severe damage to your equipment could result. Even worse, you could receive a fatal electrical shock.

## OTHER COMMUNICATION DEVICES

**Citizen Band (CB)** radios operate *simplex*, which means they transmit and receive on the same frequency. Most of Amateur Radio HF radios operate simplex also, but have the ability to also operate split frequency (that means receive on one frequency and transmit on another). A non-licensed radio service, CB has been most identified with long haul truck drivers as they cruise down the nations highways. CB radios operate at about 27 MHz in either AM or SSB modes. Many communities use CBs for emergency communications as well.

**Cell Phones** are fast becoming the most popular form of radio communications. Yes, I said *radio* communications. Cell phones are actually very sophisticated radios that have the ability to transmit and receive signals. The three most popular cellular services in the US are conventional *analog* cell phones, *digital* cell phones and *Personal Communications System (PCS)*. Originally developed in the late 1970s to early 1980s, cellular systems have been refined since that time and operate in the 800-MHz frequency range.

So how does the system work? Cities, and rural areas are divided up into “cells,” each with a base station and tower for receiving and transmitting a group of frequencies. A typical provider will receive 832 frequencies, between 824-849 MHz and 869-894 MHz, with which to divide up among the many cells. Each cell may cover an area of about 10 square miles. Most cell phones have two signal strength (power levels): 0.6 watts and 3 watts. High power is not necessary because it is only necessary to reach the local base station to communicate.

As the caller moves from cell to cell, the base stations track his signal and when the signal starts to fade in one cell, another cell’s base station will see it increase and therefore, “switch” the caller over to the next cell without any interruption in service. It is possible today to travel nationwide without losing your cell phone signal. However, there are some remote areas in the nation that do not have base stations and therefore, no cell phone coverage. This system is referred to as an analog cell phone system.

What about digital phones? Digital cell phones have the ability to compress messages (make them smaller so they don’t take up much space), therefore allowing as many as three times more calls within an individual cell. This makes the entire system more efficient than the traditional analog system. Digital cell phones also offer clearer signals, without the static and noise that you occasionally hear on analog phones.

There is a third type of cell phone system called “PCS.” The Personal Communication System is also a digital system that operates in the 1900 MHz range. It can do many things, including give users Web access.

It sounds amazing that all this technology can be packed in one cell phone. Indeed, the cell phone can shift from analog to digital, to PCS, while switching from cell to cell as you travel down the highway.

The **Family Radio Service (FRS)** is for use by the general public. There is no license required and no age limit, so it has become very popular as a radio service for families to use while traveling or at the mall. The FRS has a series of 14 channels with frequencies between 462.5625 MHz to 467.6125 MHz. The emission type is FM. FRS radios are limited to ½ watt power, thereby limiting the range to approximately ¾ mile.

FRS radios must be used just as they are manufactured. No modifications are allowed. That means you cannot make any changes to the radio. No amplifiers may be used to boost the power and no additional antenna may be attached to increase the range of the radio. They are meant for personal communication in a limited location.

The **Global Positioning System (GPS)** has, through a system of satellites, the ability to determine exactly where on Earth you are. Circulating about the Earth at 11,000 miles are 24 satellites that make up the system. GPS works its magic by measuring the precise distance between the receiver and at least four satellites. The receiver uses this information to calculate precisely where it is located on the surface of the Earth, or above it. This allows airplanes, boats, cars or even people to determine their location at any time, day or night.

The GPS system is very important to navigation. Airplanes are able to travel over the polar rout without using a magnetic compass. Ships at sea are able to pinpoint their positions regardless of weather conditions, and we are now capable of finding our way around on the nations highways by using GPS systems in our cars.

Where else are GPS systems being used? The Department of Defense (the military) uses GPS systems for navigation and locating aircraft, equipment and personnel. Police and fire departments use GPS systems to locate the nearest unit to a fire or reported crime. Car manufacturers are installing GPS systems in many new cars as an option. And GPS was actually used to precisely measure the location for digging during the construction of the tunnel under the English Channel that connects England and France.

New applications for GPS are being developed every day. From navigation to recreation, there seems to be no limit for imaginative people.

## LINKING RADIO AND THE INTERNET

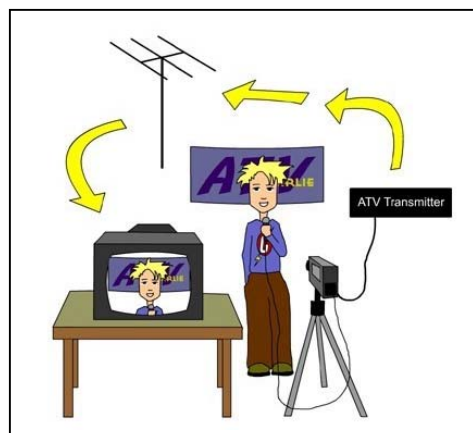
What if you live in an apartment in a big city or a condominium with restrictions against putting up antennas? Can you still operate a ham radio? The answer is yes, there are still ways to “get on the air.” Many hams are turning to their computers and the Internet to talk to their friends over the radio. All that is needed is any 300 MHz or faster IBM compatible system with a sound card, microphone and headset. These innovated hams connect (interface) their radio to their computer so they can communicate through the Internet with their radios.

The four Internet linking systems in use today are: IPHONE, ILINK, eQSO and IRLP. With these systems it is possible to link repeaters in different parts of the world through the Internet and speak to others as though everyone was in the same city. It is also possible to operate an HF station remotely using the Internet. For instance while on vacation far away from the home QTH, hams can connect through the Internet to the home station and operate their station, including changing band, frequency and turning the yagi antenna, remotely. There are different names for this process but “Internet Remote Base” seems to bit best. More information is available on line at [www.lamonica.com](http://www.lamonica.com) and [www.w4mq.com](http://www.w4mq.com).

## AMATEUR TELEVISION

Did you know you can operate your own television station? Many Amateur Radio operators operate their own station called **Amateur Television (ATV)**. ATV can be used by any ham with a Technician class license or higher on any ham band 420 MHz and above.

What do you need to start an ATV station? You may already own 2/3 of the main components in a beginner’s station, namely, the receiver and camera. Your standard cable-ready TV set will work as a



receiver without modification of any kind. The required camera is the same camcorder that you use to record your family and vacation memories. The video output can drive the transmitter directly. All you need is an ATV transmitter and antenna and you're in business.

The majority of the ATV action can be found on the 70cm (420-450MHz) band. High power transmitters are not necessary. While the broadcast station uses thousands of watts of power and antennas a thousand feet above the ground, a typical ATV station uses less than 50 watts with an antenna height of less than 50 feet. Why go through all the time and expense just to send a picture 20 or 30 miles away? It's the challenge. It's the knowledge gained and it's just plain "fun."